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Informed Traders as Liquidity Providers: Anonymity, Liquidity and Price Formation

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Abstract. The tendency to introduce anonymity into financial markets apparently runs counter to the theory supporting transparency. This paper studies the impact of pre-trade transparency on liquidity in a market where risk-averse traders accommodate the liquidity demand of noise traders. When some risk-averse investors become informed, an adverse selection problem ensues for the others, making them reluctant to supply liquidity. Hence the disclosure of traders' identities improves liquidity by mitigating adverse selection. However, informed investors are effective liquidity suppliers, as their adverse selection and inventory costs are minimized. With endogenous information acquisition, transparency reduces the number of informed investors, thus decreasing liquidity. The type of information that traders hold and the effectiveness of insider trading regulation are crucial to distinguish between equilibria.

"Overall, transparency is no panacea and there is 'disquieting evidence' that too much transparency may harm market quality, as it effectively disables some liquidity provision."
Mattias Levin, CESP Task Force report (2003)

1. Introduction

The optimal degree of pre-trade transparency is an important and controversial issue in market design. While it is accepted that transparency affects liquidity, the nature of the relationship remains complex and ambiguous, all the more

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so in that the effects of transparency can differ depending on the type of information revealed and the market structure considered.

This paper focuses on one specific form of pre-trade transparency, namely anonymity, and the effect of its introduction into centralized financial markets. In the last ten years there has been a tendency to introduce anonymity into stock, bond, and foreign exchange markets. Almost all the asset markets organized as electronic platforms are anonymous: the single platform for NASDAQ-listed securities (NASDAQ's Integrated Single Book), into which the NASDAQ Market Center, Inet and Brut recently merged, is anonymous; all European trading platforms are anonymous, as well as all electronic communication networks and foreign exchange electronic markets (e.g. Electronic Broking System). Anonymity was instituted in the Italian secondary market for treasury bonds (MTS) in 1997, in Euronext Paris in 2001, and in the Italian Stock Exchange (Borsa Italiana) in 2004. This tendency would appear to conflict with the conventional wisdom that transparency improves market quality. In view of the vast literature substantially showing that pre-trade transparency enhances liquidity by reducing adverse selection costs (e.g. Pagano and Röell (1996), Foster and George (1992), Röell (1991), Admati and Pfleiderer (1991) and Baruch (2005)), one may well ask whether the recent tendency in market design is consistent with the theory.

The answer we give in this paper is that in dealing with pre-trade transparency, what matters is the structure of the market. More precisely, in comparing transparent and anonymous regimes, the market structure is what makes the difference. For example, if the market resembles the historical New York Stock Exchange (NYSE), then going from anonymity to transparency (i.e. disclosing customers' identification codes) provides the specialist with additional information that enables him to recognize liquidity-motivated traders and offer them better liquidity. But if the same information is offered to traders on a centralized automated platform, the effects could differ significantly, for two reasons: because in centralized markets all market participants act as liquidity suppliers and because of the type of information traders may hold.

In automated markets liquidity is supplied by traders who submit limit orders rather than by a single specialist or group of dealers observing the order flow in advance. These liquidity suppliers can be either uninformed or informed, and those who are informed can acquire two types of information. One is private information, obtained exogenously by corporate insiders. From their vantage point, these insiders observe important pieces of information that are useful in valuing the company. The second type of private information is that which is acquired endogenously by using costly resources. Investment management firms, hedge funds and proprietary traders can make investments that allow them to analyze the fundamental valuation of the firm. Financial intermediaries can invest in information and trading networks that help them acquire supply and demand information for a security's valuation.

All traders recognize large financial intermediaries by name, so that when the identification codes are displayed in an automated market, they can learn about order flows by observing those intermediaries' trading strategies. That is, when traders' identity is displayed in such a market, uninformed traders get information at no cost and thus become more informed themselves. They will therefore make more aggressive limit orders and thus increase liquidity.

Up to this point, the effect of pre-trade transparency on liquidity is similar to that in Kyle's market, with uninformed market makers supplying liquidity. What alters the end result is the fact that this virtuous cycle has a drawback in the case of centralized markets in which all market participants (informed traders included) act as liquidity suppliers. Since informed traders have precise information, they face lower adverse selection and inventory-bearing costs and are efficient liquidity suppliers; so when transparency forces them to share their private information, they may leave the market, which would reverse the final effect, reducing rather than increasing liquidity. This is precisely why anonymity was introduced in 1997 on the Italian secondary bond market, MTS, the largest automated European government bond market (Cheung et al., 2004). As long as MTS was fully transparent, small banks used to free-ride on the information provided by large brokers' trading strategies, inducing the latter either to curtail their trading or to adopt more expensive trading strategies in order to conceal their position.[1] Consequently, liquidity increased when anonymity was introduced (Scalia and Vacca, 1999). This effect is at work in all centralized markets, whether quote-driven, like MTS and EuroMTS, or order-driven, like the Euronext Paris platform, and is consistent with the most recent empirical evidence. In 2001 anonymity was introduced on the French Stock Exchange, and liquidity increased (Foucault et al. (2006)); similarly, Comerton-Forde et al. (2005) show that after the removal of brokers' identification codes liquidity increased on the Tokyo Stock Exchange.[2]

The model presented in this paper considers a market in which risk-averse traders accommodate the liquidity demand of noise traders. As in Grossman and Stiglitz (1980), a fraction of these risk-averse investors are privately informed, which creates an adverse selection problem for the rest. The latter, if they observe that many shares are for sale, cannot tell whether this is

[1] Albanesi and Rindi (2000) and Massa and Simonov (2001) show that order fragmentation on MTS, captured by positive trade autocorrelation, decreased with the introduction of anonymity.
[2] The evidence on the disclosure of information about prices and quantities, however, is mixed (Madhavan et al. (1999), Boehmer et al. (2005), and Hendershott and Jones (2005)).

because of a major liquidity shock or a strongly negative signal and become reluctant to buy. It follows that when the number of informed traders is given, transparency increases liquidity by reducing adverse selection costs. But disclosing traders' identities diminishes the incentive to acquire information, so that increasing transparency can reduce the number of informed agents, hence liquidity. In conclusion this theoretical analysis shows that transparency can have different effects on liquidity depending on whether the scenario envisages fixed or endogenous entry of informed traders. From a policy perspective, it is important to determine which of the two scenarios dominates: in bond and foreign exchange markets, where information is always costly, the only relevant scenario is the one with endogenous entry of informed traders. In stock markets, however, the relevant scenario can have fixed or endogenous entry, and the effect of pre-trade transparency may ultimately depend on how strict the rules on insider trading are. If insider trading laws are lax or poorly enforced, corporate information will be very substantial and the incentive for other market players to acquire information will be very small. Since that information is obtained exogenously, enhancing transparency will not reduce the number of informed agents. In this case, transparency will increase liquidity. But if insider trading legislation is strong and well-enforced, costly, endogenously acquired information will be the most relevant, and the disclosure of traders' identities will actually deprive informed liquidity suppliers of their monopoly on fundamental information, driving them out of the market and causing a drop in liquidity supply. This effect is reminiscent of the negative impact that poor patent protection has on the incentive to innovate.[3]

This paper also relates to an abundant literature on information acquisition and aggregation (Fishman and Hagerty (1992), Mendelson and Tunca (2001)). Like the model used in this paper, Fishman and Hagerty (1992) posit that informed traders bear a cost, but with a different implication. In their model informed traders—one insider and a group of analysts holding a less precise signal—do not act as liquidity suppliers, but only as customers of the uninformed market makers. The authors find that when the insider is allowed to trade, market makers bear higher adverse selection costs and reduce liquidity; when insider trading is banned, more analysts enter the market and informational efficiency may actually be greater.

The market structure (quote-driven) and the type of information (volatility data) that dealers can obtain with pre-trade transparency are also the main differences between the model used here and the protocol of Foucault

[3] I thank a referee for stressing this connection, which implies that non-insiders should be given some degree of "patent-protection".

et al. (2006), in which uninformed liquidity suppliers, observing the identification codes, do not learn whether insiders buy or sell but only the probability that insiders have obtained a signal on the future value of the asset.

The plan of this paper is as follows: Section 2 presents the model; Sections 3 and 4 discuss the results for the cases with a fixed and an endogenous number of market participants respectively, and Section 5 concludes.

2. The Model

The market has N informed and M uninformed agents, and Z noise traders. The number of informed agents may be fixed or endogenous. In the latter case, traders initially decide whether or not to acquire private information at a cost.[4]

Let X_I, X_U and x, with $x \sim N(0, \sigma_x^2)$, be the informed, uninformed and noise traders' orders respectively. Agents are price-takers and trade a single risky asset with a liquidation value equal to:

$$F = S + \varepsilon \qquad\qquad F \sim N(0, \sigma_S^2 + \sigma_\varepsilon^2)$$

As in Glosten (1989), and Madhavan and Panchapagesan (2000), at the outset traders get an endowment shock equal to I, and a signal, S, on the future value of the asset, which are both normally distributed with zero mean and variance of σ_I^2 and σ_S^2 respectively. The endowment shock is a source of noise that makes the informed traders act not only as speculators but also as hedgers and thus prevents complete information revelation, under the regime of transparency. Assuming a CARA utility function, the informed trader maximizes end-of-period wealth and has the following demand function:

$$X_I = \frac{E(F|S) - p}{aVar(F|S)} - I \qquad (1)$$

[4] Like Grossman and Stiglitz (1980), the model posits informed and uninformed investors who are rational and risk-averse, and liquidity traders. However, there are three fundamental differences. First, our model allows for different regimes of pre-trade transparency. Second, informed agents not only speculate on their private information but also hedge. And third, our model maintains numbers rather than proportions of agents, which enables us to include agents who may choose not to trade or who opt for other investment opportunities outside the market in response to market regime change. It therefore allows us to evaluate whether the total number of market participants changes with transparency.

with $E(F|S) = S$ and $Var(F|S) = \sigma_{\varepsilon}^2$, where a is the coefficient of risk aversion and p is the market price.

Uninformed traders make conjectures on the equilibrium price and update their expectations on the liquidation value of the asset by extracting a signal from the current price. They receive an endowment shock equal to I_U, with $I_U \sim N(0, \sigma_U^2)$, and have the following demand function:[5]

$$X_U = \frac{E(F|p) - p}{aVar(F|p)} - I_U \tag{2}$$

A linear rational-expectations equilibrium implies that the equilibrium price is a linear combination of S, I , I_U and x. Substituting Equations 1 and 2 into the market clearing condition,

$$N\ X_I + M\ X_U + Z\ x = 0, \tag{3}$$

and solving for p, we derive the equilibrium price function to evaluate three indicators of market quality: liquidity (L), volatility ($Var(p)$), and informational efficiency (IE). Comparing these indicators under different regimes of transparency we can assess their effects on market quality. In what follows we concentrate on liquidity, measured as the inverse of the price impact of a noise trader's order.

So far it has been assumed that in updating their beliefs traders observe only the market price. This corresponds to anonymity. Below, this is compared with a transparency regime in which traders observe both the order flow and personal markers.

Before comparing these regimes, it will be helpful to explain intuitively how the model allows us to analyze the effects of transparency on liquidity.

