# Transparency, Liquidity and Price Formation

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**Abstract**

This paper shows that the results on market transparency from previous literature are reversed when allowing for endogenous information acquisition: transparency reduces liquidity. Most theoretical models demonstrate that transparency enhances liquidity, whilst the results obtained so far by empirical and experimental works have been mixed. This paper shows how transparency affects the quality of financial markets. We model the market for a risky asset as an open limit-order book and compare three regimes of pre-trade transparency: under full transparency agents can observe the order flow and traders' personal identifiers; under partial transparency they can observe the order sizes and under anonymity they can only observe the market price.

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# Introduction

One of the main issues to be taken into consideration when designing and regulating financial markets is that of pre-trade transparency, which depends on the different types of information available to market participants prior to trading: the visibility of quotes and transactions in the order flow or the visibility of the type of agents involved in trading.

While during the 1990's (SEC (1994) and Carsberg (1994)), particularly in the US, there was a regulatory tendency towards greater transparency, there is now an overwhelming inclination to introduce anonymity into new centralized automated secondary bond, stock and derivative markets (Domowitz and Steil (1999)). Moreover, even if large traditional markets are not anonymous by market design, competition against new markets has favored reductions in the degree of market transparency. For example, on the NASDAQ, which is not anonymous[1], liquidity providers can now trade anonymously through the Electronic Communication Networks (ECNs); similarly, on the foreign exchange market, the anonymous Electronic Brokerage System is gradually attracting most trading on benchmark foreign exchanges (BIS (2002)).

In order to evaluate the effects of pre-trade transparency on the quality of financial markets, a model with the following characteristics is required.

Firstly, considering that markets are becoming increasingly automated and centralized, the trading place must be figured as an open-limit order book where all traders submitting limit orders act as liquidity providers.

Secondly, we need to model transparency both as the visibility of the identity of all traders and as the visibility of the order flow: this allows us to capture the differences in market transparency which exist in real markets. Transparent markets, such as most European stock markets and the NASDAQ, allow traders to observe personal identifiers, whereas most Electronic Communication Networks or Alternative Trading Systems and secondary Treasury Bond markets, such as EuroMTS, do not give visibility of the identity codes but only of limit or market orders.

The model we present in this article, which has such characteristics, features an open limit-order book and can be viewed as a merger of two frameworks which are familiar to the rational expectations literature. It initially shares with Grossman and Stiglitz's (1980) noisy rational expectations model the hypothesis that agents behave competitively and it is then extended to a non competitive setup similar to Kyle's (1989), where traders behave strategically and take into account the effect their demand has on the equilibrium price. Since the effects of transparency on market quality crucially depend on traders' aggressiveness, we believe that it is relevant to compare agents' competitive and strategic behavior.

There are two fundamental differences between this model and the models by Grossman and Stiglitz (1980) and by Kyle (1989). The first is that informed agents trade not only in order to speculate on their private information, but also for hedging their endowment of risky assets. This feature prevents orders to fully reveal the agents' private signal under the regime with full transparency and, therefore, it inhibits market breakdown. The second difference is that we allow for different regimes of pre-trade transparency: under the anonymous regime, traders can only observe the market clearing price; under the regime with full transparency, traders can observe both the order flow and personal identifiers; with partial transparency, they can observe all limit and market orders submitted by market participants, but not their identification codes.

We firstly compare the anonymous and fully transparent regimes and show that the effect of transparency on liquidity crucially depends on two elements: endogenous entry and traders' strategic behavior. Consistently with previous literature[2], we show that transparency enhances liquidity; however, when we allow for endogenous information acquisition, standard results from previous literature are reversed and we find that transparency reduces liquidity. The explanation for this result is that when uninformed traders observe the insiders' demand, they learn a signal on the liquidation value of the asset, which is a noisy version of the insiders' private information: as a consequence they behave almost as if they were insiders. In markets organized like open limit-order books, all agents, informed or uninformed, who submit limit orders are liquidity providers. Since informed agents pay lower adverse selection costs than uninformed ones, they provide liquidity at lower costs. It follows that, when uninformed traders become more informed about the liquidation value of the asset, liquidity increases. In other words, transparency reduces adverse selection costs for uninformed traders and motivates them to offer liquidity. This result, which is standard in previous literature on market transparency, is reversed with endogenous entry of informed agents: transparency allows uninformed traders to learn information from other traders' net demands and this reduces their adverse selection costs; however, this also lets them free-ride on the insiders' private information; the latter effect decreases the insiders' incentive to pay a cost for acquiring information and reduces both the equilibrium number of informed traders and liquidity.

We then modify the initial model to allow traders to behave strategically and show that within this model the effect of transparency on liquidity is weaker. The explanation for this result is that when personal identifiers are displayed, uninformed agents become almost insiders and behave more aggressively under the competitive regime than the imperfectly competitive one. When agents behave strategically, they are concerned about the price impact of their trade and this reduces their willingness to provide liquidity.

When comparing the partially and fully transparent regimes, we obtain the following results. Under the regime with partial transparency, the precision of the information uninformed traders learn from the orders they can observe depends on the probability that such orders are placed by insiders. When the number of insiders relative to the number of liquidity traders is high, the regime with partial transparency is very similar to the fully transparent one and the results we obtain resemble those with full transparency. The opposite is true when few insiders are in the market.

This paper is related to at least three very prolific strands of literature: to that dealing with information acquisition and aggregation, the second dealing with the effects of a change in the equilibrium number of informed traders on market quality and the last to the literature which studies the effects of pre-trade transparency on liquidity and market quality. There exist a number of works which show how insider trading discourages other traders from acquiring information. To mention only a few of them, Fishman and Hagerty (1992) show that insider trading may deter other less informed market professionals from acquiring full information and from trading. Mendelson and Tunca (2001) extended this idea to a dynamic model with a monopolistic insider and show that, due to the strategic liquidity traders, it may be in the insider's best interest to curtail the information he acquires. In both these works, a number of competitive uniformed market makers set the price equal to the conditional expected future value of the asset and face either one single insider and a continuum of risk averse liquidity traders (Mendelson and Tunca (2001)), or a number of insiders and a group of noise traders (Holden and Subrahmanyam (1992)). In this setting, asymmetric information increases market makers' adverse selection costs and therefore reduces liquidity. In our framework, as in Kyle (1989) and in Grossman and Stiglitz (1980) on the other hand, liquidity is provided by both uninformed and informed traders and since informed traders pay the least adverse selection costs, an increase in asymmetric information may increase, rather than decrease, liquidity.

Existing literature discusses pre-trade transparency in either of the three scenarios: all traders behaving competitively (Admati and Pfleiderer 1991), Bertrand-competitive uninformed market makers facing strategic customers (Röell (1990), Foster and George (1992) and Pagano and Röell (1996)), and all liquidity providers acting strategically (Madhavan (1996)). In all these works pre-trade transparency is modelled as the visibility of the size and/or direction of noise traders' orders, an exception being provided by Pagano and Röell (1996), who model transparency as the visibility of the order sizes which are submitted by both insiders and noise traders.

Admati and Pfleiderer (1990) show that preannouncement by noise traders, by reducing adverse selection costs, reduces their transaction costs. Our model departs from this analysis, which mainly addresses the issue of sunshine trading, by assuming that all traders behave strategically and by modelling pre-trade transparency more extensively. It departs from Röell, Pagano and Röell and Foster and George under two dimensions: it assumes that liquidity providers may be strategic, informed as well as uninformed and it allows their number to be endogenous, with the result of capturing the effect that free-riding may have, not only on the equilibrium number of insiders as in Foster and George, but also on market liquidity, being insiders themselves liquidity providers. However, our model shares with Pagano and Röell the visibility of the order flow as an additional measure of pre-trade transparency, rather than looking only at noise traders' orders as Foster and George; it also assumes as Madhavan that liquidity providers behave strategically, extending his analysis to the case where liquidity providers are both informed and uninformed. Our approach departs from Naik et al. (2000) too, since they obtain results on the effects of pre-trade transparency which crucially depend on the existence of two different markets where dealers trade sequentially.

The results we obtain are consistent both with field data analysis and with experimental works which find mixed results on the effects of pre-trade transparency on liquidity.

Madhavan, Porter and Weaver (1999) find that execution costs and volatility increased with pre-trade transparency on the Toronto Stock Exchange where, starting in April 1990, a computerized system made available real-time information on the limit-order book. Garfinkel and Nimalendran (1998) reach similar conclusions by looking at the insiders' trading days on both the NYSE and the NASDAQ, and Albanesi and Rindi (2000) show that when anonymity was introduced on the MTS, the Italian secondary market for Treasury Bonds, liquidity increased. On the contrary, Theissen (2000) finds that on the non-anonymous floor-based trading system of the Frankfurt Stock

Exchange, specialists offer price improvements to traders deemed to be uninformed and conclude that transparency enhances liquidity. Similarly, Harris and Schultz (1997) find that on the anonymous Small Order Execution System of the NASDAQ market makers offer wide bid-ask spreads.

The issue of pre-trade transparency has also been approached by experimental works. Flood, Huisman, Koedjik and Mahieu (1999) show that in transparent markets liquidity is higher and informational efficiency is lower while Perotti and Rindi (2001) find opposite results and Bloomfield and O'Hara (1999) show that, by controlling for differences in market structure, the trade-off between transparency and liquidity disappears.

In Section 1 we present the model with competitive agents, in Section 2 we extend the model to imperfect competition and in Section 3 we conclude.

# 1 The model with competitive agents

The market is formed by two groups of risk averse agents, N insiders and M uninformed, and by Z noise traders. Risk averse agents are price takers: we will remove this hypothesis later. Let $X_I$, $X_U$ and $x$, with $x \sim N(0, \sigma_x^2)$, be the size of the insiders', uninformed and noise traders' orders respectively.