Since we have used the price impact of a noise trader's order, $L = \left|\frac{dp}{dx}\right|^{-1}$, as a measure of liquidity (Kyle (1985)), to see how transparency affects liquidity, we should look at the market clearing condition (3) and consider how our system reacts to a noise trader's order. Equation (4) is obtained by substituting the informed and uninformed demand functions (1) and (2)

[5] Uninformed agents are assumed to hold an endowment shock equal to I_U. This assumption will be necessary to compute the model with endogenous entry, whereas in the model without fixed entry costs it can be removed without loss of generality.

into (3).

$$\underbrace{N\left[\frac{S}{aVar(F|S)} - \frac{p}{aVar(F|S)} - I\right]}_{X_I\,:\,Informed\ trader's\ net\ demand}$$

$$\underbrace{+M\left[\frac{E(F|p)}{aVar(F|p)} - \frac{p}{aVar(F|p)} - I_U\right]}_{X_U\,:\,Uninformed\ trader's\ net\ demand} + Z[x] = 0 \qquad (4)$$

First, given that both informed and uninformed traders' demands are decreasing functions of price, all traders will be prepared to sell after a price rise and buy after a decline; second, as informed traders have lower risk-bearing costs ($Var(F|S) < Var(F|p)$), they respond more aggressively to price changes. Finally, while informed traders' demand is an increasing function of their signal, that of the uninformed is a positive function of their conditional estimate of the future value of the asset, $E(F|p)$, which is revised in the same direction as price changes. Assume, say, that a noise trader makes a buy order, $dx > 0$, which causes a price increase. The overall price impact depends on two factors: the willingness of other agents to take the other side of the noise trader's order by selling and the uninformed traders' revision of the future value of the asset, i.e. their willingness to place a buy order. Under anonymity, uninformed traders buy because they misinterpret the price rise as due to new information, not noise trading. It is precisely this effect that reduces liquidity, because it amplifies rather than reduces the price impact of the noise traders' order. Under transparency, by contrast, uninformed traders do not increase their estimate of the future value of the asset after a noise trader's buy order, since they recognize it as non-informative; hence, they do not amplify the price impact by jumping in with buy orders of their own.

Equation 4 shows that informed traders are the best liquidity providers and helps to explain why liquidity increases with transparency. With transparency, uninformed traders become "quasi-informed" and, incurring no adverse selection and lower risk-bearing costs, they improve the provision of liquidity.

However, as will be demonstrated later, this no longer holds when informed traders can leave the market after the increase in transparency. To be precise, the effect of pre-trade transparency on liquidity depends on whether the number of insiders and/or informed traders is fixed or endogenous.

In the next section, we derive the model for a market in which anti-insider trading regulations are not effective so the number of insiders is fixed. The analysis is then extended to a case that corresponds to a stock market with efficacious rules on insider trading and endogenous information acquisition.

3. Fixed Number of Market Participants

Under anonymity, uninformed traders cannot observe either the size of other traders' orders or their identities. It follows that they merely infer the future value of the asset by extracting a signal, $\Theta = S + \frac{a\sigma_\varepsilon^2 Z}{N}x - a\sigma_\varepsilon^2 I$, from the market price. Θ can be easily derived from the market price (Equation 5) that solves the market clearing condition (see Appendix). Notice that Θ is a noisy version of the insiders' signal, S, where the noise comes from the liquidity traders' demand, x, and from the informed traders' endowment shock, I. Clearly, if uninformed traders see that Θ rises they will revise their estimate of the future value of the asset upwards. However, they risk acting incorrectly, as the price rise might not be due to the insiders' demand but possibly to a noise trader's demand for liquidity (x), or to an informed trader's hedging need (I). Uninformed traders will use Θ to compute $E(F|p)$ in (2), while insiders will discard the market clearing price, since their signal, S, is a sufficient statistic of the market price, p.

Under transparency, agents observe traders' identities and their orders. It follows that even uninformed traders discard the market price as a vehicle of information, since they have already observed the informed traders' demand, X_I, which is a sufficient statistic of the market price (see the Appendix). In fact, uninformed traders extract a signal equal to $\Theta_T^{'} = S - a\sigma_\varepsilon^2 I$ from the informed trader's order X_I and update their expectations on the value of the asset accordingly. It follows that when the number of informed agents is fixed, the equilibrium price in the anonymous regime is

$$p_A = \lambda_A[\frac{N}{a\sigma_\varepsilon^2}S - NI - M\Psi I_U + Zx] \tag{5}$$

and under the transparent regime is:

$$p_T = \lambda_T\left[\left(\frac{N + M\Omega}{a\sigma_\varepsilon^2}\right)S - (N + M\Omega)I - MI_U + Zx\right] \tag{6}$$

$$\text{with} \quad \Psi = \left[1 + \frac{M\sigma_\varepsilon^2\sigma_S^2}{NVar(\Theta)Var\ (F|\Theta)}\right]^{-1} \quad \text{and} \quad \Omega = \left(\frac{\frac{Cov(F,\Theta_T^{'})}{Var(\Theta_T^{'})}a\sigma_\varepsilon^2}{aVar\ (F|\Theta_T^{'})}\right)$$

Proof: See the Appendix.

These prices can be used to derive the indicators of liquidity as the inverse of the price elasticity (L_A and L_T), of volatility ($Var(p_A)$ and $Var(p_T)$), and of informational efficiency (IE_A and IE_T) under the two regimes.

Liquidity (L_A and L_T) is measured as the inverse of the price impact of each noise trader's order (λ_A and λ_T):

$$L_A = \frac{1}{\lambda_A} = \left[\frac{N}{aVar\ (F|S)} + MH\right] \tag{7}$$

$$= \left[\frac{N}{aVar\ (F|S)} + M\frac{1 - \frac{Cov(F,\Theta)}{Var(\Theta)}}{aVar\ (F|\Theta) + \frac{Cov(F,\Theta)}{Var(\Theta)}\frac{MA\sigma_\varepsilon^2}{N}}\right]$$

$$L_T = \frac{1}{\lambda_T} = \left[\frac{N}{aVar\ (F|S)} + \frac{M}{aVar(F|\Theta_T^{'})}\right]$$

Under the anonymous regime, market liquidity (L_A) is formed by two terms. The first term, $N\ [aVar\ (F|S)]^{-1}$, corresponds to the contribution of the N informed traders to liquidity; the second, MH, to that of the M uninformed traders. Notice that both terms are inverse functions of the conditional variance of F, which gauges the risk-bearing costs of risk-averse agents and is greater for uninformed than for informed traders, $Var\ (F|S) < Var\ (F|\Theta)$. Note also that H is the contribution of uninformed traders to liquidity in the presence of both risk-bearing and adverse selection costs, whilst $[aVar\ (F|\Theta)]^{-1}$ would be their contribution without adverse selection costs; it follows that the difference $\left([aVar\ (F|\Theta)]^{-1} - H\right)$ illustrates the reduction in uninformed traders' willingness to offer liquidity due to adverse selection costs, and so can be used as a measure of these costs.[6] Equation 7 also shows that while liquidity can be affected by the informed traders' endowment shock,

[6] Note that the price-noise coefficient λ_A, which we use as a measure of the cost of liquidity trading, is the measure used by Brown and Zhang (1997) to compare liquidity costs in different market structures; specifically, the parameter b_3, which they use to measure liquidity costs in limit order markets, can be obtained by plugging $J = N$, $(R - J) = M$, $Zx = \phi$, $\sigma_I = 0$ into λ_A in Equation 7. In fact, making the notation uniform, the model presented here under anonymity corresponds to their framework for a limit order market.

I, it is invariant to I_U, which is not a source of noise in the uninformed traders' updating process.[7]

Under transparency, uninformed traders behave as if they were informed by a signal, $\Theta_T^{'}$, which is a noisy version of the informed trader's signal. The more precise the signal they extract from the equilibrium price, the lower the risk-bearing and adverse selection costs and thus greater the liquidity. Comparing the indicators of liquidity under anonymity and under transparency, L_A and L_T, we can see how transparency affects those two components of trading costs. The first term in L_T is unaffected by the regime, as it is the same under both anonymity and transparency; informed traders do not change their liquidity contribution because of an increase in transparency, since they already get the best possible signal and have no adverse selection costs. But pre-trade transparency does affect the contribution of uninformed traders. Under transparency they too have no adverse selection costs, and as the conditional variance of F is less than under anonymity, they also have lower risk-bearing costs ($aVar\ (F|\Theta_T') < aVar\ (F|\Theta)$).

It follows that under transparency, uninformed traders' costs decrease by:

$$\Xi = \left([aVar\ (F|\Theta_T')]^{-1} - [aVar\ (F|\Theta)]^{-1}\right) + \left([aVar\ (F|\Theta)]^{-1} - H\right)]. \tag{8}$$

The first term shows the reduction of risk-bearing costs and the second measures the adverse selection costs under anonymity. Figures 1, 2 and 3, respectively, plot the total cost reduction and each of the two components. As expected, adverse selection costs are a positive function of the number of informed traders and a negative function of the noise; the reverse holds for risk-bearing costs reduction.

$IE_{A,T}$, the inverse of the conditional variance of F, measures informational efficiency.

$$IE_A = [Var\ (F|\Theta)]^{-1} = \left[\sigma_s^2 + \sigma_\varepsilon^2 - \frac{\sigma_s^4}{\left(\sigma_s^2 + a^2\sigma_\varepsilon^4\sigma_I^2 + \frac{a^2\sigma_\varepsilon^4 Z^2}{N^2}\sigma_x^2\right)}\right]^{-1} \tag{9}$$

$$IE_T = [Var\ (F|\Theta_T^{'})]^{-1} = \left[\sigma_s^2 + \sigma_\varepsilon^2 - \frac{\sigma_s^4}{\left(\sigma_s^2 + a^2\sigma_\varepsilon^4\sigma_I^2\right)}\right]^{-1} > IE_A$$

[7] The simulations run in the following sections show that Kyle's measure of liquidity is robust to changes in σ_I.

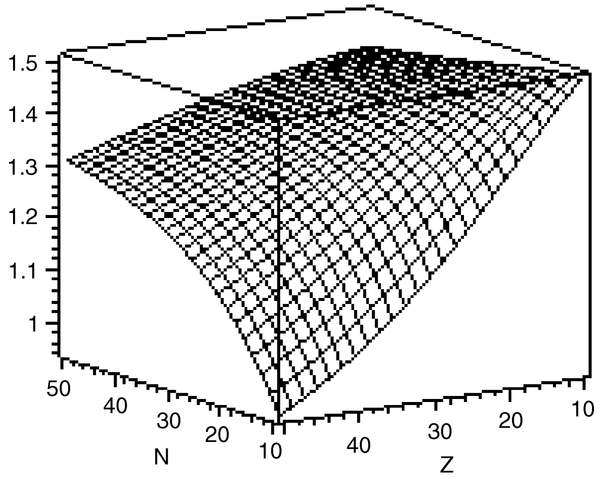

Figure 1. Total cost reduction due to pre-trade transparency. On the vertical axes: $\Xi = [aVar\ (F|\Theta_T')]^{-1} - [aVar\ (F|\Theta)]^{-1} + [[aVar\ (F|\Theta)]^{-1} - H]$ with $a = 2$, $\sigma_\varepsilon^2 = 0.5$, $\sigma_I^2 = 0.5$, $\sigma_x^2 = 0.5$, $\sigma_S^2 = 0.5$, $M = 20$.

The more precise the signal that traders get from the equilibrium price, the lower the residual variance of the future value of the asset and the more informative the equilibrium price will be. As expected, transparency makes prices more informative on the future value of the asset.

Finally, volatility, $Var(p)$, depends on the price-impact parameter and on the variance of the informed traders' signal, endowment shocks and noise.

$$Var(p_A) = \left((\lambda_A)^2 (\frac{N^2}{a^2\sigma_\varepsilon^4}\sigma_S^2 + N^2\sigma_I^2 + M^2\Psi^2\sigma_U^2 + Z^2\sigma_x^2\right) \tag{10}$$

$$Var(p_T) = (\lambda_T)^2 \left(\frac{(N + M\Omega)^2}{a^2\sigma_\varepsilon^4}\sigma_S^2 + (N + M\Omega)^2\sigma_I^2 + M^2\sigma_U^2 + Z^2\sigma_x^2\right) \gtrless Var(p_A)$$

The results on volatility are mixed. Transparency produces two conflicting effects: it increases the information content of uninformed traders' orders, which increases volatility, but it decreases the price impact of a trade, which reduces volatility. Numerical simulations show that the net effect depends on the values of the parameters. Nevertheless, the results suggest some remarks that may be of help to market regulators. Figure 4 shows that an increase in the variance of the noise, σ_x^2, increases the difference between $Var(p_T)$ and $Var(p_A)$; this is because raising σ_x^2 decreases the price impact under

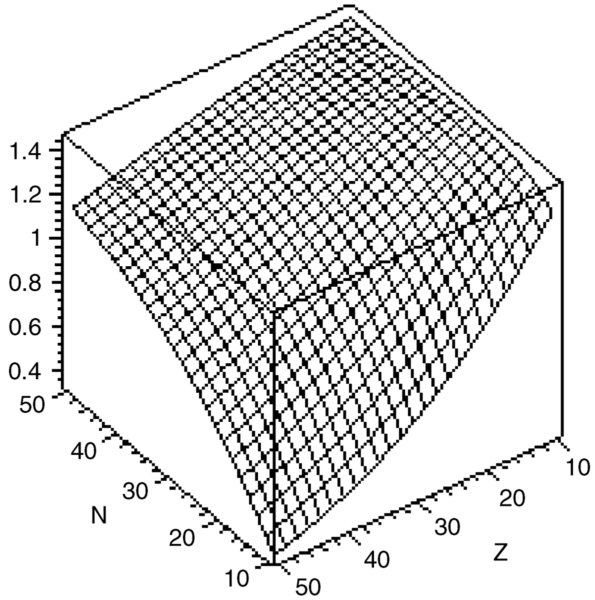

Figure 2. Adverse selection costs under anonymity. On the vertical axes: $[[aVar\ (F|\Theta)]^{-1} - H]$ with $a = 2, \sigma_\varepsilon^2 = 0.5, \sigma_I^2 = 0.5, \sigma_x^2 = 0.5, \sigma_S^2 = 0.5, M = 20.$

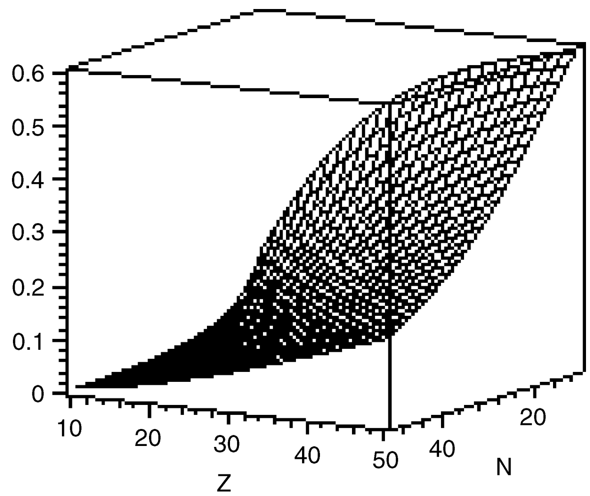

Figure 3. Risk-bearing costs reduction due to pre-trade transparency. On the vertical axes: $[aVar\ (F|\Theta_T')^{-1}] - [aVar\ (F|\Theta)]^{-1}$ with $a = 2, \sigma_\varepsilon^2 = 0.5, \sigma_I^2 = 0.5, \sigma_x^2 = 0.5, \sigma_S^2 = 0.5, M = 20.$

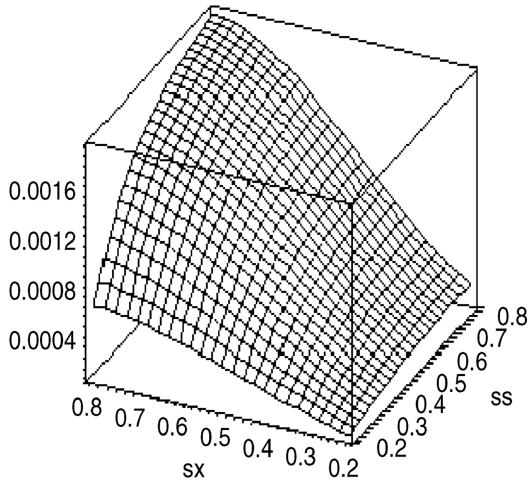

Figure 4. On the horizontal axes: $sx = \sigma_x$ and $ss = \sigma_S$, and on the vertical axis: $Var(p^T) - Var(p^A)$ with $a = 1, \sigma_S = 0.8, \sigma_\varepsilon = 0.5, \sigma_I = 0.8, N = 20, M = 20, Z = 20$.

anonymity (λ_A) (reducing $Var(p_A)$ and not $Var(p_T)$) and the second effect becomes weaker. It follows that in markets with a large amount of liquidity trading, transparency will mainly increase uninformed traders' aggressiveness, and as liquidity is already great, it will not substantially diminish the price impact. Similarly, an increase in σ_S^2, all else equal, makes the insiders' signal more informative and consequently induces free-riders to speculate more aggressively, thus increasing $Var(p_T)$. Numerical simulations (Figure 5) also show that the greater the number of traders who benefit from transparency (M), the greater is $Var(p_T)$ compared to $Var(p_A)$; this effect holds for a wide range of parameter values even in cases where the magnitude of the uninformed traders' endowment shock (σ_U^2) also increases (Figure 5), thus heightening their hedging needs. It follows that in markets that are populated by a large number of uninformed traders, transparency is more likely to increase volatility.

To conclude, the comparison of the indicators of market quality can be summarized in the following proposition:

Proposition 1. *Liquidity and price efficiency are greater under transparency than under anonymity; the results on volatility are mixed.*

4. Endogenous Information Acquisition

So far it has been assumed that the number of informed traders is fixed. This is consistent with stock market rules on insider trading that are ineffective

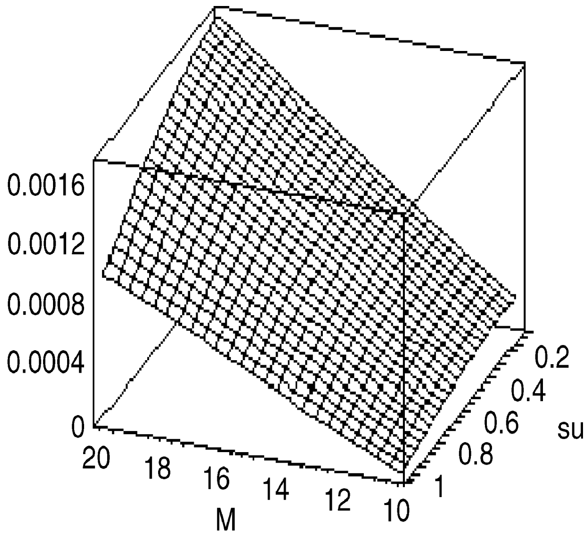

Figure 5. On the horizontal axes: M and $su = \sigma_U$, and on the vertical axis: $Var(p^T) - Var(p^A)$ with $a = 1$, $\sigma_S = 0.8$, $\sigma_\varepsilon = 0.5$, $\sigma_I = 0.8$, $\sigma_x = 0.8$, $N = 20$, $Z = 20$.

and insiders are not subject to competition from large informed traders. Large brokers/dealers who are informed, either because they can observe their customers' order flow or because they have paid analysts for costly information, have no incentive to enter the market if they have to compete with insiders who can get better information at no cost. In stock markets where insider trading regulations are effective, however, or in bond and currency markets where insider trading is fairly rare, the number of these market participants is endogenous. Now we analyze how the effects of pre-trade transparency change under this new assumption.

In this section we assume that informed traders pay a fixed cost equal to C to extract their signal. The condition for being informed is derived as follows.

When an informed trader can choose between buying a costly signal to speculate and not buying the signal and so entering the market uninformed, the equilibrium number of informed traders can be obtained from the following condition:

$$E[-exp(-a(\Pi_I^z - C))] \geqslant E[-exp(-a(\Pi_U^z))] \tag{11}$$

which is derived analytically in the Appendix, and where $\Pi_{I,U}^z = X_{I,U}^z(F - p^z) + I_{.,U}F$ (with $z = A, T$) is the end-of-period profits of each informed and uninformed trader under anonymity (A) and transparency (T) respectively.

Table I. Exogenous Parameters

Z	Number of liquidity traders
a	Coefficient of risk aversion
C	Information cost
σ_X^2	Noise variance
σ_I^2	Informed traders' endowment variance
σ_U^2	Uninformed traders' endowment variance
σ_S^2	Informed traders' signal variance
σ_ϵ^2	Asset liquidation values' conditional variance

To compute the expected utility of each trader's end-of-period profits, one can substitute the equilibrium price functions obtained under the regimes with anonymity (5) and transparecy (6), and use the Law of Iterative Expectations. By solving the model under Condition 11, it is then possible to derive the equilibrium number of informed and uninformed traders under the two regimes and to evaluate the impact of transparency on liquidity by inserting the equilibrium values for N and M into the indicators presented above. The equilibrium number of informed and uninformed traders under the two regimes depends on the value of the parameters summarized in Table I. The model's solutions can then be used to perform numerical simulations on the effects of transparency on liquidity. These results can be summarized in the following proposition:

Proposition 2. *Numerical simulations show that with endogenous information acquisition the equilibrium number of informed traders is higher, and liquidity is greater under anonymity than under transparency.*

The results for the effects of transparency on liquidity are obtained by inserting the solutions to Condition 11 (i.e. the number of informed and uninformed traders) into L_A and L_T, and by using this inverse of the price elasticity (Equation 7) to evaluate liquidity under the two regimes.

Starting with the most parsimonious model, liquidity is computed allowing only the number of informed traders to be endogenous. Table II shows the equilibrium number of informed traders under anonymity, N_A, and under transparency, N_T, and the difference in liquidity $(L_A(N_A) - L_T(N_T))$ on the assumption that informed traders enter the market either to speculate on the signal they bought or to hedge their endowment shock. The effects of transparency on liquidity changes under the assumption that uninformed

Table II. Equilibrium number of informed traders, liquidity and volatility

This table shows the equilibrium number of informed traders under anonymity and transparency, respectively (N_A, N_T). It also shows the difference in liquidity both when holding the number of market participants constant at $N_A(L_A(N_A) - L_T(N_A))$ and with endogenous entry of informed traders $(L_A(N_A) - L_T(N_T))$. Results are for $a = 2$ and $C = 0.02$.

Row n°	M	Z	σ_S	σ_ϵ	σ_I	σ_x	σ_U	N_A	N_T	$L_A(N_A)-L_T(N_T)$	$L_A(N_A)-L_T(N_A)$
1	20	20	0.5	0.5	0.5	0.5	0.5	60	12	68.549	−27.451
2	20	20	0.5	0.5	0.48	0.5	0.5	66	17	69.909	−28.091
3	20	20	0.5	0.5	0.48	0.8	0.5	69	19	72.426	−25.514
4	20	20	0.3	0.5	0.48	0.8	0.5	57	17	58.566	−21.434
5	20	20	0.3	0.4	0.48	0.8	0.5	45	12	59.369	−43.756
6	20	20	0.3	0.4	0.48	0.8	0.6	71	37	61.511	−44.736
7	20	20	0.3	0.4	0.48	0.8	0.55	56	23	58.769	−44.356
8	20	50	0.3	0.4	0.48	0.8	0.55	78	31	107.358	−39.517
9	50	50	0.3	0.4	0.48	0.8	0.55	140	57	148.485	−110.890

traders and not informed traders are endogenous. The effects are then shown in Table III.