Agents trade a single risky asset with liquidation value equal to:

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

As in Glosten (1989), Madhavan and Panchapagesan (2000) and Leshchinski (2001), at the beginning of the trading game insiders receive an endowment shock equal to $I$, and a signal, $S$, on the future value of the asset both normally distributed with zero mean and variance equal to $\sigma_I^2$ and $\sigma_S^2$ respectively. The endowment shock is a source of noise which prevents full information revelation, since it induces insiders to act both as hedgers and as speculators. Assuming CARA utility function, each insider maximizes her end of period wealth and submits the following limit order:

$$X_I = \frac{S - p}{A\,\sigma_\varepsilon^2} - I \tag{1}$$

where $A$ is the coefficient of risk aversion and $p$ is the market price. Each uninformed trader forms a conjecture on the equilibrium price and updates her expectations on the liquidation value of the asset by extracting a signal from the current price. In order to keep the model simple, we will first assume that uninformed traders do not receive an endowment shock at the beginning of the trading game and submit:

$$X_U = \frac{E(F|p) - p}{A \quad VAR(F|p)} \tag{2}$$

This hypothesis does not change qualitatively the results since, being the insiders' signal a sufficient statistic for the market price, their strategies are not affected by the noise produced by the uninformed traders' endowment and neither is their willingness to supply liquidity.

In Section 1.3 we show that the results obtained do not qualitatively change when assuming uninformed traders receive an endowment shock equal to $I_U$ and submit:

$$X_U = \frac{E(F|p) - p}{A \quad VAR(F|p)} - I_U \tag{3}$$

A linear rational expectation equilibrium implies that the equilibrium price observed in the market is indeed a linear combination of $S$, $I$ (and $I_U$) and $x$. Substituting equations 1 and 2 (or 3) into the market clearing condition,

$$N \ X_I + M \ X_U + Z \ x = 0, \tag{4}$$

and solving for $p$, we derive the equilibrium price and three indicators of market quality: liquidity ($\left|\frac{dp}{dx}\right|^{-1}$), volatility ($Var(p)$) and informational efficiency ($IE = \dfrac{1}{Var(F|p)}$). In the next section, three regimes of pre-trade transparency will be compared: different regimes of transparency will not affect the strategies of the insiders who already possess the most precise signal, but this will no longer hold with imperfect competition, where agents take into account the price impact of their trade. Transparency modifies the demand elasticity of market price and therefore it influences agents' perception of their price impact.

## 1.1 Anonymity

We will first solve the model with anonymity where uninformed traders observe neither traders' orders size, nor their identification codes. They can only get information on the future value of the asset by looking at the market price and extracting the signal $\Theta = S + \frac{A\sigma_\varepsilon^2 Z}{N}x - A\sigma_\varepsilon^2 I$:

**Proposition 1** *The following equilibrium price ($p^A$) and indicators of market quality characterize the regime with anonymity.*

$$p^A = \lambda_A[\frac{N}{A\sigma_\varepsilon^2}S - NI + Zx] \tag{5}$$

$$LA = \frac{1}{\lambda_A} \tag{6}$$

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

$$\begin{aligned} IE_A &= [Var\ (F|\Theta)]^{-1} = \\ &= \left[ \sigma_s^2 + \sigma_\varepsilon^2 - \frac{\sigma_s^4}{\left( \sigma_s^2 + A^2\sigma_\varepsilon^4\sigma_I^2 + \frac{A^2\sigma_\varepsilon^4 Z^2}{N^2}\sigma_x^2 \right)} \right]^{-1} \end{aligned} \tag{7}$$

$$Var(p^A) = (\lambda_A)^2 \left(\frac{N^2}{A^2\sigma_\varepsilon^4}\sigma_S^2 + N^2\sigma_I^2 + Z^2\sigma_x^2\right) \tag{8}$$

Proof: See the Appendix.

Under the anonymous regime, market liquidity is an inverse function of the conditional variance of F and a direct function of the variance of the signal uninformed traders can extract from the equilibrium price. A smaller conditional variance makes uninformed risk averse traders more willing to provide liquidity, whereas a smaller variance of their signal increases their estimate of that part of the net demand of both insiders and uninformed traders which depends on prices and therefore is a shock absorber, e.g. is negative (positive) after a buy (sell) order. Assume as an example that a noise trader submits a buy order, which causes a price increase. Uninformed traders, who cannot recognize that order as liquidity motivated, will make an estimate of the increase in the fundamental value of the asset which corresponds to that price increase. Within this process, the higher their estimate of other traders' sell orders, the higher their wrong estimate of the "effective" price increase and the lower their willingness to provide liquidity and take the other side of the noise trader's buy order.

## 1.2 Full Transparency

Under the regime with full transparency, agents can observe traders' identity codes and net demands. Uninformed traders extract a signal equal to $\Theta_T^{'} = S - A\sigma_\varepsilon^2 I$ from the insider's order $X_I$ and update their expectations on the liquidation value of the asset.

**Proposition 2** *The following equilibrium price ($p^T$) and indicators of market quality characterize the regime with full transparency.*

$$p^T = \lambda_T[(\frac{N + M\Omega}{A\sigma_\varepsilon^2})S - (N + M\Omega)I + Zx] \tag{9}$$

with $\Omega = \left( \frac{\frac{Cov(F,\Theta_T^{'})}{Var(\Theta_T^{'})} A\sigma_\varepsilon^2}{A\ Var\ (F|\Theta_T^{'})} \right)$

$$LT = \frac{1}{\lambda_T} \tag{10}$$

with $\lambda_T = \left[ \frac{N}{A\sigma_\varepsilon^2} + \frac{M}{AVar(F|\Theta_T^{'})} \right]^{-1}$

$$IE_T = [Var\ (F|\Theta_T^{'})]^{-1} = [\sigma_s^2 + \sigma_\varepsilon^2 - \frac{\sigma_s^4}{(\sigma_s^2 + A^2\sigma_\varepsilon^4\sigma_I^2)}]^{-1} \tag{11}$$

$$Var(p^T) = (\lambda_T)^2 (\frac{(N + M\Omega)^2}{A^2\sigma_\varepsilon^4} \sigma_S^2 + (N + M\Omega)^2\sigma_I^2 + Z^2\sigma_x^2) \tag{12}$$

Proof: see the Appendix.

**Proposition 3** *Under the regime with full transparency, market liquidity and informational efficiency are higher; there exists a wide range of exogenous parameter values such that with full transparency volatility is higher.*

Proof: see the Appendix.

With full transparency uninformed traders behave as if they were insiders holding a signal, $\Theta_T^{'}$, which is a noisy version of the insiders' one. The more precise is the traders' signal, the lower adverse selection costs they pay and therefore the higher is liquidity. It follows that when uninformed traders get a more precise signal from the market, they are more willing to offer liquidity to noise traders and liquidity increases. Inspection of equations 7 and 11 shows that under full transparency the conditional variance of the liquidation value of the asset is lower; this means that informational efficiency is higher. Finally, Figure 1 shows that the difference between $Var(p^T)$ and $Var(p^A)$ is positive. Intuitively, under the transparent regime uninformed traders behave as "quasi-insiders" and the number of "informative shocks" is higher than under anonymity. Figure 1 also shows that the difference between $Var(p^T)$ and $Var(p^A)$ is an increasing function[3] of $\sigma_x^2$ and $Z$. An increase in the variance of the noise, $\sigma_x^2$, and/or in $Z$, produces two effects: it directly increases a component ($Z^2\ \sigma_x^2$) of volatility under both regimes with transparency and anonymity and for this reason it equally increases $Var(p^T)$ and $Var(p^A)$; in addition, it reduces the price impact under the anonymous regime ($\lambda_A$), the latter effect reducing $Var(p^A)$ and not $Var(p^T)$.

## 1.3 Endogenous information acquisition

In this section we assume that each informed trader pays a fixed cost equal to $C$ to buy her signal. She will decide to acquire information if her unconditional expected utility from trading exceeds the utility from not trading.

The unconditional expected utility each insider obtains from trading on her signal is derived in Lemma 2 where the insider's end of period expected utility, i.e. $E[-\exp(-A(\Pi_I - C))]$, is equated to the expected utility she obtains from not trading; the latter being equal to the expected utility of her endowment shock, i.e. $\mathrm{E}[-\exp(-A(FI))]$, under the hypothesis that agents' initial wealth is normalized to zero.

However, since the insider can also choose not to buy the signal and enter the market in order to hedge her endowment shock, we will also analyze the more complex case where the insider decides to acquire information up to the point where her unconditional expected utility from trading on the signal is equated to the expected utility from entering the market and hedging her endowment shock, i.e. $E[-\exp(-A(\Pi_U))]$. The latter condition is obtained in Lemma 3.

**Lemma 2** *The equilibrium number of insiders can be derived from the following condition:*

$$-\exp(AC)\frac{V_z}{\sqrt{1-2\sigma_I^2(c_z+f_z^2\frac{\sigma_\varepsilon^2}{2}+W_z^2Q_z+Y_zR_z^2)}} = \tag{13}$$

$$= -\frac{1}{\sqrt{1 - 2\sigma_I^2(\frac{A^2\sigma_\varepsilon^2}{2} + \frac{A^2\sigma_S^2}{2})}}$$

**Lemma 3** *When each insider can decide either to buy a costly signal and trade, or not to buy a costly signal and trade in order to hedge her endowment shock, the equilibrium number of insiders can be derived from the following condition.*

$$-\exp(AC)\frac{\Upsilon_z}{\sqrt{1 - 2\sigma_U^2(d_z + h_z^2\frac{\sigma_\varepsilon^2}{2} + L_z F_z^2 + R_z\Lambda_z^2 + J_z U_z^2)}} = \tag{14}$$

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

*Proof: see the Appendix.*

We will now comment on the results obtained from Lemma 2 and Lemma 3 respectively.

Using the two Lemmas, it is possible to solve the models for the equilibrium number of insiders under the two regimes, with anonymity and full transparency, and evaluate the impact of transparency on market quality both under the assumption that only insiders receive an endowment shock at the beginning of the trading game (Table 1) and under the assumption that all traders receive an endowment shock (Tables 1.1 and 1.2). The next Proposition summarizes these results.