Consistent with the theoretical predictions of the model without endogenous information acquisition, when the number of informed traders is held constant (at N_A), transparency increases liquidity and $L_A(N_A) - L_T(N_A)$ (Table II) is negative; with endogenous entry of informed traders, the opposite holds: transparency reduces liquidity and the simulations reported in Table II show that $(L_A(N_A) - L_T(N_T))$ is positive.[8] Transparency has two effects on market participants. First, uninformed traders can recognize the liquidity-motivated, and so are willing to take the other side of the latter's orders and offer more liquidity. Second, uninformed traders can free-ride on the informed traders' signal, which reduces the latter's incentive to buy costly information and thus reduces their equilibrium number. Clearly, the first effect increases liquidity, while the second decreases it, since it lowers the number of informed traders who decide to stay in the market.[9] As mentioned above, informed traders pay the lowest adverse selection costs and for that reason they are the best liquidity providers. The first effect prevails when the number of informed traders is not allowed to vary across different regimes of transparency, while the second is stronger with endogenous entry of informed traders.[10]

Table II also reports the results for changes in different parameter values. As one would expect, when the number of market participants, M or Z, increases, the equilibrium number of informed traders also increases; hence the more the market participants, the stronger these results. Intuitively, the higher the number of uninformed traders, the greater the profits the informed traders can extract from their private information, and so the greater the incentive to acquire such information. The same intuition explains the effect of an increase in σ_x (from 0.5 to 0.8) on the equilibrium number of informed traders. And a rise in σ_U (from 0.5 to 0.6), which increases liquidity-motivated trading and hence the informed traders' expected profits, raises the equilibrium number of

[8] Simulations were run for a wide range of all the parameter values; only the most interesting ones are reported here.

[9] Informed traders, in this model, receive signals that are perfect substitutes. It would be interesting to check for robustness where signals can be imperfect substitutes or complements. In theory, if insiders can learn by observing the other traders' signals, conclusions about the model with endogenous entry could differ, as this might weaken the incentive of informed traders to leave the market. But if in theory this is a matter of conjecture, in practice when large intermediaries are offered the choice between an anonymous regime and one that allows them to observe their fellows' orders, they choose anonymity. A striking real-world example is the Italian secondary bond market, MTS, which was discussed in the introduction.

[10] Consistent with the model's predictions, experimental results (Perotti and Rindi, 2006) also show that under the assumption of endogenous information acquisition, transparency reduces both the equilibrium number of informed traders and liquidity.

Table III. Equilibrium number of informed and uninformed traders and liquidity

This table shows the equilibrium number of informed and uninformed traders under anonymity and transparency, $((N_A, N_T), (M_A, M_T))$, together with the difference in liquidity, either with endogenous entry of informed traders (N) holding constant the number of uninformed ($\overline{M}$), or with M endogenous, holding constant $\overline{N}$. Results are for the following parameter values: $\sigma_S = \sigma_\epsilon = 0.5$, $a = 2$, $C = 0.02$.

σ_I	σ_x	σ_U	Z	$\overline{M}$	N_A	N_T	$L_A(N_A, \overline{M}) - L_T(N_T, \overline{M})$	$\overline{N}$	M_A	M_T	$L_A(\overline{N}, M_A) - L_T(\overline{N}, M_T)$
0.5	0.5	0.5	20	20	60	12	68.549	20	5	34	−54.444
0.48	0.5	0.5	20	20	66	17	69.909	20	4	24	−38.651
0.5	0.6	0.5	20	20	61	12	70.553	20	4	34	−54.650
0.5	0.5	0.55	20	20	79	29	71.954	20	3	13	−20.271
0.5	0.5	0.5	50	50	151	30	173.376	50	12	85	−137.051
0.5	0.5	0.5	80	80	242	49	276.203	80	18	136	−106.666
0.5	0.5	0.5	100	100	302	61	455.070	100	23	170	−276.032

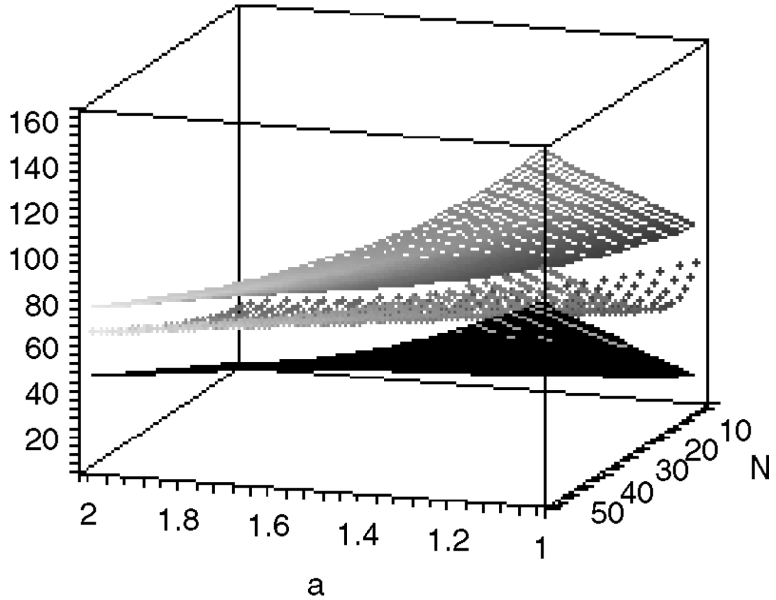

Figure 6. $L_A(N_A)$ dotted plane, $L_T(N_A)$ grey plane and $L_T(N_T)$ black plane.

informed traders. Finally, an increase in σ_I (from 0.48 to 0.5) decreases N_A from 66 to 60 under anonymity and from 17 to 12 under transparency.

The robustness of the model's results has been further checked by running simulations for different ranges of all the parameter values. In Figures 6 and 7 we present the results on liquidity which have been drawn as joint functions of the number of the informed traders, N, and the parameters a and σ_x respectively. Both figures show that the previous results hold. The black plane, which shows the pattern of liquidity under transparency, lies below both the dotted plane (liquidity under anonymity) and the grey plane, which shows liquidity under transparency as a function of the equilibrium number of informed traders N_A, obtained under the regime with anonymity for different values of a ($L_T(N_A) > L_A(N_A) > L_T(N_T)$). Figure 6 also shows that liquidity is decreasing in the coefficient of risk aversion, a. Figure 7 reports results for different values of the standard deviation of the noise, σ_x, and shows that this affects liquidity only under anonymity, where an increase in σ_x, reduces adverse selection costs and thus increases liquidity.

Even if the decision to enter the market is generally associated with the opportunity to buy information, which explains the focus on the endogenous entry of informed traders, it is worth checking whether the results change when the equilibrium number of uninformed traders is made endogenous (Table III).

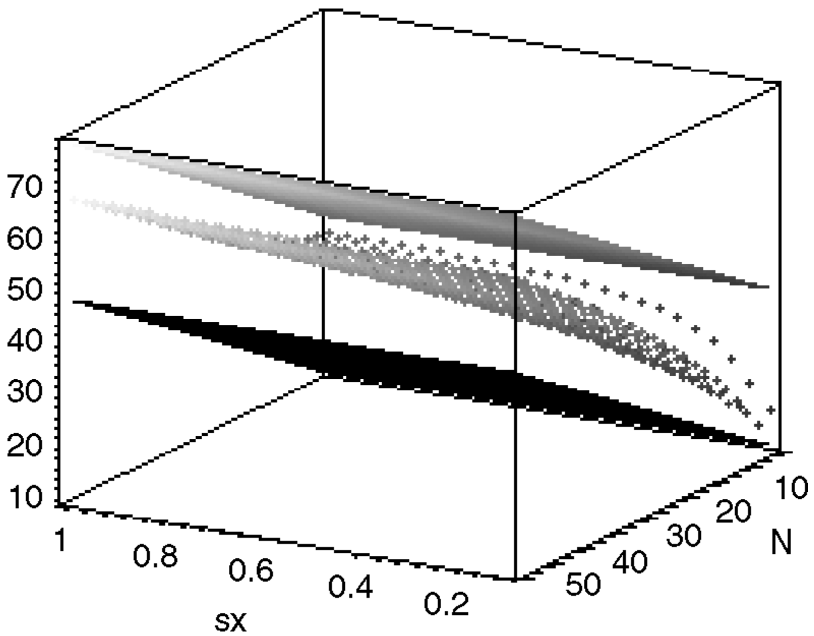

Figure 7. $L_A(N_A)$ dotted plane, $L_T(N_A)$ grey plane and $L_T(N_T)$ black plane.
Figures 6 and 7 report the pattern of liquidity drawn as a function of both the number of informed traders, N, and the parameters a and σ_X (sx) respectively. Liquidity is shown under both anonymity [$L_A(N_A)$, dotted line] and transparency without (and with) endogenous information acquisition [$L_T(N_A)$ grey line (and $L_T(N_T)$ black line)]. Parameter values: $M = 20$, $Z = 20$, $a = 2$, $C = 0.02$, $\sigma_S = 0.5$, $\sigma_\varepsilon = \sigma_I = 0.8$, $\sigma_U = \sigma_X = 1$.

Clearly, uninformed traders benefit from the enhanced informational efficiency induced by transparency and have a greater incentive to enter a transparent rather than an anonymous market. Since this effect increases liquidity, we compare the liquidity effect of an increase in the number of informed with that of a reduction in the number of uninformed traders. Table III presents results for a representative selection of simulations and tells us that, all else equal, when transparency increases, the reduction of liquidity due to the smaller number of informed traders $(L_A(N_A, \overline{M}) - L_T(N_T, \overline{M}))$ outweighs the increase due to the additional uninformed investors $|L_A(\overline{N}, M_A) - L_T(\overline{N}, M_T)|$. For example, the first row shows that, with endogenous entry of informed traders, liquidity decreases by 68.549 when moving from anonymity to transparency, whereas with endogenous entry of uninformed traders it increases by 54.444. This effect is strengthened as the number of traders increases. Table III gives results obtained by solving Condition 11 either for N holding M constant or vice versa.

To compare the effects of transparency on liquidity induced by the variation in the equilibrium number of uninformed and informed traders, the endogenous numbers of M_A and M_T have further been calculated for different values of σ_I (Table IV) and then substituted into L_A and L_T to compute the liquidity difference between anonymity and transparency (Figure 8). Analogous simulations were run to obtain the equilibrium value of the informed traders, holding the number of uninformed fixed (Figure 9). The results (Figure 10) confirm that when transparency increases, the reduction of liquidity due to there being fewer informed traders ($L_A(N_A, \overline{M}) - L_T(N_T, \overline{M})$ in Figure 9) outweighs the increase due to additional uninformed investors ($L_A(\overline{N}, M_A) - L_T(\overline{N}, M_T)$ in Figure 8). These simulations could have been performed by allowing any parameter of the model to change; we chose σ_I^2 in order to check for the robustness of Kyle's definition of liquidity.

4.1 WELFARE ANALYSIS

So far, we have seen that without fixed entry costs, transparency increases liquidity. This means that noise traders are better off under transparency than under anonymity. Following most of the literature since Kyle (1985), liquidity is computed as the price impact of a noise trader's order, and as in Admati and Pfleiderer (1988) it is assumed that noise traders are better off when liquidity increases. As for optimizing and risk-averse informed and uninformed traders, changes in their welfare are measured by the unconditional expected utility of end-of-period profits.