**Proposition 4** *With endogenous information acquisition, there exists a wide range of exogenous parameter values such that the equilibrium number of insiders and liquidity are higher with anonymity than with full transparency. The results on volatility are mixed.*

Tables 1, 1.1 and 1.2 show the equilibrium number of insiders both under the anonymous regime ($N_A$) and under the fully transparent one ($N_T$) for different values of the parameters $\sigma_S^2, \sigma_\varepsilon^2, \sigma_I^2, \sigma_x^2, \sigma_U^2, M, Z, A$ and $C$. They also show the difference in liquidity $(LA - LT)$ and volatility $(VA - VT)$. Transparency reduces the agents' incentive to acquire information causing a decline of the equilibrium number of insiders. This is the reason why under this regime liquidity decreases. A higher $C$ makes information more expensive and the equilibrium number of insiders lower. Tables 1 and 1.1 also show that when the number of market participants $(M, Z)$ doubles from 10 to 20, the equilibrium number of insiders is two times higher. They also show that the higher the number of market participants, the stronger are these results, which gives robustness to the model with competitive agents. Intuitively, the higher the number of uninformed traders, the greater are the profits insiders can extract from their private information and the greater is the incentive to acquire information. The same intuition explains the effect of an increase of $\sigma_x$ (from .5 to .8) on the equilibrium number of insiders. Conversely, when $\sigma_S$ decreases from .5 to .3 (Tables 1 and 1.2), the value of the insiders' signal decreases and the equilibrium number of insiders is generally lower. A reduction of $A$, the coefficient of risk aversion, from 2 to 1.9 produces two effects: on the one hand, it makes agents more aggressive when trading on their private information; on the other, it reduces their risk-sharing needs and therefore their incentive to enter the market. The results show that when agents can choose either to enter the market and buy information or to stay out of the market, the second effect prevails and they enter the market mainly for sharing the higher risk they perceive; conversely, when the decision to enter the market only depends on their willingness to exploit their private information, being able to hedge their endowment anyhow, $N_A$ increases. Finally, it is difficult to interpret exactly the consequences of an increase of $\sigma_\epsilon^2, \sigma_I^2$ and $\sigma_U^2$ since a number of different effects take place at the same time. However, it is interesting to notice that, under the regime with transparency, a reduction of $\sigma_U^2$ decreases the equilibrium number of insiders; this finding makes the results obtained assuming $\sigma_U^2 = 0$ more robust.

### 1.4 Partial Transparency

Under the regime with partial transparency, agents can observe prices and quantities, but not personal identifiers. As a consequence, the order each uninformed trader observes, $\theta'_{PT}$, belongs with probability $\frac{N}{N+Z}$ to an insider and with probability $\frac{Z}{N+Z}$ to a noise trader. Uninformed traders observe a realization of the following random variable:

$$\left\{\Theta'_{PT}|\Theta'_{PT} \neq X_U\right\} = qX_I + (1-q)x \text{ with } q \sim \begin{cases} 0 & \frac{Z}{N+Z} \\ 1 & \frac{N}{N+Z} \end{cases} \tag{15}$$

Moreover, uninformed agents extract the signal $\Theta_{PT}$ from the current price using their conjecture on other uninformed agents' orders, $X_U^{PT} = -H^{PT}p + \Omega^{PT}\theta'_{PT}$, and the market clearing condition[4]. Uninformed traders use the two signals, $\Theta_{PT} = S - A\sigma_\varepsilon^2 I + \frac{ZA\sigma_\varepsilon^2}{N}x$ and $\Theta'_{PT} = S - A\sigma_\varepsilon^2 I$, to update their believes and evaluate $E\left[F|\Theta_{PT}, \Theta'_{PT}\right]$ , which is derived in Lemma 3 in the Appendix.

**Proposition 5** *The following equilibrium price* ($p^{PT}$) *and indicator of liquidity characterize the regime with partial transparency.*

$$p^{PT} = \lambda_{PT}[\frac{N + M\Omega^{PT} q}{A\sigma_\varepsilon^2} S - (N + M\Omega^{PT} q)I + (M\Omega^{PT}(1-q) + Z)x] \quad (16)$$

with $\lambda_{PT} = [\dfrac{N}{A\sigma_\varepsilon^2} + MH^{PT} + \frac{M\Omega^{PT} q}{A\sigma_\varepsilon^2}]^{-1}$

$$E[LPT(q)] = \frac{\lambda_{PT}^{-1}}{\frac{M\Omega^{PT}(1-q)}{Z} + 1} = \quad (17)$$

$$= \left( \frac{\dfrac{N}{A\sigma_\varepsilon^2} + MH^{PT}}{\frac{M\Omega^{PT}}{Z} + 1} \right) \frac{Z}{N+Z} + \left( \frac{N}{A\sigma_\varepsilon^2} + MH^{PT} + \frac{M\Omega^{PT}}{A\sigma_\varepsilon^2} \right) \frac{N}{N+Z}$$

*Proof: see the Appendix.*

Comparing the two regimes with full and partial transparency, we obtain the following result:

**Proposition 6** *There exists a wide range of exogenous parameter values such that liquidity is lower under the partially transparent regime than under the fully transparent one.*

Figure 2 shows that the higher the proportion of informed ($N$) with respect to noise traders ($Z$), the higher is liquidity under the partially transparent regime. When the number of insiders is relatively high, uninformed traders, by looking at the orders on the market, learn a more precise signal on the liquidation value of the asset and, since they pay lower adverse selection costs, they are more willing to offer liquidity.

# 2 The model with strategic traders

Up to here we have assumed that risk averse agents are price taker. We now assume agents behave strategically and take into account the effects their orders have on equilibrium price. This hypothesis is particularly relevant when evaluating the effect of transparency on market depth, which is influenced by the aggressiveness of liquidity providers. If liquidity suppliers take into account the price impact of their trade, they scale back their orders accordingly. Conversely, if they behave competitively they submit more aggressive orders. We have previously shown that transparency makes uninformed agents more informed about the liquidation value of the asset and therefore makes them more willing to provide liquidity and act as a counterpart of the noise traders' orders. This effect is stronger with agents behaving competitively, since with imperfect competition agents trade less aggressively.

**Proposition 7** *Under the assumption that risk averse traders behave strategically, the following equilibrium prices and indicators of liquidity characterize the regimes with anonymity and full transparency respectively.*

*Anonymity:*

$$p^S = [LSA]^{-1}[NDS - NGI + Zx] \tag{18}$$

$$LSA = [ND + MH^S]) = \tag{19}$$

$$= \frac{N}{A\sigma_\varepsilon^2 + \lambda_I} + M \frac{1 - \dfrac{Cov(F, \Theta_S)}{Var(\Theta_S)}}{A\,Var\ (F|\Theta_S) + \lambda_U + \dfrac{Cov(F, \Theta_S)M}{Var(\Theta_S)N}(A\sigma_\varepsilon^2 + \lambda_I)}$$

*Full transparency:*

$$p^{ST} = [LST]^{-1}[(ND^T + M\Omega^T D^T)S - (NG + M\Omega^T)I + Zx] \tag{20}$$

$$LST = [ND^T + MH^{ST} + M\Omega^T D^T] = \tag{21}$$
$$= \left[\frac{N}{A\sigma_\varepsilon^2 + \lambda_I^T} + \frac{M}{A\,Var\,(F|\Theta_{ST}, \Theta'_{ST}) + \lambda_U^T}\right]$$

*Proof: see the Appendix.*

**Proposition 8** *Agents' strategic behavior reduces the effect of pre-trade transparency on liquidity.*

Tables 2 and 3 compare liquidity ($L$) under the two regimes with anonymity ($An.$) and full transparency ($Tr.$) given the assumption that agents behave either strategically or competitively. These tables also report the values of the parameters $\lambda_I$, $\lambda_U$, $H$, $\Delta$, $\Omega$. Independently of the regime under analysis and of the parameter values, when agents behave competitively, liquidity is higher. In fact, when agents do not take into account the effects their demand has on equilibrium price, they trade more aggressively, e.g. they are more willing to sell after a noise trader's buy order. What influences the results is the assumption on the insiders' rather than on the uninformed traders' behavior. Take as an example Table 2.1. Under the anonymous regime, with strategic agents, liquidity is equal to 5.63, while, when traders behave competitively, liquidity is 6.56. However, when only uninformed traders are strategic ($\lambda_I = 0$), $L$ is 6.45, while when only insiders are strategic ($\lambda_U = 0$), $L$ decreases to 5.77. Notice that this result holds independently of the relative number of $N$, $M$ and $Z$ (Tables 2.2– 2.4). Notice also that when the number of insiders is four times higher than the number of uninformed traders, liquidity is also four times higher (Table 2.2). As expected, liquidity increases with the number of market participants. Table 2.4 shows that the higher the number of $N$, $M$ and $Z$, the higher is liquidity, being the percentage increase in liquidity due to transparency almost the same with strategic and with competitive agents (.308 and .305 respectively). As expected, the difference in the percentage increase in liquidity under the two regimes narrows as the number of market participants increases. As previously explained, when switching from anonymity to full transparency, liquidity increases due to uninformed traders learning a signal similar to the one held by insiders; when transparency increases, uninformed traders learn how to identify -even not perfectly- liquidity motivated orders and become more willing to supply liquidity. Since traders submit more aggressive orders when behaving competitively, under the competitive regime the increase in liquidity conveyed by transparency is higher.

# 3 Conclusions

This paper showed how pre-trade transparency affects liquidity and market quality. This issue was analyzed both with competitive and with strategic agents: under the scenario with competitive agents, the number of insiders was endogenous. This is a crucial feature within our analysis since we proved that allowing for endogenous information acquisition previous results on the effects of pre-trade transparency on liquidity are reversed. We found that transparency reduces the equilibrium number of informed agents who enter the market and therefore reduces liquidity. Most noticeably, we found that the larger the initial number of market participants is, the stronger these results are. The effect of transparency was analyzed under three different regimes: anonymity, where traders can only observe the current price; full transparency, where traders can also observe personal identifiers; and partial transparency, where agents can observe the order flow but not personal identifiers. By using this set up, we were able to analyze all the different degrees of transparency one may find in real markets.

Liquidity, measured as the price impact of a noise trader's order, depends on two opposite elements which follow the initial price change: traders' willingness to accommodate a liquidity shock and traders' updating process following this order. When a noise trader submits a buy order, she causes an increase of the current price and the magnitude of such an increase will depend on the other traders' reaction. On the one hand, both insiders' and uninformed maximizing traders' demands are inverse functions of the current price and therefore these traders are willing to accommodate the noise trader's order, thus increasing liquidity. On the other hand, following a noise trader's buy order, uninformed traders revise upwards their estimate of the future value of the asset and, increasing their speculative demand, they cause a reduction in liquidity. It follows that the price impact of a liquidity shock depends on the net effect of these two forces which influence the reaction of liquidity suppliers.

The market is modelled here as an open limit-order book where liquidity is offered by all market participants.