Now let us discuss the welfare implications of the analysis. How do the different regimes influence the welfare of informed and uninformed traders? We can answer both for the case without fixed entry costs and for the case with endogenous information acquisition, using the numerical simulations shown in Table V. Informed and uninformed traders' unconditional expected utility changes when shifting from anonymity to transparency under different values for Z, N, M and the other parameters. Each row reports the welfare analysis corresponding to the same row of Table II; for instance, the first shows that for $M = Z = 20$ and $\sigma_\epsilon = \sigma_S = \sigma_I = \sigma_x = \sigma_U = 0.5$, the equilibrium expected utility under anonymity (EU_A) is -1.420, while under transparency it is -1.300. Columns 5 and 6 give the expected utility of the informed ($EUI_T(N_A)$) and uninformed ($EUU_T(N_A)$) traders, holding the number of market participants constant at N_A and moving from anonymity to transparency. Columns 7 and 8 show that after the change of regime, informed traders are worse off ($EUI_T(N_A) - EU_A = -0.024$) and uninformed traders better off ($EUU_T(N_A) - EU_A = 0.177$). These results are consistent across

Table IV. Equilibrium Number of Traders

Shows the equilibrium number of informed and uninformed traders under both anonymity and transparency, $((N_A, N_T), (M_A, M_T))$ for different values of σ_I and $Z = 20, a = 2, C = 0.02, \sigma_S = \sigma_\varepsilon = \sigma_U = \sigma_x = 0.5$

σ_I	$\overline{N}$	M_A	M_T	$\overline{M}$	N_A	N_T
0.5	20	5	34	20	60	12
0.49	20	4	28	20	63	15
0.48	20	4	24	20	65	17
0.47	20	4	20	20	69	20
0.46	20	3	16	20	73	24
0.45	20	3	14	20	77	28
0.44	20	2	11	20	82	33

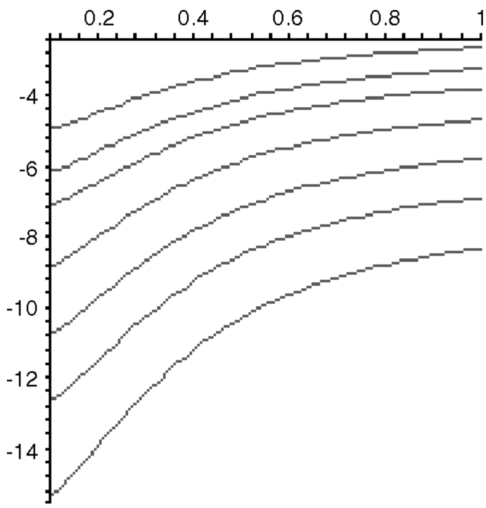

Figure 8. $L_A(\overline{N}, M_A) - L_T(\overline{N}, M_T) = D1$ (σ_I on the horizontal axis).
Figure 8 shows the difference between liquidity under anonymity and under transparency, with endogenous entry of uninformed traders (M) and the number of the informed traders (N) constant: the lines from bottom to top report the values of $L_A(\overline{N}, M_A) - L_T(\overline{N}, M_T)$ as a function of the equilibrium number of uninformed traders under both anonymity, M_A, and transparency, M_T, which are computed for different values of σ_I. For instance, the bottom line corresponds to $L_A(\overline{N} = 20, M_A = 5) - L_T(\overline{N} = 20, M_T = 34)$, where M_A and M_T are the equilibrium numbers of uninformed traders associated with $\sigma_I = 0.5$. Figure 9 is similarly built on the assumption that N rather than M is endogenous. Figure 10 reports the sum of the differences shown in Figures 8 and 9 respectively. For instance, the bottom line corresponds to $[L_A(\overline{N}, M_A = 5) - L_T(\overline{N}, M_T = 34)] + [L_A(N_A = 60, \overline{M}) - L_T(N_T = 12, \overline{M})]$. These differences are then plotted over a range of different values of σ_I since our measure of liquidity is itself a function of σ_I.

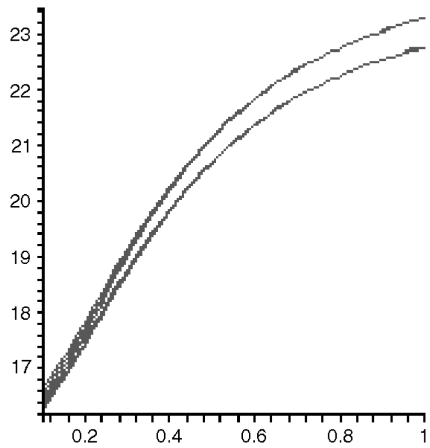

Figure 9. $L_A(N_A, \overline{M}) - L_T(N_T, \overline{M}) = D2$ (σ_I on the horizontal axis).

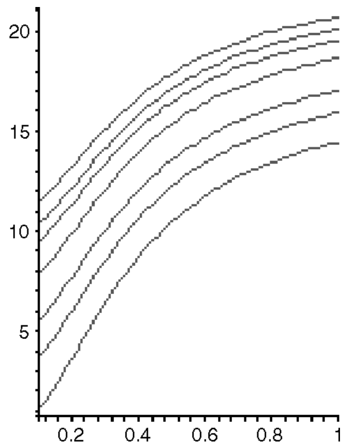

Figure 10. $D1 + D2$ (σ_I on the horizontal axis).

different parameter values, and the gains of the uninformed are greater than the losses of the informed.

Further, since under transparency informed traders have less incentive to buy information, endogenous information acquisition will induce some to leave the market and liquidity will decrease, leaving noise traders worse off. Under the new regime, the unconditional expected utility in equilibrium increases[11] and uninformed traders are better off. It can be concluded that with fixed entry

[11] The values of EU_T in column 3 of Table V are all higher than the corresponding values of EU_A in column 2.

Table V. Equilibrium number of informed traders and liquidity: welfare implications

Columns 2 and 3 show the equilibrium expected utility under anonymity (EU_A) and transparency (EU_T); informed and uninformed traders' expected utility under the regime with transparency is also shown, holding the equilibrium number of informed traders constant at N_A ($EUI_T(N_A)$, $EUU_T(N_A)$). Columns 7 and 8 show the change in the informed and uninformed traders' expected utility moving from anonymity to transparency under the assumption of no entry cost. This table also provides a welfare analysis for the comparative statics discussed in Table II. To this end, N_A^* reports the equilibrium number of informed traders before any change in the parameter values occurs, whereas $EUI_A(N_A^*)$ and $EUU_A(N_A^*)$ give the informed and uninformed traders' expected utility evaluated at N_A^*.

Row n°	EU_A	EU_T	N_A	$EUI_T(N_A)$	$EUU_T(N_A)$	$EUI_T(N_A) - EU_A$	$EUU_T(N_A) - EU_A$	N_A^*	$EUI_A(N_A^*)$	$EUU_A(N_A^*)$
1	−1.420	−1.300	60	−1.444	−1.243	−0.024	0.177			
2	−1.378	−1.295	66	−1.395	−1.239	−0.017	0.138	60	−1.368	−1.421
3	−1.361	−1.244	69	−1.382	−1.229	−0.021	0.132	66	−1.356	−1.378
4	−1.189	−1.086	57	−1.213	−1.088	−0.024	0.101	69	−1.210	−1.144
5	−1.127	−1.054	45	−1.152	−1.077	−0.025	0.049	57	−1.147	−1.110
6	−1.158	−1.138	71	−1.167	−1.122	−0.009	0.036	45	−1.119	−1.216
7	−1.143	−1.105	56	−1.156	−1.100	−0.016	0.044	71	−1.159	−1.124
8	−1.099	−0.980	78	−1.120	−1.057	−0.021	0.042	56	−1.041	−1.103
9	−1.144	−1.104	140	−1.160	−1.100	−0.016	0.044	78	−1.068	−1.231

costs, transparency harms noise traders and the informed traders who leave the market, but benefits uninformed traders.

Table V shows that the same welfare implications of an increase of transparency hold for different sets of parameter values. As an example, to evaluate the effects of a reduction of σ_I, from 0.5 to 0.48 (rows 1 and 2), one has to consider the expected utility in equilibrium under, say, anonymity with $\sigma_I = 0.5$ ($EU_A = -1.42$), and compare this with the informed and uninformed traders' unconditional expected utility, this time computed for $\sigma_I = 0.48$ and holding the number of informed traders constant at the initial value (60). This yields $EUI_A(N_A^*) = -1.368$ for the informed trader, and $EUU_A(N_A^*) = -1.421$ for the uninformed. That is, the insider's ex ante expected utility increases because of the reduction of σ_I, while that of uninformed traders decreases. It follows that, depending on the cost of information acquisition, insiders may enter the market, and the equilibrium number of informed traders will rise until the new equilibrium condition, at $EU_A = -1.378$ with $N_A = 66$, is satisfied. The opposite goes for uninformed traders, whose ex ante expected utility decreases to -1.421. Table III (rows 1 and 2) shows that with the reduction of σ_I from 0.5 to 0.48 the equilibrium number of uninformed traders falls from 5 to 4.

The results obtained have thus been checked for diverse markets characterized by different parameter values.

4.2 DISCUSSION

There are two possible ways to extend the model. First, rather than positing either anonymity or transparency, a regime of partial transparency could be allowed for. And second, one could postulate that agents behave strategically rather than competitively.

It could be argued that anonymity is a good theoretical benchmark but lacks realism, as in real-world centralized markets traders normally have access at the very least to information on prices and quantities. Thus, though analytically complicated, a protocol with such partial transparency could be derived by assuming that uninformed traders use two signals to update their price expectation. First, since they do not observe agents' identifiers, they would observe an order, say θ'_{PT}, which would come with probability $\frac{N}{N+Z}$ from an informed trader and with probability $\frac{Z}{N+Z}$ from a noise trader. They would thus observe a realization of the following random variable:

$$\left\{\Theta'_{PT} | \Theta'_{PT} \neq X_U\right\} = qX_I + (1-q)x$$

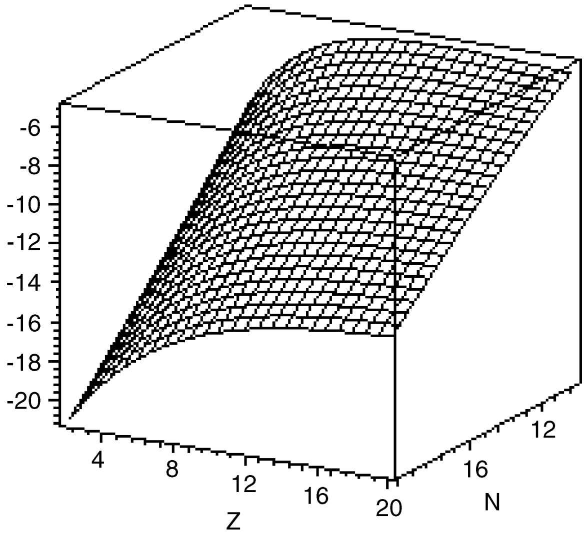

Figure 11. $L_T - E[LP_T(q)]$ with $a = 1$, $\sigma_S = 0.8$, $\sigma_\varepsilon = 1$, $\sigma_x = 0.1$, $\sigma_I = 1$, $\sigma_U = 1$, $M = 20$.

$$\text{with} \quad q \sim \begin{cases} 0 & \frac{Z}{N+Z} \\ 1 & \frac{N}{N+Z} \end{cases} .$$

Next, since this signal would not be a sufficient statistic of the market price, they would also extract the signal $\Theta_{PT} = S - a\sigma_\varepsilon^2 I + \frac{Za\sigma_\varepsilon^2}{N} x$ from the current price by using their conjecture on other uninformed agents' orders, $X_U^{PT} = -H^{PT} p + \Omega^{PT} \theta'_{PT}$, and the market clearing condition. The solution to this model is only sketched in the Appendix, but when derived following the same analytical process as above, it confirms our previous finding that transparency increases liquidity; here, the higher the ratio of informed traders (N) to noise traders (Z), the greater the market's liquidity (Figure 11).