We showed that when agents are competitive, transparency increases liquidity; the explanation being that transparency reduces uninformed traders' adverse selection costs. On the contrary, when allowing for endogenous information acquisition, under the fully transparent regime both the equilibrium number of insiders and liquidity are lower. Informed agents, who pay the least adverse selection costs, are the best liquidity suppliers: since transparency reduces the incentive to buy costly information and hence reduces the number of informed traders who are willing to enter the market, it reduces market depth. We also showed that transparency increases informational efficiency and volatility.

When agents behave strategically, they are concerned about the price impact of their trade and are less willing to supply liquidity; hence the difference in the degree of liquidity between anonymity and full transparency is substantially reduced.

Our theoretical findings are supported by the existing empirical evidence which finds mixed results about the effect of pre-trade transparency on liquidity and market quality. Particularly it helps explaining recent empirical results from field data on two automated markets: the Toronto Stock Exchange and the Italian Secondary Market for Treasury Bonds (MTS). Madhavan, Porter and Weaver (2000) showed that following the increase in pre-trade transparency trading costs increased in the Toronto Stock exchange and Albanesi and Rindi (2000) showed that the introduction of anonymity increased liquidity on the MTS.

The results obtained in this paper suggest that anonymity may be desirable in automated markets.

As previously mentioned, this model deals with information acquisition and aggregation. Both Mendelson and Tunca (2001) and Holden and Subrahmanyam (1992) showed that in equilibrium, market liquidity and informational efficiency depend on the number of insiders and on the behavior of the market makers' opponents. By contrast, we examine how equilibria in which the type of agents' orders is publicly known differ from equilibria in which such information is not known. It would be interesting to extend this analysis by investigating the effects of pre-trade transparency in a dynamic model of price formation where both informed and uninformed traders act as liquidity suppliers who condition their strategies on the beliefs of the other agents.

# 4 Appendix

**Proof of Proposition 1.**

Each uninformed trader forms a conjecture on other traders' net demand equal to $X_U^A = -Hp^A$, and, extracting the following signal from the current price, $\Theta = S + \frac{A\sigma_\varepsilon^2 Z}{N}x - A\sigma_\varepsilon^2 I = \left(\frac{N+A\sigma_\varepsilon^2(M-1)H}{N}\right)p^A - \frac{A\sigma_\varepsilon^2}{N}X_U = \gamma_1 p^A - \gamma_2 X_U$ with $\gamma_1 = \left(\frac{N+A\sigma_\varepsilon^2(M-1)H}{N}\right)$ and $\gamma_2 = \frac{A\sigma_\varepsilon^2}{N}$, submit the limit order $X_U^A = \frac{E(F|\Theta)-p^A}{A\,Var\,(F|\Theta)} = \frac{\delta_U^A(\gamma_1 p^A - \gamma_2 X_U\,) - p^A}{A\,Var\,(F|\Theta)}$, with $\delta_U^A = \frac{Cov(F,\Theta)}{Var(\Theta)} = \dfrac{\sigma_S^2}{\sigma_s^2 + A^2\sigma_\varepsilon^4\sigma_I^2 + \frac{A^2\sigma_\varepsilon^4 Z^2}{N^2}\sigma_x^2}$, $Var\,(F|\Theta) = \sigma_s^2 + \sigma_\varepsilon^2 - \dfrac{\sigma_s^4}{\sigma_s^2 + A^2\sigma_\varepsilon^4\sigma_I^2 + \frac{A^2\sigma_\varepsilon^4 Z^2}{N^2}\sigma_x^2}$ 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 parameter of the realized demand to $H$, we get:

$$X_U^A = -\left[\frac{1 - \dfrac{Cov(F,\Theta)}{Var(\Theta)}}{A\,Var\,(F|\Theta) + \dfrac{Cov(F,\Theta)}{Var(\Theta)}\frac{AM\sigma_\varepsilon^2}{N}}\right]p^A$$

Substituting this equation and equation 1 into 4 and solving for $p$ we obtain equation 5.

**Proof of Proposition 2.**

With full transparency each uninformed agent forms a conjecture on the other uninformed traders' net demand equal to $X_U^T = -H^T p^T + \Omega\theta_T'$ and extracts the following signal from the market price, $p^T$: $\Theta_T = S - A\sigma_\varepsilon^2 I + \frac{A\sigma_\varepsilon^2 Z}{N}x = -\frac{A\sigma_\varepsilon^2}{N}X_U + \frac{N+A\sigma_\varepsilon^2(M-1)H^T}{N}p^T - \frac{A\sigma_\varepsilon^2(M-1)\Omega}{N}\theta_T' = \gamma_1^T p^T - \gamma_2 X_U - \gamma_3\theta_T' = \theta_T$ with

$\gamma_1^T = \frac{N+A\sigma_\varepsilon^2(M-1)H^T}{N}$, $\gamma_2 = \frac{A\sigma_\varepsilon^2}{N}$ and $\gamma_3 = \frac{A\sigma_\varepsilon^2(M-1)\Omega}{N}$. Since she can observe personal identifiers, she can also extract the signal $\Theta_T^{'} = S - A\sigma_\varepsilon^2 I = A\sigma_\varepsilon^2\theta_T^{'} + p^T$ from the insider'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 $\Theta_T$.

**Proof:**

$$E\left[F|\Theta_T, \Theta_T^{'} = S - A\sigma_\varepsilon^2 I\right] = \begin{bmatrix} Cov(F,\Theta_T) & Cov(F,\Theta_T^{'}) \end{bmatrix} *$$

$$*\frac{1}{\left[Var(\Theta_T^{'})Var(\Theta_T) - (Cov(\Theta_T,\Theta_T^{'}))^2\right]} * \begin{bmatrix} Var(\Theta_T^{'}) & -Cov(\Theta_T,\Theta_T^{'}) \\ -Cov(\Theta_T,\Theta_T^{'}) & Var(\Theta_T) \end{bmatrix}$$

$$* \begin{bmatrix} \theta_T & A\sigma_\varepsilon^2\theta_T^{'} + p^T \end{bmatrix}^{'} = \frac{\sigma_S^2}{\sigma_S^2 + A^2\sigma_\varepsilon^4\sigma_I^2}\left(A\sigma_\varepsilon^2\theta_T^{'} + p\right) = \delta_U^T\left(A\sigma_\varepsilon^2\theta_T^{'} + p\right) =$$

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

From Lemma 1 it follows that uninformed agents, when updating their believes on the liquidation value of the asset, discard the signal from the current price and submit the net demand schedule $X_U^T = \frac{E(F|\Theta_T^{'})-p^T}{A\,Var\,(F|\Theta_T^{'})} = \frac{\delta_U^T(A\sigma_\varepsilon^2\theta_T^{'}+p^T)-p^T}{A\,Var\,(F|\Theta_T^{'})} = \left(\frac{\delta_U^T A\sigma_\varepsilon^2}{A\,Var\,(F|\Theta_T^{'})}\right)\theta_T^{'} - \left(\frac{1-\delta_U^T}{A\,Var\,(F|\Theta_T^{'})}\right)p^T$ .

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

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

Using the market clearing condition, it is straightforward to derive the equilibrium price, $p^T$, and the results discussed in Proposition 2.

**Proof of Proposition 3.**

$$LT - LA = \frac{\begin{array}{c}\sigma_S^2 A[A^2\sigma_\varepsilon^4\sigma_I^2 MN + \sigma_S^2 MN + \sigma_S^2 A^2\sigma_\varepsilon^2 Z^2\sigma_x^2 + \\ +\sigma_S^2 A^2\sigma_\varepsilon^2\sigma_I^2 N^2 + \sigma_S^2 N^2 + A^2\sigma_\varepsilon^4\sigma_I^2 N^2]\end{array}}{\begin{array}{c}[\sigma_S^2 A^2\sigma_\varepsilon^2 Z^2\sigma_X^2 + \sigma_S^2 A^2\sigma_I^2 N^2 + \sigma_S^2 N^2 + A^2\sigma_\varepsilon^4\sigma_x^2 Z^2 + \\ +A^2\sigma_\varepsilon^4\sigma_I^2 N^2 + \sigma_S^2 MN]A\sigma_\varepsilon^2(\sigma_S^2 A^2\sigma_\varepsilon^2\sigma_I^2 + \sigma_S^2 + A^2\sigma_\varepsilon^4\sigma_I^2)\end{array}} > 0$$

**Proof of Lemma 2 and of Proposition 4**

Let $\Pi_I^z = X_I^z(F - p^z) + IF$ with $z = A, T$ , be the end of period profits of each insider under the anonymous $(A)$ and the fully transparent $(T)$ regime. Let $p^z$, $F - p^z$ and $X_I^z$ be: $p^z = \alpha_1^z S + \alpha_2^z x + \alpha_3^z I$, $F - p^z = (1 - \alpha_1^z)S - \alpha_2^z x - \alpha_3^z I + \varepsilon$ and $X_I^z = \beta_1^z S + \beta_2^z x + \beta_3^z I$. It follows that the expected utility of each insider's profits is equal to:

$$\begin{aligned} E[-\exp(-A\Pi_I^z)] &= -E[\exp(b_z S^2 + c_z I^2 + d_z x^2 + e_z(\varepsilon S) + f_z(\varepsilon I) \\ &\quad +g_z(\varepsilon x) + h_z(SI) + i^z(Sx) + j^z(Ix)) \end{aligned} \tag{22}$$

$$\begin{aligned} \text{with } b_z &= -\beta_1^z(1-\alpha_1^z)A, \quad c_z = \beta_3^z\alpha_3^z A, \quad d_z = \beta_2^z\alpha_2^z A, \quad e_z = -\beta_1^z A, \\ f_z &= -(\beta_3^z + 1)A, \quad g_z = -\beta_2^z A, \ j_z = -(-\beta_2^z\alpha_3^z - \beta_3^z\alpha_2^z)A \\ i_z &= -(-\beta_1^z\alpha_2^z + \beta_2^z(1-\alpha_1^z))A, \quad h_z = -(-\beta_1^z\alpha_3^z + \beta_3^z(1-\alpha_1^z) + 1)A, \end{aligned} \tag{23}$$

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

$$E_I = [E_x] = \frac{V_z}{\sqrt{1 - 2\sigma_I^2(c_z + f_z^2\frac{\sigma_\varepsilon^2}{2} + W_z^2 Q_z + Y_z R_z^2)}} \tag{24}$$

$$\begin{aligned} \text{with } D_z &= b_z + \frac{e_z^2\sigma_\varepsilon^2}{2};\ L_z = d_z + \frac{\sigma_\varepsilon^2}{2}g_z^2 + F_z^2 Q_z; W_z = h_z + e_z f_z \sigma_\varepsilon^2; \qquad (25) \\ V_z &= \frac{1}{\sqrt{(1 - 2\sigma_S^2 D_z)(1 - 2\sigma_x^2 L_z)}};\ F_z = i_z + e_z g_z \sigma_\varepsilon^2;\ Q_z = \frac{\sigma_S^2}{2(1 - 2\sigma_\varepsilon^2 D_z)} \\ R_z &= j_z + \sigma_\varepsilon^2 f_z g_z + 2W_z F_z Q_z; \quad Y_z = \frac{\sigma_x^2}{2(1 - 2L_z\sigma_x^2)} \qquad \textbf{c.v.d}. \end{aligned}$$

In order to solve for the equilibrium number of insiders, we need to evaluate the insiders' profits under different regimes of transparency. By looking at the equilibrium price, given by expression 5 and 9, under anonymity and full transparency respectively, we infer that:

$p^A = \alpha_1^A S + \alpha_2^A x + \alpha_3^A I$ with $\alpha_1^A = \lambda_A \frac{N}{A\sigma_\varepsilon^2}$, $\alpha_2^A = \lambda_A Z$, $\alpha_3^A = -\lambda_A N$ and $p^T = \alpha_1^T S + \alpha_2^T x + \alpha_3^T I$ with $\alpha_1^T = \lambda_T \frac{N+M\Omega}{A\sigma_\varepsilon^2}$, $\alpha_2^T = \lambda_T Z$, $\alpha_3^T = -\lambda_T(N+M\Omega)$.