The second possible objection regards the assumption that agents behave competitively. As the effect of transparency is heavily dependent upon uninformed traders' response to a noise trader's demand for liquidity, it could be argued that if agents behaved strategically and took the price impact of their trade into account, these results might change. The model presented so far can be easily modified to include strategic agents; the resulting framework would be a simplified version of Kyle (1989) model. This can be used to show that the previous results do not change qualitatively.[12] If agents take the price impact of their trades into account, they will scale back their orders

[12] The results for the model with strategic agents are available from the author on request.

accordingly, while if they act competitively they will submit more aggressive orders. Strategic behavior only diminishes the effect of pre-trade transparency on liquidity.[13]

5. Conclusions and Policy Implications

This paper clarifies the way in which pre-trade transparency affects liquidity in a centralized market.

Following Brown and Zhang (1997), the market is modeled as an open limit order book where liquidity is provided by all participants, both informed and uninformed. It is further assumed that information is acquired endogenously, and that traders can enter and leave the market at their convenience. This is a crucial feature of the analysis.

The model produced the following results: for a given number of informed agents transparency increases liquidity. With endogenous information acquisition, however, this result can be reversed, because informed and uninformed agents placing limit orders accommodate the liquidity shocks generated by the liquidity traders. Informed agents are in a particularly good position to supply liquidity, as they have no adverse selection costs. While uninformed agents are reluctant to accommodate large market orders, suspecting that they may be based on inside information, informed agents have no reason to fear. Greater transparency reduces the incentive to acquire information and consequently reduces the number of informed agents and the amount of liquidity offered to the market. It follows that the effect of transparency on liquidity can differ significantly, depending on whether the number of informed traders is fixed or endogenous. Which scenario will prevail in equilibrium depends on the type of information that liquidity suppliers hold. In bond and currency markets, there is generally no corporate insider information, so the relevant setting is necessarily costly information acquisition. Within this framework, increasing transparency might be detrimental to the market. This prediction is consistent with the empirical evidence from the Italian secondary government bond market (MTS), where liquidity increased when anonymity was introduced.

In stock markets, however, the two types of information can coexist, so the scenario will depend on the efficacy of the insider trading rules. If they are weak, corporate insiders can trade on their private information. In this scenario, private information is exogenous and transparency does not reduce the number of informed agents; as a result, it increases liquidity. If insider trading regulation is strong, information can be obtained by using costly resources. Well-paid, skilled analysts can provide information.

[13] See also Spiegel and Subrahmanyam (1992).

Alternatively, resources may be devoted to attracting and handling order flows, conveying some information. In that case, the number of informed agents is endogenous, and transparency can reduce information acquisition, hence liquidity.

To conclude, in markets with strong insider trading regulation (as well as in bond and currency markets, where there is no corporate information), increasing transparency would be detrimental as it would reduce the incentive to acquire information and in turn reduce liquidity. By contrast, increasing transparency might be beneficial to a stock market in which insider trading regulation is not strict.

From a policy perspective, this prescription is in line with the recent actions taken by the US Security and Exchange Commission and the financial community regarding insider trading regulations to promote greater transparency of insiders' activity. In 2000 the SEC implemented Regulation FD, which widened public disclosure of new insider information.[14] In 2002, following the Sarbanes-Oxley Act, it shortened the allowable time between the insider trades and their disclosure, and since then it has been repeatedly suggested by law reviews, the legal press, listed companies and even the Supreme Court that insiders be required to disclose their intention to trade in advance (Huddart et al., 2004).[15]

Appendix

Proof of Proposition 1

Each uninformed trader forms a conjecture on other traders' net demand equal to $X_U^A = -Hp_A - \Psi I_U$, and, extracting the following signal from the current price,

$$\Theta = S + \frac{a\sigma_\varepsilon^2 Z}{N}x - a\sigma_\varepsilon^2 I = \left(\frac{N + a\sigma_\varepsilon^2(M-1)H}{N}\right)p_A + \frac{(M-1)\Psi a\sigma_\varepsilon^2}{N}I_U - \frac{a\sigma_\varepsilon^2}{N}X_U$$
$$= \gamma_1 p_A + \gamma_2 I_U - \gamma_3 X_U$$

[14] Similarly, when Euronext introduced liquidity providers in the Dutch equity market in 2001, greater transparency requirements for specialists were put in place; they were required to report all their transactions to the local regulator. This rule was enforced to strengthen guarantees against illegal insider trading (Menkveld, 2006).

[15] Using a Kyle-type framework, Huddart et al. (2004) show that pre-announcement increases trading costs and reduces risk-shedding by insiders, which should also reduce their propensity to elude accounting standards increasing pre-disclosure. In this framework, the disclosure of traders' identification codes has the same effect on the insiders' welfare as pre-announcement.

with $\gamma_1 = \left(\frac{N + a\sigma_\varepsilon^2(M-1)H}{N}\right)$, $\gamma_2 = \left(\frac{(M-1)\Psi a\sigma_\varepsilon^2}{N}\right)$ and $\gamma_3 = \frac{a\sigma_\varepsilon^2}{N}$,

places the limit order $X_U^A = \frac{E(F|\Theta)-p_A}{a\ Var\ (F|\Theta)} - I_U = \frac{\delta_U^A(\gamma_1 p_A + \gamma_2 I_U - \gamma_3 X_U) - p_A}{a\ Var\ (F|\Theta)} - I_U$,

with $\delta_U^A = \frac{Cov(F,\Theta)}{Var(\Theta)} = \frac{\sigma_S^2}{\sigma_s^2 + a^2\sigma_\varepsilon^4\sigma_I^2 + \frac{a^2\sigma_\varepsilon^4 Z^2}{N^2}\sigma_x^2}$,

$Var\ (F|\Theta) = \sigma_s^2 + \sigma_\varepsilon^2 - \frac{\sigma_s^4}{\sigma_s^2 + a^2\sigma_\varepsilon^4\sigma_I^2 + \frac{a^2\sigma_\varepsilon^4 Z^2}{N^2}\sigma_x^2}$ and

$Var(\Theta) = \sigma_s^2 + a^2\sigma_\varepsilon^4\sigma_I^2 + \frac{a^2\sigma_\varepsilon^4 Z^2}{N^2}\sigma_x^2$.

Solving for X_U^A and equating the parameters of the realized demand to H and Ψ, we get:

$$X_U^A = -\left[\frac{1 - \dfrac{Cov(F,\Theta)}{Var(\Theta)}}{a\ Var\ (F|\Theta) + \dfrac{Cov(F,\Theta)}{Var(\Theta)}\dfrac{aM\sigma_\varepsilon^2}{N}}\right] \times p_A - \left[1 + \frac{M\sigma_\varepsilon^2\sigma_S^2}{NVar(\Theta)Var\ (F|\Theta)}\right]^{-1} I_U$$

Substituting both this equation and Equation 1 into 3 and solving for p we obtain Equation 5.

With transparency each uninformed agent forms a conjecture on the others' net demand equal to $X_U^T = -H^T p_T + \Omega\theta_T^{'} - \Psi^T I_U$ and extracts the following signal from the market price, p_T:

$$\begin{aligned}\Theta_T &= S - a\sigma_\varepsilon^2 I + \frac{a\sigma_\varepsilon^2 Z}{N}x = -\frac{a\sigma_\varepsilon^2}{N}X_U \\ &\quad - \frac{(M-1)a\sigma_\varepsilon^2\Psi^T}{N}I_U + \frac{N + a\sigma_\varepsilon^2(M-1)H^T}{N}p_T - \frac{a\sigma_\varepsilon^2(M-1)\Omega}{N}\theta_T^{'} \\ &= \gamma_1^T p_T + \gamma_2^T I_U - \gamma_3 X_U - \gamma_4\theta_T^{'} = \theta_T\end{aligned}$$

with $\gamma_1^T = \frac{N + a\sigma_\varepsilon^2(M-1)H^T}{N}$, $\gamma_2^T = -\frac{(M-1)a\sigma_\varepsilon^2\Psi^T}{N}$, $\gamma_3^T = \frac{a\sigma_\varepsilon^2}{N}$ and $\gamma_4 = \frac{a\sigma_\varepsilon^2(M-1)\Omega}{N}$.

Since he can observe personal identities, he can also extract the signal $\Theta_T^{'} = S - a\sigma_\varepsilon^2 I = a\sigma_\varepsilon^2\theta_T^{'} + p_T$ from the informed trader's demand, X_I. One should notice that $\theta_T^{'}$ is a realization of X_I.

Lemma 1. *$\Theta_T^{'}$ is a sufficient statistic for Θ_T.*

Proof. $E\left[F|\Theta_T, \Theta_T^{'} = S - a\sigma_\varepsilon^2 I\right] = \left[\begin{array}{cc} Cov(F,\Theta_T) & Cov(F,\Theta_T^{'}) \end{array}\right]$

$$\times \frac{1}{\left[Var(\Theta_T^{'})Var(\Theta_T) - (Cov(\Theta_T,\Theta_T^{'}))^2\right]}$$

$$\times \left[\begin{array}{cc} Var(\Theta_T^{'}) & -Cov(\Theta_T,\Theta_T^{'}) \\ -Cov(\Theta_T,\Theta_T^{'}) & Var(\Theta_T) \end{array}\right]$$

$$\times \left[\begin{array}{cc} \theta_T & a\sigma_\varepsilon^2\theta_T^{'} + p_T \end{array}\right]^{'} = \frac{\sigma_S^2}{\sigma_S^2 + a^2\sigma_\varepsilon^4\sigma_I^2}\left(a\sigma_\varepsilon^2\theta_T^{'} + p\right) = \delta_U^T\left(a\sigma_\varepsilon^2\theta_T^{'} + p\right)$$

$$= E\left[F|\Theta_T^{'} = S - a\sigma_\varepsilon^2 I\right], \text{ with } \delta_U^T = \frac{Cov(F,\Theta_T^{'})}{Var(\Theta_T^{'})} = \frac{\sigma_S^2}{\sigma_S^2 + a^2\sigma_\varepsilon^4\sigma_I^2} \text{ c.v.d.} \quad \blacksquare$$

From Lemma 1 it follows that when uninformed agents update their price beliefs they discard the signal from the current price and submit the net demand schedule

$$X_U^T = \frac{E(F|\Theta_T^{'}) - p_T}{a\ Var\ (F|\Theta_T^{'})} - I_U = \frac{\delta_U^T(a\sigma_\varepsilon^2\theta_T^{'} + p_T) - p_T}{a\ Var\ (F|\Theta_T^{'})} - I_U$$

$$= -\left(\frac{1 - \delta_U^T}{a\ Var\ (F|\Theta_T^{'})}\right) p_T - I_U + \left(\frac{\delta_U^T a\sigma_\varepsilon^2}{a\ Var\ (F|\Theta_T^{'})}\right)\theta_T^{'}.$$

By equating the parameters obtained with those previously conjectured, we have:

$$H^T = \left(\frac{1 - \frac{Cov(F,\Theta_T^{'})}{Var(\Theta_T^{'})}}{a\ Var\ (F|\Theta_T^{'})}\right), \Omega = \left(\frac{\frac{Cov(F,\Theta_T^{'})}{Var(\Theta_T^{'})} a\sigma_\varepsilon^2}{a\ Var\ (F|\Theta_T^{'})}\right) \text{ and } \Psi^T = 1$$

Using the market clearing condition, it is straightforward to derive the equilibrium price, p_T, and the results on market quality discussed in Proposition 1:

$$L_T - L_A = \frac{\sigma_S^2 a[a^2\sigma_\varepsilon^4\sigma_I^2 MN + \sigma_S^2 MN + \sigma_S^2 a^2\sigma_\varepsilon^2 Z^2\sigma_x^2 + \sigma_S^2 a^2\sigma_\varepsilon^2\sigma_I^2 N^2 + \sigma_S^2 N^2 + a^2\sigma_\varepsilon^4\sigma_I^2 N^2]}{[\sigma_S^2 a^2\sigma_\varepsilon^2 Z^2\sigma_X^2 + \sigma_S^2 a^2\sigma_I^2 N^2 + \sigma_S^2 N^2 + a^2\sigma_\varepsilon^4\sigma_x^2 Z^2 + a^2\sigma_\varepsilon^4\sigma_I^2 N^2 + \sigma_S^2 MN]a\sigma_\varepsilon^2(\sigma_S^2 a^2\sigma_\varepsilon^2\sigma_I^2 + \sigma_S^2 + a^2\sigma_\varepsilon^4\sigma_I^2)} > 0.$$

Proof of Condition 11

Here it is demonstrated that the condition for being informed:

$$E[-\exp(-a(\Pi_I - C))] \geqslant E[-\exp(-a(\Pi_U))]$$

is equal to:

$$-\exp(aC)\frac{\Upsilon_z}{\sqrt{1-2\sigma_U^2(d_z+h_z^2\frac{\sigma_\varepsilon^2}{2}+L_zF_z^2+R_z\Lambda_z^2+J_zU_z^2)}} \geq \tag{12}$$

$$-\frac{\Upsilon_{zu}}{\sqrt{1-2\sigma_U^2(d_{zu}+h_{zu}^2\frac{\sigma_\varepsilon^2}{2}+L_{zu}F_{zu}^2+R_{zu}\Lambda_{zu}^2+J_{zu}U_{zu}^2)}}$$

Let $\Pi_{I,U}^z = X_{I,U}^z(F-p^z) + I_{.,U}F$ with $z = A, T$, be the end-of-period profits of each informed and uninformed trader respectively under anonymity (A) and transparency (T). Let p^z, $F-p^z$ and $X_{I,U}^z$ be:

$$p^z = \alpha_1^z S + \alpha_2^z x + \alpha_3^z I + \alpha_4^z I_U,\ F-p^z = (1-\alpha_1^z)S - \alpha_2^z x - \alpha_3^z I - \alpha_4^z I_U + \varepsilon$$
$$\text{and}\ \ X_{I,U}^z = \beta_{1,1u}^z S + \beta_{2,2u}^z x + \beta_{3,3u}^z I + \beta_{4,4u}^z I_U.$$

It follows that the expected utility of each trader's profits is equal to:

$$E[-exp(-a\Pi_{I,U}^z)] \tag{13}$$
$$= -E[exp(b_{z,zu}S^2 + c_{z,zu}I^2 + d_{z,zu}I_U^2 + e_{z,zu}x^2 + f_{z,zu}(\varepsilon S) +$$
$$g_{z,zu}(\varepsilon I) + h_{z,zu}(\varepsilon I_U) + i_{z,zu}(\varepsilon x) + l_{z,zu}(SI) + m_{z,zu}(SI_U) +$$
$$+ n_{z,zu}(Sx) + p_{z,zu}(II_U) + q_{z,zu}(Ix) + r_{z,zu}(I_U x))]$$

$$\text{with}\ \ b_{z,zu} = -\beta_{1,1u}^z(1-\alpha_1^z)a, \qquad c_{z,zu} = \beta_{3,3u}^z\alpha_3^z a, \tag{14}$$

$$\begin{array}{ll}
d_{z,zu} = \beta_{4,4u}^z\alpha_4^z a,\ e_{z,zu} = \beta_{2,2u}^z\alpha_2^z a, & f_{z,zu} = -\beta_{1,1u}^z a,\ g_z = -(\beta_3^z+1)a, \\
g_{zu} = -\beta_{3u}^z a,\ h_z = -\beta_4^z a, & h_{zu} = -(\beta_{4u}^z+1)a,\ i_{z,zu} = -\beta_{2,2u}^z a, \\
l_z = -(-\beta_1^z\alpha_3^z + \beta_3^z(1-\alpha_1^z)+1)a, & l_{zu} = -(-\beta_{1u}^z\alpha_3^z + \beta_{3u}^z(1-\alpha_1^z))a, \\
m_z = -(-\beta_1^z\alpha_4^z + \beta_4^z(1-\alpha_1^z))a, & m_{zu} = -(-\beta_{1u}^z\alpha_4^z + \beta_{4u}^z(1-\alpha_1^z)+1)a, \\
n_{z,zu} = -(-\beta_{1,1u}^z\alpha_2^z + (1-\alpha_1^z)\beta_{2,2u}^z)a, & p_{z,zu} = -(-\beta_{3,3u}^z\alpha_4^z - \beta_{4,4u}^z\alpha_3^z)a, \\
q_{z,zu} = -(-\beta_{2,2u}^z\alpha_3^z - \beta_{3,3u}^z\alpha_2^z)a, & r_{z,zu} = -(-\beta_{2,2u}^z\alpha_4^z - \beta_{4,4u}^z\alpha_2^z)a
\end{array}$$

Using the Law of Iterative Expectations we obtain $E_\varepsilon = E[\exp(-a\Pi_{I,U})|S, I, I_U, x]$, $E_S = [E_\varepsilon | I, I_U, x]$, $E_x = [E_S|I, I_U]$, $E_I = [E_x|I_U]$ and

$$E_{I_U} = \frac{\Upsilon_{z,zu}}{\sqrt{1 - 2\sigma_U^2(d_{z,zu} + h_{z,zu}^2 \frac{\sigma_\varepsilon^2}{2} + L_{z,zu} F_{z,zu}^2 + R_{z,zu}\Lambda_{z,zu}^2 + J_{z,zu} U_{z,zu}^2)}} \quad (15)$$

with:

$$\Upsilon_{z,zu} = \frac{Q_{z,zu}}{\sqrt{1 - 2\sigma_I^2 V_{z,zu}}}; \qquad Q_{z,zu} = \frac{H_{z,zu}}{\sqrt{1 - 2\sigma_x^2 M_{z,zu}}}; \quad (16)$$

$$H_{z,zu} = \frac{1}{\sqrt{1 - 2\sigma_S^2(\frac{\sigma_\varepsilon^2}{2} f_{z,zu}^2 + b_{z,zu})}}; \quad M_{z,zu} = L_{z,zu} G_{z,zu}^2 + \frac{\sigma_\varepsilon^2}{2} i_{z,zu}^2 + e_{z,zu};$$

$$G_{z,zu} = f_{z,zu} i_{z,zu} \sigma_\varepsilon^2 + n_{z,zu}; \qquad L_{z,zu} = \frac{\sigma_S^2}{2[1 - 2\sigma_S^2(\frac{\sigma_\varepsilon^2}{2} f_{z,zu}^2 + b_{z,zu})]};$$

$$F_{z,zu} = f_{z,zu} h_{z,zu} \sigma_\varepsilon^2 + m_{z,zu}; \qquad R_{z,zu} = \frac{\sigma_x^2}{2(1 - 2\sigma_x^2 M_{z,zu})};$$

$$\Lambda_{z,zu} = L_{z,zu} 2F_{z,zu} G_{z,zu} + h_{z,zu} i_{z,zu} \sigma_\varepsilon^2 + r_{z,zu}; \quad J_{z,zu} = \frac{\sigma_I^2}{2(1 - 2\sigma_I^2 V_{z,zu})};$$

$$V_{z,zu} = R_{z,zu}\chi_{z,zu}^2 + L_{z,zu} C_{z,zu}^2 + \frac{\sigma_\varepsilon^2}{2} g_{z,zu}^2 + c_{z,zu}; \quad C_{z,zu} = f_{z,zu} g_{z,zu} \sigma_\varepsilon^2 + l_{z,zu};$$

$$\chi_{z,zu} = L_{z,zu} 2C_{z,zu} G_{z,zu} + g_{z,zu} i_{z,zu} \sigma_\varepsilon^2 + q_{z,zu};$$

$$U_{z,zu} = R_{z,zu} 2\chi_{z,zu}\Lambda_{z,zu} + h_{z,zu} g_{z,zu} \sigma_\varepsilon^2 + p_{z,zu} + 2L_{z,zu} F_{z,zu} C_{z,zu}.$$

In order to solve for the equilibrium number of informed traders, we need to evaluate agents' profits under different transparency regimes. Looking at the equilibrium price, given by Expressions 5 and 6, under anonymity and under transparency respectively, we infer that:

$$p_A = \alpha_1^A S + \alpha_2^A x + \alpha_3^A I + \alpha_4^A I_U \quad \text{with}$$

$$\alpha_1^A = \lambda_A \frac{N}{a\sigma_\varepsilon^2}, \; \alpha_2^A = \lambda_A Z, \; \alpha_3^A = -\lambda_A N, \; \alpha_4^A = -\lambda_A M\Psi \; \text{ and}$$

$$p_T = \alpha_1^T S + \alpha_2^T x + \alpha_3^T I + \alpha_4^T I_U \text{ with}$$
$$\alpha_1^T = \lambda_T \frac{N + M\Omega}{a\sigma_\varepsilon^2}, \alpha_2^T = \lambda_T Z, \alpha_3^T = -\lambda_T(N + M\Omega), \alpha_4^T = -\lambda_T M.$$

Substituting the expressions for the equilibrium price into each trader's demand $X_{I,U}^z$ we get:

$$X_I^z = \frac{S-p^z}{a\ \sigma_\varepsilon^2} - I = (\frac{1-\alpha_1^z}{a\sigma_\varepsilon^2})S - \frac{\alpha_2^z}{a\sigma_\varepsilon^2}x - (\frac{\alpha_3^z}{a\sigma_\varepsilon^2}+1)I - \frac{\alpha_4^z}{a\sigma_\varepsilon^2}I_U = \beta_1^z S + \beta_2^z x + \beta_3^z I + \beta_4^z I_U$$

with

$$\beta_1^z = (\frac{1-\alpha_1^z}{a\sigma_\varepsilon^2}),\ \beta_2^z = -\frac{\alpha_2^z}{a\sigma_\varepsilon^2},\ \beta_3^z = -(\frac{\alpha_3^z}{a\sigma_\varepsilon^2}+1),\ \beta_4^z = -\frac{\alpha_4^z}{a\sigma_\varepsilon^2}$$

and
$$X_U^z = -H^{1,T} p^{z'} + \Psi^{1,0} I_U = \beta_{1u}^z S + \beta_{2u}^z x + \beta_{3u}^z I + \beta_{4u}^z I_U$$

with

$$\beta_{1u}^z = -H^{1,T}\alpha_1^z, \qquad \beta_{2u}^z = -H^{1,T}\alpha_2^z + \Omega^{-\infty,1}\beta_2^z,\ \beta_{3u}^z = -H^{1,T}\alpha_3^z,$$
$$\beta_{4u}^z = -H^{1,T}\alpha_4^z - \Omega^{0,1} \text{where } z = A, T.$$

Now, by substituting the values of α^z and β^z into (14) and (16) the expected utility of each trader's profit under the anonymity and transparency regimes can be evaluated, and by using (12) one can obtain the results presented in Proposition 2.

The model's solution under partial transparency.