Substituting the expression for the equilibrium price into the insider's demand $X_{I,}$ we get:

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

where $z = A, T$ and, therefore,

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

Now, substituting the values of $\alpha^z$ and $\beta^z$ into (23), (24) and (25) the expected utility of each insider's profit under the two regimes with anonymity and transparency can be evaluated and using (13) one can obtain the results in Table 1 and Proposition 4.

In order to prove Lemma 3, it is necessary to solve the model under the assumption that uninformed traders receive an endowment shock as well as insiders and submit a demand equal to:

$$X_U^A = \frac{E(F|\Theta) - p^A}{A\ Var\ (F|\Theta)} - I_U = -Hp^A - \Psi I_U \tag{26}$$

with $H = \dfrac{1-\dfrac{Cov(F,\Theta)}{Var(\Theta)}}{A\ Var\ (F|\Theta) + \dfrac{Cov(F,\Theta)}{Var(\Theta)}\frac{AM\sigma_\varepsilon^2}{N}}$ and $\Psi = \dfrac{1}{1+\dfrac{M\sigma_\varepsilon^2\sigma_S^2}{NVar(\Theta)Var\ (F|\Theta)}}$

and

$$p^A = \lambda_A[\frac{N}{A\sigma_\varepsilon^2}S - NI - M\Psi I_U + Zx] \tag{27}$$

under anonymity and

$$X_U^T = \frac{E(F|\Theta') - p^T}{A\ Var\ (F|\Theta')} - I_U = -H^T p^T + \Omega\theta_T^{'} + \Psi^T I_U \tag{28}$$

with $\Psi^T = 1$ and

$$p^T = \lambda_T[(\frac{N + M\Omega}{A\sigma_\varepsilon^2})S - (N + M\Omega)I - MI_U + Zx] \tag{29}$$

under full transparency.

**Proof of Lemma 3**

Let $\Pi_{I,U}^z = X_{I,U}^z(F - p^z) + I_{\cdot,U}F$ with $z = A, T$ , be the end of period profits of each insider and uninformed trader respectively under the anonymous $(A)$ and the fully transparent $(T)$ regime. Let $p^z$, $F - p^z$ and $X_{I,U}^z$ be: $p^z = \alpha_1^z S + \alpha_2^z x + \alpha_3^z I + +\alpha_4^z I_U$, $F - p^z = (1 - \alpha_1^z)S - \alpha_2^z x - \alpha_3^z I - \alpha_4^z I_U + \varepsilon$ 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:

$$E[-\exp(-A\Pi_{I,U}^z)] = -E[\exp(b_{z,zu}S^2 + c_{z,zu}I^2 + d_{z,zu}I_U^2 + e_{z,zu}x^2 + f_{z,zu}(\varepsilon S) + \tag{30}$$

$$g_{z,zu}(\varepsilon I) + +h_{z,zu}(\varepsilon I_U) + i_{z,zu}(\varepsilon x) + l_{z,zu}(SI) + m_{z,zu}(SI_U) +$$

$$+n_{z,zu}(Sx) + p_{z,zu}(II_U) + q_{z,zu}(Ix) + r_{z,zu}(I_U x))]$$

$$\text{with} \quad \begin{aligned} b_{z,zu} &= -\beta^z_{1,1u}(1-\alpha^z_1)A, \quad c_{z,zu} = \beta^z_{3,3u}\alpha^z_3 A, \\ d_{z,zu} &= \beta^z_{4,4u}\alpha^z_4 A, \quad e_{z,zu} = \beta^z_{2,2u}\alpha^z_2 A, \;\; f_{z,zu} = -\beta^z_{1,1u}A, \quad g_z = -(\beta^z_3 + 1)A, \\ g_{zu} &= -\beta^z_{3u}A, \;\; h_z = -\beta_z A, \quad h_{zu} = -(\beta^z_{4u}+1)A, \quad i_{z,zu} = -\beta^z_{2,2u}A, \\ l_z &= -(-\beta^z_1\alpha^z_3 + \beta^z_3(1-\alpha^z_1)+1)A, \quad l_{zu} = -(-\beta^z_{1u}\alpha^z_3 + \beta^z_{3u}(1-\alpha^z_1))A, \\ m_z &= -(-\beta^z_1\alpha^z_4 + \beta^z_4(1-\alpha^z_1))A, \quad m_{zu} = -(-\beta^z_{1u}\alpha^z_4 + \beta^z_{4u}(1-\alpha^z_1)+1)A, \\ n_{z,zu} &= -(-\beta^z_{1,1u}\alpha^z_2 + (1-\alpha^z_1)\beta^z_{2,2u})A, \quad p_{z,zu} = -(-\beta^z_{3,3u}\alpha^z_4 - \beta^z_{4,4u}\alpha^z_3)A, \\ q_{z,zu} &= -(-\beta^z_{2,2u}\alpha^z_3 - \beta^z_{3,3u}\alpha^z_2)A, \quad r_{z,zu} = -(-\beta^z_{2,2u}\alpha^z_4 - \beta^z_{4,4u}\alpha^z_2)A \end{aligned} \tag{31}$$

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

$$E_{I_U} = [E_I] = \frac{\Upsilon_{z,zu}}{\sqrt{1 - 2\sigma_U^2 (d_{z,zu} + h_{z,zu}^2 \frac{\sigma_\varepsilon^2}{2} + L_{z,zu} F_{z,zu}^2 + R_{z,zu} \Lambda_{z,zu}^2 + J_{z,zu} U_{z,zu}^2)}} \tag{32}$$

with:

$$\begin{aligned}
\Upsilon_{z,zu} &= \frac{R_{z,zu}}{\sqrt{1 - 2\sigma_I^2 V_{z,zu}}}; \qquad J_{z,zu} = \frac{\sigma_I^2}{2(1 - 2\sigma_I^2 V_{z,zu})} ; \qquad (33)\\
V_{z,zu} &= R_{z,zu}\chi^2 + L_{z,zu} C_{z,zu} + \frac{\sigma_\varepsilon^2}{2} g_{z,zu} + C_{z,zu}; \quad Q_{z,zu} = \frac{H_{z,zu}}{\sqrt{1 - 2\sigma_x^2 M_{z,zu}}};\\
R_{z,zu} &= \frac{\sigma_x^2}{2(1 - \Upsilon_{z,zu} \sigma_x^2 M_{z,zu})}; \quad \chi_{z,zu} = L_{z,zu} 2 C_{z,zu} G_{z,zu} + \frac{\sigma_\varepsilon^2}{2} 2 g_{z,zu} i_{z,zu} + r_{z,zu};\\
M_{z,zu} &= L_{z,zu} G_{z,zu}^2 + \frac{\sigma_S^2}{2} i_{z,zu}^2 + e_{z,zu}; \quad H_{z,zu} = \frac{1}{\sqrt{1 - 2\sigma_S^2 (\frac{\sigma_S^2}{2} f_{z,zu}^2 + b_{z,zu})}};\\
L_{z,zu} &= \frac{\sigma_S^2}{2[1 - 2\sigma_S^2 (\frac{\sigma_S^2}{2} f_{z,zu}^2 + b_{z,zu})}; \quad C_{z,zu} = \frac{\sigma_S^2}{2} 2 f_{z,zu} g_{z,zu} + l_{z,zu};\\
F_{z,zu} &= \frac{\sigma_S^2}{2} r_{z,zu} f_{z,zu} h_{z,zu} + m_{z,zu}; \quad G_{z,zu} = 2 f_{z,zu} i_{z,zu} + n_{z,zu}
\end{aligned}$$

In order to solve for the equilibrium number of insiders, we need to evaluate agents' profits under different regimes of transparency. By looking at the equilibrium price, given by expression 27 and 29, under anonymity and full transparency respectively, we infer that:

$p^A = \alpha_1^A S + \alpha_2^A x + \alpha_3^A I + \alpha_4^A I_U$ with $\alpha_1^A = \lambda_A \frac{N}{A\sigma_\varepsilon^2}$, $\alpha_2^A = \lambda_A Z$, $\alpha_3^A =$

$-\lambda_A N$ , $\alpha_4^A = -\lambda_A M\Psi$ and $p^T = \alpha_1^T S + \alpha_2^T x + \alpha_3^T I + \alpha_4^T I_U$ 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

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

with

$\beta_{1u}^z = -H^{1,T}\alpha_1^z + \Omega^{-\infty,1}\beta_1^z$, $\beta_{2u}^z = -H^{1,T}\alpha_2^z + \Omega^{-\infty,1}\beta_2^z$, $\beta_{3u}^z = -H^{1,T}\alpha_3^z + \Omega^{-\infty,1}\beta_3^z$, $\beta_{4u}^z = -H^{1,T}\alpha_4^z - \Omega^{0,1} + \Omega^{-\infty,1}\beta_4^z$

where $z = A, T$ .

Now, substituting the values of $\alpha^z$ and $\beta^z$ into (31), (32) and (33) the expected utility of each trader's profit under the two regimes with anonymity and transparency can be evaluated and using (14) one can obtain the results in Tables 1.1 and 1.2 and Proposition 4.

**Proof of Proposition 5.**

Under partial transparency uninformed traders update their believes on the future value of the asset by using the information from other traders' net demands and the signal $\Theta_{PT}$ they can extract from the market price: $\Theta_{PT} = S - A\sigma_\varepsilon^2 I + \frac{ZA\sigma_\varepsilon^2}{N}x = \gamma_1^{PT}p - \gamma_2 X_U^{PT} - \gamma_3^{PT}\theta'_{PT}$ with $\gamma_1^{PT} = \frac{N+A\sigma_\varepsilon^2(M-1)H^{PT}}{N}$, $\gamma_2 = \frac{A\sigma_\varepsilon^2}{N}$, $\gamma_3^{PT} = \frac{A\sigma_\varepsilon^2(M-1)\Omega^{PT}}{N}$.

**Lemma 4** By assuming that $Var(x) = Var(X_I)$ and that $\frac{ZA\sigma_\varepsilon^2}{N} = 1$, then $E[F|\Theta_{PT}, \Theta'_{PT}] = \delta_U^T[\mu_1 p^{PT} - \mu_2 X_U - \mu_3\theta'_{PT}]$.

**Proof:**

$E\left[F|\Theta_{PT}, \Theta'_{PT}\right] = E\left[F|\Theta_{PT}, \Theta'_{PT} = S - A\sigma_\varepsilon^2 I\right] \Pr ob\left(q = 1|\Theta_{PT}, \Theta'_{PT} = S - A\sigma_\varepsilon^2 I\right) +$

$+E\left[F|\Theta_{PT}, \Theta'_{PT} = x\right] \Pr ob\left(q = 0|\Theta_{PT}, \Theta'_{PT} = x\right)$

Using Lemma 1, it is straightforward to show that: $E\left[F|\Theta_{PT}, \Theta'_{T} = S - A\sigma_\varepsilon^2 I\right] = \delta_U^T(p^{PT} + A\sigma_\varepsilon^2\theta'_{PT})$ and that $E\left[F|\Theta_{PT}, \Theta'_{PT} = x\right] = \delta_U^T(\gamma_1^{PT}p - \gamma_2 X_U - (\gamma_3^{PT} + \frac{ZA\sigma_\varepsilon^2}{N})\theta'_{PT})$ with $\gamma_1^{PT} = \frac{N+A\sigma_\varepsilon^2(M-1)H^{PT}}{N}$; $\gamma_2 = \frac{A\sigma_\varepsilon^2}{N}$; $\gamma_3^{PT} = \frac{A\sigma_\varepsilon^2(M-1)\Omega^{PT}}{N}$;

therefore:

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

$+\delta_U^T[\gamma_1^{PT}p - \gamma_2 X_U - (\gamma_3^{PT} + \frac{ZA\sigma_\varepsilon^2}{N})\theta'_{PT}] \Pr ob\left(q = 0|\Theta_{PT}, \Theta'_{PT}\right).$

By assuming that $Var(x) = Var(X_I)$, and that $Cov(\Theta_{PT}, x) = Cov(\Theta_{PT}, X_I)$, we have: $\Pr ob\left(q = 1|\Theta_{PT}, \Theta'_{PT}\right) = \Pr ob\left(q = 1\right) = \frac{N}{N+Z}$ and

$\Pr ob\left(q=0|\Theta_{PT},\Theta_{PT}^{'}\right)=\Pr ob\left(q=0\right)=\frac{Z}{N+Z}$; hence, we obtain:

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

with $\mu_1=\frac{N+\gamma_1^{PT}Z}{N+Z}=(N+\frac{N+A\sigma_\varepsilon^2(M-1)H^{PT}}{N}Z)/(N+Z)$, $\mu_2=\frac{Z\gamma_2}{N+Z}=(Z\frac{A\sigma_\varepsilon^2}{N})/(N+Z)$ and $\mu_3=(A\sigma_\varepsilon^2 N-(\gamma_3^{PT}+\frac{ZA\sigma_\varepsilon^2}{N})Z)/\left(N+Z\right)=(A\sigma_\varepsilon^2 N-(\frac{A\sigma_\varepsilon^2(M-1)\Omega^{PT}}{N}+\frac{ZA\sigma_\varepsilon^2}{N})Z)/(N+Z)$. We can now substitute $E\left[F|\Theta_{PT},\Theta_{PT}^{'}\right]$ into the uninformed trader's demand, $X_U^{PT}$, and solve for the parameters from previous conjecture: $H^{PT}=(1-\delta_U^T)[A\ Var\ (F|\Theta_{PT},\Theta_{PT}^{'})+\delta_U^T\frac{ZMA\sigma_\varepsilon^2}{N(N+Z)}]^{-1}$ and $\Omega^{PT}=(\delta_U^T\frac{A\sigma_\varepsilon^2}{(N+Z)}(N+\frac{Z^2}{N}))[A\ Var\ (F|\Theta_{PT},\Theta_{PT}^{'})+\delta_U^T\frac{ZMA\sigma_\varepsilon^2}{N(N+Z)}]^{-1}$ with $Var\ (F|\Theta_{PT},\Theta_{PT}^{\prime})=\sigma_S^2+\sigma_\varepsilon^2-\frac{\sigma_s^4}{\sigma_S^2+A^2\sigma_\varepsilon^4\sigma_I^2}$. Using the market clearing condition $N\left[\dfrac{S-P^{PT}}{A\sigma_\varepsilon^2}-I\right]-MH^{PT}p^{PT}-M\Omega^{PT}\Theta_{PT}^{'}+Zx=0$, where $\left\{\Theta_{PT}^{'}|\Theta_{PT}^{'}\neq X_U\right\}=qX_I+(1-q)x$, we obtain equations 16 and 17.

**Proof of Proposition 7.**

When traders behave strategically, transparency influences not only uninformed traders' strategies, but also the insiders' ones. It follows that, unlike the competitive framework, we need now to evaluate informed traders' strategies under the three regimes, with anonymity, full transparency and partial transparency respectively.

With anonymity each insider submits a limit order equal to $X_I^S=\frac{S-p^S-A\sigma_\varepsilon^2 I}{A\sigma_\varepsilon^2+\lambda_I}=D(S-p^S)-GI$, being $D=\frac{1}{A\sigma_\varepsilon^2+\lambda_I}$ and $G=\frac{A\sigma_\varepsilon^2}{A\sigma_\varepsilon^2+\lambda_I}$. The latter parameters can be easily derived from the first order condition, $S - p^S - \frac{\partial p^S}{\partial X_I} X_I^S - \frac{A}{2}[2(X_I^S + I)]\sigma_\varepsilon^2 = 0$, being $\lambda_I = \frac{\partial p^S}{\partial X_I^S}$ the price elasticity each insider calculates solving for $p$ her conjectured market clearing conditions: $(N-1)(D(S-p^S) - GI) - MH^S p^S + Zx + X_I^S = 0$. Each uninformed trader extracts the following signal from the market price, $\Theta_S = S - A\sigma_\varepsilon^2 I + \frac{(A\sigma_\varepsilon^2+\lambda_I)Z}{N} x = -\frac{(A\sigma_\varepsilon^2+\lambda_I)}{N} X_U^S + \frac{N+(A\sigma_\varepsilon^2+\lambda_I)(M-1)H^S}{N} p^S = \gamma_1^S p^S - \gamma_2^S X_U^S$, which she uses to update her expectations on $F$ and to formulate her limit order equal to $X_U^S = \frac{E[F|\Theta_S]-p^S}{AVar[F|\Theta_S]+\lambda_U} = -H^S p^S$ with $H^S = (1 - \frac{Cov(F,\Theta_S)}{Var(\Theta_S)})/[A\ Var\ (F|\Theta_S) + \lambda_U + Cov(F,\Theta_S)M(A\sigma_\varepsilon^2 + \lambda_I)/(Var(\Theta_S)N)]$, $\lambda_I = [(N-1)D+MH^S]^{-1}$and $\lambda_U = [ND+(M-1)H^S]^{-1}$. The equilibrium value for $H^S$ is obtained by equating the parameter from the solution of each uninformed trader's first order condition to the previous conjecture for that parameter, while $\lambda_U$ can be derived as before solving for $p$ her conjectured market clearing conditions: $N(D(S-p^S)-GI)-(M-1)H^S p^S+Zx+X_U^S = 0$. Substituting $D$ into $H^S, \lambda_U$ and $\lambda_I$, the solution to the model with strategic traders and anonymity can be obtained by solving the system with 3 equations and 3 unknowns, which has 2 complex roots and 3 real roots, 2 negative and 1 positive.

With full transparency each insider submits $X_I^S = \frac{S-p^{ST}-A\sigma_\varepsilon^2 I}{A\sigma_\varepsilon^2+\lambda_I^T} = D^T(S - p^{ST}) - G^T I$ with $D^T = \frac{1}{A\sigma_\varepsilon^2+\lambda_I^T}$ and $G^T = \frac{A\sigma_\varepsilon^2}{A\sigma_\varepsilon^2+\lambda_I^T}$. This demand is derived from the first order condition: $S - p^{ST} - \frac{\partial p^{ST}}{\partial X_I} X_I^S - \frac{A}{2}[2(X_I^S + I)]\sigma_\varepsilon^2 = 0$ with $\lambda_I^T = \frac{\partial p^{ST}}{\partial X_I^S} = [(N-1)D^T + MH^{ST} + M\Omega^T D^T]^{-1}$. Each uninformed trader submits a net demand equal to $X_U^{ST} = \frac{E(F|\Theta'_{ST}) - p^{ST}}{A\, Var\, (F|\Theta'_{ST}) + \lambda_U^T} = -H^{ST} p^{ST} + \Omega^T \theta'_{ST}$ where $H^{ST} = (1 - \dfrac{Cov(F, \Theta_{ST})}{Var(\Theta'_{ST})})/(A\ Var\ (F|\Theta'_{ST}) + \lambda_U^T)$, $\Omega^T = [\dfrac{Cov(F, \Theta_{ST})}{Var(\Theta'_{ST})}(A\sigma_\varepsilon^2 + \lambda_I^T)]/[A\, Var\ (F|\Theta'_{ST}) + \lambda_U^T]$ and $\lambda_U^T = [ND^T + (M-1)H^{ST} + (M-1)\Omega^T D^T]^{-1}$. $\lambda_I^T$ and $\lambda_U^T$ can be obtained solving for $p$ the insiders' and uninformed traders' conjectured market clearing conditions, which are equal to $(N-1)(D^T(S - p^{ST}) - G^T I) - MH^{ST}p^{ST} + M\Omega^T\theta'_{ST} + Zx + X_I^S = 0$ and $N(D^T(S - p^{ST}) - G^T I - (M-1)H^{ST}p^{ST} + (M-1)\Omega^T\theta'_{ST} + Zx + X_U^{ST} = 0$ respectively. Notice that uninformed traders use the signal $\Theta'_{ST}$ to update their expectations on $F$. Using Lemma 1 it is straightforward to show that uninformed traders discard the signal from the market price and update their believes on $F$ by observing $X_I^S$ and extracting $\Theta'_{ST} = S - A\sigma_\varepsilon^2 I = p^{ST} + (A\sigma_\varepsilon^2 + \lambda_I^T)\theta'_{ST}$. Solving the system with 3 equations and 3 unknown, $H^{ST}, \lambda_U^T$ and $\lambda_I^T$, allows for numerical simulations and comparisons with the anonymous regimes.