Under partial transparency uninformed traders update their beliefs on the future value of the asset by using the information from other traders' net demands and the signal Θ_{PT} they can extract from the market price:

$$\Theta_{PT} = S - a\sigma_\varepsilon^2 I + \frac{Za\sigma_\varepsilon^2}{N}x = \gamma_1^{PT} p^{PT} + \gamma_2^{PT} I_U - \gamma_3^{PT} X_U^{PT} - \gamma_4 \theta'_{PT}$$

with $\gamma_1^{PT} = \frac{N+a\sigma_\varepsilon^2(M-1)H^{PT}}{N}$, $\gamma_2^{PT} = \frac{a\sigma_\varepsilon^2(M-1)\Psi^{PT}}{N}$, $\gamma_3^{PT} = \frac{a\sigma_\varepsilon^2}{N}$, $\gamma_4 = \frac{a\sigma_\varepsilon^2(M-1)\Omega^{PT}}{N}$.

Lemma 2. *Assuming that* $Var(x) = Var(X_I)$ *and that* $\frac{Za\sigma_\varepsilon^2}{N} = 1$, *then* $E[F|\Theta_{PT}, \Theta'_{PT}] = \delta_U^T[\mu_1 p^{PT} + \mu_2 I_U - \mu_3 X_U + \mu_4 \theta'_{PT}]$.

Proof. $E\left[F|\Theta_{PT},\Theta'_{PT}\right] = E\left[F|\Theta_{PT},\Theta'_{PT}= S - a\sigma_\varepsilon^2 I\right]$
$\times Prob\left(q=1|\Theta_{PT},\Theta'_{PT}= S - a\sigma_\varepsilon^2 I\right)$
$+E\left[F|\Theta_{PT},\Theta'_{PT}= x\right] Prob\left(q=0|\Theta_{PT},\Theta'_{PT}= x\right)$

Using Lemma 1, it is straightforward to show that:

$$E\left[F|\Theta_{PT},\Theta'_{PT}= S - a\sigma_\varepsilon^2 I\right] = \delta_U^T(p^{PT} + a\sigma_\varepsilon^2\theta'_{PT})$$

and that

$$E\left[F|\Theta_{PT},\Theta'_{PT}= x\right] = \delta_U^T(\gamma_1^{PT}p + \gamma_2^{PT}I_U - \gamma_3^{PT}X_U - \left(\gamma_4 + \frac{Za\sigma_\varepsilon^2}{N})\theta'_{PT}\right),$$

therefore: $E\left[F|\Theta_{PT},\Theta'_{PT}\right] = \delta_U^T(p^{PT} + a\sigma_\varepsilon^2\theta'_{PT})Prob\left(q=1|\Theta_{PT},\Theta'_{PT}\right)$

$$+\delta_U^T(\gamma_1^{PT}p + \gamma_2^{PT}I_U - \gamma_3^{PT}X_U - (\gamma_4 + \frac{Za\sigma_\varepsilon^2}{N})\theta'_{PT})Prob\left(q=0|\Theta_{PT},\Theta'_{PT}\right).$$

Assuming that $Cov(\Theta_{PT},x) = Cov(\Theta_{PT},X_I)$, we have:

$Prob\left(q=1|\Theta_{PT},\Theta'_{PT}\right) = Prob\,(q=1) = \dfrac{N}{N+Z}$ and

$Prob\left(q=0|\Theta_{PT},\Theta'_{PT}\right) = Prob\,(q=0) = \dfrac{Z}{N+Z}$; hence, we obtain:

$E\left[F|\Theta_{PT},\Theta'_{PT}\right] = \delta_U^T[\mu_1 p^{PT} + \mu_2 I_U - \mu_3 X_U + \mu_4\theta'_{PT}]$

with $\mu_1 = \dfrac{N+\gamma_1^{PT}Z}{N+Z} = \left(N + \dfrac{N + a\sigma_\varepsilon^2(M-1)H^{PT}}{N}Z\right)/(N+Z)$

$\mu_2 = \frac{Z\gamma_2^{PT}}{N+Z} = \frac{Za\sigma_\varepsilon^2(M-1)\Psi^{PT}}{N(N+Z)}$ and $\mu_3 = \frac{\gamma_3^{PT}Z}{N+Z} = \frac{a\sigma_\varepsilon^2 Z}{N(N+Z)}$,
$\mu_4 = \frac{a\sigma_\varepsilon^2(N^2-Z^2)-NZ\gamma_4}{N(N+Z)} = \frac{a\sigma_\varepsilon^2(N^2-Z^2)-Za\sigma_\varepsilon^2(M-1)\Omega^{PT}}{N(N+Z)}$

We can now substitute $E\left[F|\Theta_{PT},\Theta'_{PT}\right]$ into the uninformed trader's demand, $X_U^{PT} = \frac{E\left[F|\Theta_{PT},\Theta'_{PT}\right]-p^{PT}}{a\,Var\,(F|\Theta_{PT},\Theta'_{PT})} - I_U$, and solve for the parameters from previous conjecture:

$$H^{PT} = (1-\delta_U^T)\left[a\,Var\,(F|\Theta_{PT},\Theta'_{PT}) + \frac{Za\sigma_\varepsilon^2}{N(N+Z)}(1+\delta_U^T(M-1))\right]^{-1},$$

$$\Omega^{PT} = ((N-Z)\sigma_\varepsilon^2\delta_U^T)\left[Var\ (F|\Theta_{PT},\Theta'_{PT})N + \frac{Z\sigma_\varepsilon^2(1+\delta_U^T(M-1))}{(N+Z)}\right]^{-1} \text{ and}$$

$$\Psi^{PT} = \left[1 + \frac{\sigma_\varepsilon^2 Z(1+\delta_U^T(M-1))}{Var(F|\Theta_{PT},\Theta'_{PT})N(N+Z)}\right]^{-1}$$

with $Var\ (F|\Theta_{PT},\Theta'_{PT}) = \sigma_S^2+\sigma_\varepsilon^2 - \frac{\sigma_s^4}{\sigma_S^2+a^2\sigma_\varepsilon^4\sigma_I^2}$.

Using the market clearing condition

$$N\left[\frac{S-P^{PT}}{a\sigma_\varepsilon^2}-I\right]-MH^{PT}\ p^{PT}-M\Omega^{PT}\Theta'_{PT}-M\Psi^{PT}I_U+Zx=0,$$

where $\left\{\Theta'_{PT}|\Theta'_{PT}\neq X_U\right\} = qX_I+(1-q)x$, we obtain the following equations for the equilibrium price and the price impact:

$$p^{PT}=\lambda_{PT}\left[\frac{N+M\Omega^{PT}q}{a\sigma_\varepsilon^2}S-(N+M\Omega^{PT}q)I-M\Psi^{PT}I_U\right.$$
$$\left.+(M\Omega^{PT}(1-q)+Z)x\right]$$

$$\text{with } \lambda_{PT} = \left[\frac{N}{a\sigma_\varepsilon^2}+MH^{PT}+\frac{M\Omega^{PT}q}{a\sigma_\varepsilon^2}\right]^{-1},$$

$$E[LP_T(q)] = \frac{\lambda_{PT}^{-1}}{\frac{M\Omega^{PT}(1-q)}{Z}+1} = \left(\frac{\frac{N}{a\sigma_\varepsilon^2}+MH^{PT}}{\frac{M\Omega^{PT}}{Z}+1}\right)\frac{Z}{N+Z}$$

$$+\left(\frac{N}{a\sigma_\varepsilon^2}+MH^{PT}+\frac{M\Omega^{PT}}{a\sigma_\varepsilon^2}\right)\frac{N}{N+Z} \text{ with } L_A > E[LP_T(q)] > L_T.$$

■

References

Admati, A. and Pfleiderer, P. (1988) A theory of intrady patterns: Volumes and price variability, *Review of Financial Studies* **1**, 3–40.

Admati, A. and Pfleiderer, P. (1991) Sunshine trading and financial market equilibrium, *Review of Financial Studies* **4**, 443–481.

Albanesi, S. and Rindi, B. (2000) The quality of the Italian treasury bond market, asymmetric information and transaction costs, *Annales d'Economie et de Statistique* **60**, 1–19.

Baruch, S. (2005) Who benefits from an open limit-order book? *Journal of Business* **78**, 1267–1306.

Boehmer, E., Saar, G. and Yu, L. (2005) Lifting the veil: an analysis of pre-trade transparency at the NYSE, *Journal of Finance* **60**, 783–815.

Brown, D. P. and Zhang, Z. M. (1997) Market orders and market efficiency, *Journal of Finance* **52**, 277–308.
Cheung, Y. C., de Jong, F. and Rindi, B. (2004) *Trading European sovereign bonds: the microstructure of the MTS trading platforms*, European Central Bank Working Paper # 432.
Comerton-Forde, C., Frino, A. and Mollica, V. (2005) *The Impact of Limit Order Anonymity on Liquidity: Evidence from Paris*, Tokyo and Korea, unpublished working paper, SSRN electronic paper collection.
Fishman, M. and Hagerty, K. (1992) Insider trading and the efficiency of stock prices, *RAND Journal of Economics* **23**, 106–122.
Foster, M. M. and George, T. J. (1992) Anonymity in securities markets, *Journal of Financial Intermediation* **2**, 168–206.
Foucault, T., Moinas, S. and Theissen, E. (2006) Does anonymity matter in electronic limit order markets, Forthcoming in *Review of Financial Studies*.
Glosten, L. (1989) Insider trading, liquidity and the role of monopolist specialist, *Journal of Business* **52**, 211–235.
Grossman, S. and Stiglitz, J. (1980) On the impossibility of informationally efficient markets, *American Economic Review* **70**, 393–408.
Hendershott, T. and Jones, C. M. (2005) Island goes dark: Transparency, fragmentation, liquidity externalities, and Multimarket regulation, *Review of Financial Studies* **18**, 743–793.
Huddart, S., Hughes, J. S. and Williams, M. (2004) Pre-announcement of insiders' trades, unpublished working paper, Smeal College of Business, Penn State University.
Kyle, A. (1985) Continuous auctions and insider trading, *Econometrica* **53**, 1315–1336.
Kyle, A. (1989) Informed speculation with imperfect competition, *Review of Economic Studies* **56**, 317–356.
Levin, M. (2003) *Competition, Fragmentation and Transparency*. Providing the Regulatory framework for Fair, Efficient and Dynamic European Securities Markets, Assessing the ISD review, CEPS Task Force Report.
Madhavan, A. and Panchapagesan, V. (2000) Price discovery in auction markets: a look inside the black box, *Review of Financial Studies* **13**, 627–658.
Madhavan, A., Porter, D. and Weaver, D. (1999) *Should Securities Markets be Transparent?* unpublished working paper, University of Wisconsin.
Massa, M. and Simonov, A. (2001) *Reputation and Interdealer Trading. A Microstructure Analysis of the Treasury Bond Market*, unpublished working paper, INSEAD and Stockholm School of Economics.
Mendelson, H. and Tunca, T. (2001) Strategic trading, liquidity and information acquisition, *Review of Financial Studies* **17**, 295–337.
Menkveld, A. (2006) Designated market makers for small-cap stocks: is one enough? unpublished working paper, EFA Annual Meeting.
Pagano, M. and Röell, A. (1996) Transparency and liquidity: a comparison of auction and dealer markets with informed trading, *Journal of Finance* **2**, 580–611.
Perotti, P. and Rindi B. (2006) Market for information and identity disclosure in an experimental open limit order book, *Economic Notes* **1**, 95–116.
Röell, A. (1991) Dual capacity trading and the quality of the market, *Journal of Financial Intermediation* **1**, 105–124.
Scalia, A. and Vacca, V. (1999) Does Market Transparency Matter? A Case Study, unpublished working paper, 359, Bank of Italy, Research Department.
Spiegel, M. and Subrahmanyam, A. (1992) Informed speculation and hedging in a noncompetitive securities market, *Review of Financial Studies* **5**, 307–329.