With partial transparency the model can be solved analogously with insiders and uninformed traders submitting the following net demands respectively: $X_I^{SPT} = \frac{S - p^{SPT} - A\sigma_\varepsilon^2 I}{A\sigma_\varepsilon^2 + \lambda_I^{PT}} = D^{PT}(S - p^{SPT}) - G^{PT} I$ with $D^{PT} = \frac{1}{A\sigma_\varepsilon^2 + \lambda_I^{PT}}$ and $G^{PT} = \frac{A\sigma_\varepsilon^2}{A\sigma_\varepsilon^2 + \lambda_I^{PT}}$ and $X_U^{SPT} = \frac{E(F|\Theta_{SPT}, \Theta'_{SPT}) - p^{SPT}}{A\, Var\ (F|\Theta_{SPT}, \Theta'_{SPT})} = -H^{SPT} p^{SPT} -$

$\Omega^{SPT}\theta'_{SPT}$ where $H^{SPT} = [1 - \frac{Cov(F,\Theta_{SPT})}{Var(\Theta'_{SPT})}][A\ Var\ (F|\Theta_{SPT},\Theta'_{SPT}) + \lambda_U^{PT} + \frac{Cov(F,\Theta_{SPT})(A\sigma_\varepsilon^2 + \lambda_I^{PT})MZ}{Var(\Theta'_{SPT})N(N+Z)}]^{-1}$ and $\Omega^{SPT} = [\frac{Cov(F,\Theta_{SPT})}{Var(\Theta'_{SPT})}\frac{(Z^2+N^2)}{(N+Z)N}(A\sigma_\varepsilon^2 + \lambda_I^{PT})][A\ Var\ (F|\Theta_{SPT},\Theta'_{SPT}) + \lambda_U^{PT} + \frac{Cov(F,\Theta_{SPT})(A\sigma_\varepsilon^2 + \lambda_I^{PT})MZ}{Var(\Theta'_{SPT})N(N+Z)}]^{-1}$, $Var(\Theta'_{SPT}) = \sigma_S^2 + A^2\sigma_\varepsilon^4\sigma_I^2$, $Var\ (F|\Theta_{SPT},\Theta'_{SPT}) = \sigma_S^2 + \sigma_\varepsilon^2 - \frac{\sigma_s^4}{\sigma_S^2 + A^2\sigma_\varepsilon^4\sigma_I^2}$ and $Cov(F,\Theta_{SPT}) = \sigma_S^2$ . As before, from the insiders' and uninformed traders' conjectured market clearing conditions, it is straightforward to show that $\lambda_I^{SPT}$ and $\lambda_U^{SPT}$ are equal to: $\lambda_I^{SPT} = [(N-1)D^{PT} + MH^{SPT} + M\Omega^{SPT}D^{PT}]^{-1}\frac{N}{N+Z} + [(N-1)D^{PT} + MH^{SPT}]^{-1}\frac{Z}{N+Z}$ and $\lambda_U^{SPT} = [ND^{PT} + (M-1)H^{SPT} + (M-1)\Omega^{SPT}D^{PT}]^{-1}\frac{N}{N+Z} + [ND^{PT} + (M-1)H^{SPT}]^{-1}\frac{Z}{N+Z}$. Notice that with agents behaving strategically, the signal uninformed traders can extract from the order they observe is equal to: $\left\{\Theta'_{SPT}|\Theta'_{SPT} \neq X_U^{SPT}\right\} = qX_I^{SPT} + (1-q)x$.

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# Footnotes

**1.** The NASDAQ is not anonymous since dealers' identities are publicly displayed. This does not imply that traders can also observe the identity of the dealers' customers. According to the classification used in this work under the regime with full transparency traders can observe the order flow and the identification codes of all other agents who actually trade on the market;

**2.** See among others Admati and Pfleiderer (1991), Foster and George (1992) and Pagano and Röell (1996).

**3.** Numerical simulations also show that the difference between $Var(p^T)$ and $Var(p^A)$ is an inverse function of $A$ and $\sigma_\varepsilon^2$.

**4.** Under the regime with partial transparency uninformed agents observe a price and a quantity and they don't know whether they are observing an insider's limit order or a noise trader's market order, since the latter is displayed on the screen only associated to the best market price. This feature is modelled here by assuming that uninformed agents use both the order they observe and the market price to update their estimate of the future value of the asset.

Table 1: . Equilibrium number of insiders, $(N_A, N_T)$,

difference in liquidity $(LA - LT)$ and volatility $(VA - VT)$.

Results from Lemma 2: $\sigma_U = 0$

| $\sigma_S$ | $\sigma_\varepsilon$ | $\sigma_I$ | $\sigma_x$ | $M$ | $Z$ | $A$ | $C$ | $N_A$ | $N_T$ | $LA - LT$ | $VA - VT$ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **.5** | **.5** | **.5** | **.5** | **10** | **10** | **2** | **.02** | 18 | 11 | 0.249 | .0442 |
| .5 | .5 | .5 | .5 | 10 | 10 | 2 | **.05** | 11 | 4 | 0.569 | 0.0051 |
| .5 | .5 | .5 | .5 | 10 | 10 | 2 | **.06** | 10 | 3 | 0.666 | 0.0402 |
| .5 | .5 | .5 | .5 | 10 | **20** | 2 | **.02** | 35 | 28 | 0.736 | 0.054 |
| .5 | .5 | .5 | .5 | **20** | **20** | 2 | .06 | 19 | 5 | 1.452 | 0.04 |
| .5 | .5 | .5 | .5 | **50** | **50** | 2 | .06 | 48 | 14 | 1.567 | 0.04 |
| .5 | .5 | .5 | .5 | **100** | **100** | 2 | .06 | 92 | 59 | 3.369 | 0.039 |
| .5 | .5 | .5 | **.8** | **50** | **50** | 2 | **.02** | 140 | 106 | 1.08 | 0.055 |
| .5 | .5 | **.52** | .8 | 50 | 50 | 2 | .02 | 141 | 108 | 0.612 | 0.06 |
| .5 | .5 | **.5** | **.5** | **20** | **20** | **1.9** | **.06** | 18 | 4 | 0.719 | .035 |
| .5 | .5 | .5 | **.8** | 20 | 20 | 1.9 | .06 | 29 | 15 | 1.745 | .032 |
| .5 | .5 | .5 | .8 | 20 | 20 | 1.9 | **.02** | 54 | 40 | .397 | .037 |
| .5 | .5 | .5 | .8 | 20 | 20 | **2** | .02 | 56 | 42 | 1.232 | .055 |
| .5 | .5 | **.48** | .8 | 20 | 20 | 2 | .02 | 56 | 42 | 0.6087 | .037 |
| **.3** | .5 | .48 | .8 | 20 | 20 | 2 | .02 | 54 | 42 | 2.67 | .037 |
| .3 | **.4** | .48 | .8 | 20 | 20 | 2 | .02 | 42 | 28 | 0.2444 | .0551 |

Table 1.1: Equilibrium number of insiders, $(N_{Au}, N_{Tu})$,

difference in liquidity $(LA - LT)$ and volatility $(VA_u - VT_u)$.

Results from Lemma 3: $\sigma_U \neq 0$

| $\sigma_S$ | $\sigma_\varepsilon$ | $\sigma_I$ | $\sigma_x$ | $\sigma_U$ | $M$ | $Z$ | $A$ | $C$ | $N_{Au}$ | $N_{Tu}$ | $LA - LT$ | $VA_u - VT_u$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| .5 | .5 | .5 | .5 | .5 | 10 | 10 | 2 | .02 | 30 | 6 | 34.275 | -0.002 |
| .5 | .5 | .5 | .5 | .5 | 10 | 10 | 2 | **.05** | 27 | 3 | 34.266 | 0.04 |
| .5 | .5 | .5 | .5 | .5 | 10 | 10 | 2 | **.06** | 26 | 2 | 34.264 | -0.08 |
| .5 | .5 | .5 | .5 | .5 | 10 | **20** | 2 | **.02** | 33 | 7 | 38.774 | -0.08 |
| .5 | .5 | .5 | .5 | .5 | **20** | **20** | 2 | **.02** | 60 | 12 | 68.5 | 0.002 |
| .5 | .5 | .5 | .5 | .5 | 20 | 20 | 2 | **.06** | 53 | 4 | 71.2 | -0.24 |
| .5 | .5 | .5 | .5 | .5 | 20 | 20 | **1.9** | .06 | 59 | 3 | 88.1 | -0.08 |
| .5 | .5 | .5 | .5 | .5 | **50** | **50** | 2 | .06 | 132 | 10 | 217.302 | -0.28 |
| .5 | .5 | .5 | .5 | .5 | **100** | **100** | 2 | .06 | 265 | 20 | 352.647 | -0.08 |

Table 1.2: Equilibrium number of insiders, $(N_{Au}, N_{Tu})$,

difference in liquidity $(LA - LT)$ and volatility $(VA_u - VT_u)$.

Results from Lemma 3: $\sigma_U \neq 0$

| $\sigma_S$ | $\sigma_\varepsilon$ | $\sigma_I$ | $\sigma_x$ | $\sigma_U$ | $M$ | $Z$ | $A$ | $C$ | $N_{Au}$ | $N_{Tu}$ | $LA - LT$ | $VA_u - VT_u$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| .5 | .5 | .5 | .5 | .5 | 20 | 20 | 2 | .02 | 60 | 12 | 68.5 | 0.002 |
| .5 | .5 | .5 | **.8** | .5 | 20 | 20 | 2 | .02 | 63 | 13 | 73.1 | -0.07 |
| .5 | .5 | **.52** | .5 | .5 | 20 | 20 | 2 | .02 | 56 | 8 | 69.2 | -0.02 |
| .5 | .5 | **.48** | .5 | .5 | 20 | 20 | 2 | .02 | 66 | 17 | 71.9 | 0.008 |
| .5 | .5 | .48 | **.8** | .5 | 20 | 20 | 2 | .02 | 69 | 19 | 72.5 | -0.04 |
| **.3** | .5 | .48 | .8 | .5 | 20 | 20 | 2 | .02 | 57 | 17 | 58.5 | -0.07 |
| .3 | **.4** | .48 | .8 | .5 | 20 | 20 | 2 | .02 | 45 | 12 | 59,4 | -0.02 |
| .3 | .4 | .48 | .8 | **.6** | 20 | 20 | 2 | .02 | 71 | 37 | 61.51 | -0.0069 |
| .3 | .4 | .48 | .8 | **.55** | 20 | 20 | 2 | .02 | 56 | 23 | 58.76 | -0.0089 |
| .3 | .4 | .48 | .8 | **.45** | 20 | 20 | 2 | .02 | 45 | 12 | 59.4 | -0.021 |

TABLE 2.1: Equilibrium parameter values* and liquidity for:

$A = 1, \sigma_x^2 = 1, \sigma_\varepsilon^2 = 1, \sigma_s^2 = 1.1, \sigma_I^2 = 1, N = 5, M = 5, Z = 5$

| | | $\lambda_I$ | $\lambda_U$ | $H$ | $\Delta$ | $\Omega$ | $L$ |
|---|---|---|---|---|---|---|---|
| An. | strategic | .208 | .188 | .198 | .828 | - | 5.626 |
| | $\lambda_I = 0$ | 0 | .162 | .290 | 1 | - | 6.449 |
| | $\lambda_U = 0$ | .202 | 0 | .324 | .832 | - | 5.777 |
| | competitive | 0 | 0 | .313 | 1 | - | 6.563 |
| Tr. | strategic | .152 | .146 | .285 | .868 | .389 | 7.569 |
| | $\lambda_I = 0$ | 0 | .133 | .287 | 1 | .341 | 8.255 |
| | $\lambda_U = 0$ | .144 | 0 | .313 | .874 | .427 | 7.933 |
| | competitive | 0 | 0 | .313 | 1 | .373 | 8.758 |

Informed and uninformed traders' demand under the 2 regimes:

An: $X_I^S = D(S - p^S) - GI,$ $\quad X_U^S = -H^S p^S$

Tr: $X_I^{ST} = D^T(S - p^{ST}) - G^T I,$ $\quad X_U^{ST} = -H^{ST} p^{ST} + \Omega^T \theta'_{ST}$

TABLE 2.2: Equilibrium parameter values* and liquidity for:

$A = 1, \sigma_x^2 = 1, \sigma_\varepsilon^2 = 1, \sigma_s^2 = 1.1, \sigma_I^2 = 1, N = 20, M = 5, Z = 5$

| | | $\lambda_I$ | $\lambda_U$ | $H$ | $\Delta$ | $\Omega$ | $L$ |
|---|---|---|---|---|---|---|---|
| An. | strategic | .051 | .050 | .286 | .951 | - | 20.453 |
| | $\lambda_I = 0$ | 0 | .047 | .287 | 1 | - | 21.433 |
| | $\lambda_U = 0$ | .051 | 0 | .294 | .951 | - | 20.497 |
| | competitive | 0 | 0 | .295 | 1 | - | 21.473 |
| Tr. | strategic | .047 | .046 | .303 | .956 | .378 | 22.562 |
| | $\lambda_I = 0$ | 0 | .044 | .304 | 1 | .362 | 23.456 |
| | $\lambda_U = 0$ | .046 | 0 | .313 | .956 | .391 | 22.679 |
| | competitive | 0 | 0 | .313 | 1 | .373 | 23.564 |

Informed and uninformed traders' demand under the 2 regimes:

An: $X_I^S = D(S - p^S) - GI,$ $\qquad X_U^S = -H^S p^S$

Tr: $X_I^{ST} = D^T(S - p^{ST}) - G^T I,$ $\qquad X_U^{ST} = -H^{ST} p^{ST} + \Omega^T \theta'_{ST}$

TABLE 2.3: Equilibrium parameter values* and liquidity for:

$A = 1, \sigma_x^2 = 1, \sigma_\varepsilon^2 = 1, \sigma_s^2 = 1.1, \sigma_I^2 = 1, N = 20, M = 5, Z = 20$

| | | $\lambda_I$ | $\lambda_U$ | $H$ | $\Delta$ | $\Omega$ | $L$ |
|---|---|---|---|---|---|---|---|
| An. | strategic | .050 | .049 | .353 | .952 | - | 20.805 |
| | $\lambda_I = 0$ | 0 | .047 | .350 | 1 | - | 21.748 |
| | $\lambda_U = 0$ | .050 | 0 | .362 | .952 | - | 20.855 |
| | competitive | 0 | 0 | .359 | 1 | - | 21.794 |
| Tr. | strategic | .047 | .046 | .303 | .956 | .378 | 22.562 |
| | $\lambda_I = 0$ | 0 | .044 | .304 | 1 | .362 | 23.456 |
| | $\lambda_U = 0$ | .046 | 0 | .313 | .956 | .391 | 22.679 |
| | competitive | 0 | 0 | .313 | 1 | .373 | 23.564 |

Informed and uninformed traders' demand under the 2 regimes:

An: $X_I^S = D(S - p^S) - GI,$ $\quad X_U^S = -H^S p^S$

Tr: $X_I^{ST} = D^T(S - p^{ST}) - G^T I,$ $\quad X_U^{ST} = -H^{ST} p^{ST} + \Omega^T \theta'_{ST}$

TABLE 2.4.: Equilibrium parameter values* and liquidity for:

$A = 1, \sigma_x^2 = 1, \sigma_\varepsilon^2 = 1, \sigma_s^2 = 1.1, \sigma_I^2 = 1, N = 50, M = 50, Z = 50$

| | | $\lambda_I$ | $\lambda_U$ | $H$ | $\Delta$ | $\Omega$ | $L$ |
|---|---|---|---|---|---|---|---|
| An. | strategic | .016 | .016 | .311 | .985 | - | 64.779 |
| | $\lambda_I = 0$ | 0 | .015 | .311 | 1 | - | 65.510 |
| | $\lambda_U = 0$ | .016 | 0 | .313 | .985 | - | 64.897 |
| | competitive | 0 | 0 | .313 | 1. | - | 65.625 |
| Tr. | strategic | .012 | .012 | .310 | .988 | .375 | 84.739 |
| | $\lambda_I = 0$ | 0 | .012 | .310 | 1 | .370 | 85.340 |
| | $\lambda_U = 0$ | .012 | 0 | .313 | .988 | .378 | 85.045 |
| | competitive | 0 | 0 | .313 | 1. | .373 | 85.643 |
| (LTC-LAC)/LAC=.305 | | | | (LTS-LAS)/LAS=.308 | | | |

Informed and uninformed traders' demand under the 2 regimes:

An: $X_I^S = D(S - p^S) - GI,$ $\quad X_U^S = -H^S p^S$

Tr: $X_I^{ST} = D^T(S - p^{ST}) - G^T I,$ $\quad X_U^{ST} = -H^{ST} p^{ST} + \Omega^T \theta'_{ST}$

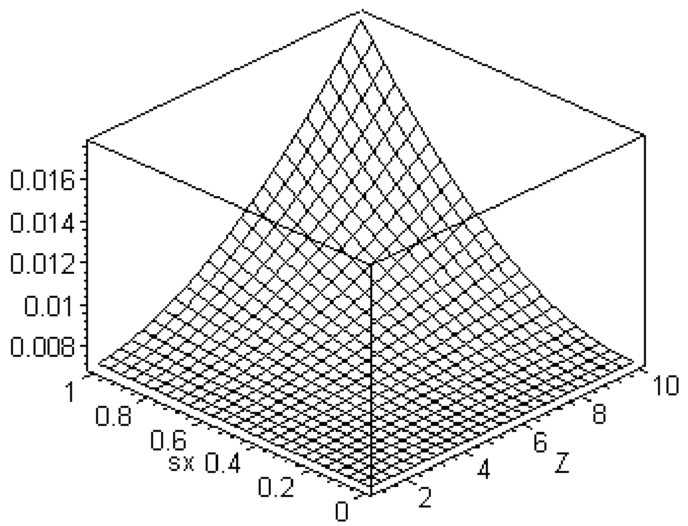


Figure 1: On the horizontal axes: $SX = \sigma_x, Z$ and on the vertical axis : $Var(p^T) - Var(p^A)$ with $A = .6$, $\sigma_S = .8$, $\sigma_\varepsilon = .5$, $\sigma_I = .8$ $M = N = 10$.

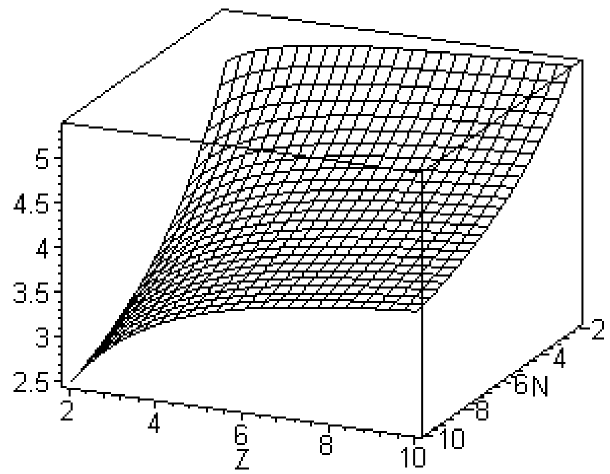


Figure 2: $LT - E[LPT(q)]$ with $A = \sigma_S^2 = \sigma_\varepsilon^2 = \sigma_x^2 = \sigma_I^2 = 1, M = 10$