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Market versus Limit Orders in an Imperfectly Competitive Security Market[†]

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Abstract

This paper analyzes the choice between limit and market orders in an imperfectly competitive noisy rational expectations economy. There is a unique insider, who takes into account the effect their trading has on prices. If the insider behaves as a price taker, she will choose market orders if her private information is very precise and she will choose limit orders otherwise. On the contrary, if the insider recognizes and exploits her ability to affect the market price, her optimal choice is to place limit orders whatever the precision of her private information.

1. Introduction

Security markets allow investors to trade through different kinds of orders. The two primary types are market orders (MO) and limit orders (LO). A market order is an order to buy or sell a fixed quantity at any price³. A limit order specifies, in addition to a quantity, a limit price on which execution is conditioned. As pointed out by Amihud and Mendelson (1992), a limit order provides liquidity to the rest of the market, reveals much information about the trader's assessment of the value of the security, and is executed at a specified limit price but the time and likelihood of execution are uncertain. On the contrary, a market order consumes liquidity from the market, releases much less information about the trader's beliefs about the value of the asset, and is executed immediately but at an uncertain price. Furthermore, a trader submitting a limit order acts as an effective "price setter" while a trader submitting a market order is rather a "price taker".

My purpose is to obtain a better understanding of why and how traders choose between limit and market orders and to explore the effects of the diversity of types of orders on market performance (liquidity, depth, volatility of prices, and informativeness of prices) in models that explicitly include traders' behavior. I analyze these issues in a noisy rational expectations model, under the standard assumptions of constant absolute risk aversion and joint normality of all random variables. There are two main reasons for addressing these issues. First, diversity of types of orders is a fairly common feature of real securities markets so that it is interesting to understand how well such a market will perform. One would expect that policy implications would arise from the analysis. The second, theoretical reason is the fact that these issues still have not been studied under the noise trader approach to financial markets.

In an influential paper, Kyle (1989) developed an adverse selection model in which privately informed traders, who take into account the effect their trading has on prices, submit limit orders in order to optimally exploit their information. Kyle considered an order-driven trading mechanism where traders submit orders before prices are determined. In this paper, I extend the Kyle (1989) framework to include market orders. Specifically, I consider an imperfectly competitive economy in which a single informed investor (the insider) trades against a continuum of rational uninformed market makers in the presence of some noise traders. Since the insider is the unique investor who observes some privileged information θ , this is a proper model of insider trading. In this setup, I characterize the informed trader's

³ In fact, it will be executed at the market price, which could be the price set by some market maker or the limit price specified by a limit order that acts as counterpart of the market order.

optimal choice between limit and market orders and the effect of her choice on market performance.

The insider's ex ante expected utility can be decomposed into G_θ , which measures the utility level derived from trading on the inside information, and G_p , which represents the utility coming from the market making activity undertaken by the insider. G_θ represents the utility level derived from the money that the insider makes out of market makers due to the informational advantage of the former. On the other hand, G_p is equal to the product of the insider's marginal market share and the expected loss of noise traders.

I consider two versions of the model. In the competitive version, the insider's optimal choice is to place a limit order if her private information is not too precise and to submit a market order in the opposite case. The insider faces a trade off between maximizing her insider trading gains by using market orders or maximizing her market making gains by placing limit orders. If inside information is not too precise, the market making activity is very profitable (since market is thin) while the insider trading gains are small (since the informational advantage of the insider is low). At the other extreme, if inside information is very precise and the insider uses limit orders, both the market making gains and the insider trading gains are small. Since the insider's demand is too sensitive to inside information, the price precision is very high, the insider's informational advantage is low and the market is very liquid. On the other hand, if the insider uses market orders, she restrains her trading intensity and, as a consequence, she preserves some informational advantage since the price is not too informative. In this setup, using market orders is a sensible way to ensure that she will not react excessively to her private information since she is willing to accept the price risk introduced by noise traders.

If the insider recognizes and exploits her ability to affect the market price, her optimal choice is to place limit orders whatever the precision of her private information. Considering only insider trading gains, the insider's optimal choice would be to place a limit order if private information was not too precise and to submit a market order otherwise. On the other hand, considering only market making gains, the insider's optimal choice is to place a limit order, since these gains are equal to zero if she places market orders. It is obvious that, if the precision of inside information is low, the insider will use limit orders because both her market making gains and her insider trading gains are higher. On the other hand, if the precision of inside information is high, the insider maximizes her market making gains by using a limit order while she maximizes her insider trading gains by placing market orders. We prove that the former effect dominates the latter. When the insider acts strategically, she restrains her trades so that market depth is low and market making gains are potentially high.

Thus, she does not have to use market orders as a sensible way to ensure that she will not react excessively to her private information.

Concerning the effect of the insider's choice about the type of order on market performance, we have found that the price precision and the market depth are greater when the insider submits limit orders. The insider reacts more to her private information when she trades through limit orders. The price conveys information about the liquidation value because the insider trades on her private information. Thus, it is natural to expect that the informativeness of the price will be increasing in the weight put by the insider on her private information. Finally, market depth is equal to the trader's aggregate price sensibility. If the insider places limit orders, her strategy is price sensitive, which directly increases market depth and (more than) offsets the decrease in the outsider's price sensibility.

Although there is a large number of papers on the microstructure of securities markets, little attention has been paid to the strategic aspects of the choice between limit and market orders. Many papers focus on the specialist's bid- and ask-price determination behavior (Demsetz (1968), Stoll (1978), and Glosten (1987), for example). There are also many papers on some market anomalies (see Dimson (1988) and Shiller (1989)). With respect to the noisy rational expectations literature⁴ attention was primarily paid to the informational efficiency of equilibrium prices (see, for instance, Grossman and Stiglitz (1980), Hellwig (1980), Diamond and Verrecchia (1981), Admati (1985), Kyle (1985), Brown and Jennings (1989), Danthine and Moressi (1993), Vayanos (1993) and Vives (1992)). In all of these papers the traders' choice between LO and MO has not been considered. Generally, each agent is assumed to place a given type of order. For example, in the noisy rational expectations literature, noise traders are usually assumed to submit market orders while rational traders are assumed to place limit orders. I think that models which recognize the existence of both types of orders should include investors optimally choosing the type of order to place.

There are few papers that explicitly include traders' decision about the type of order in their analysis: Rock (1990), Jang and Jun (1989), Easley and O'Hara (1991), Black (1992), Caballé (1992), Angel (1994), Foucault (1994), Chakravarty and Holden (1994), Biais, Hillion and Spatt (1994), and Medrano (1995).

Rock (1990) studies a broker market in which three kinds of investors interact: (i) informed traders, (ii) time-sensitive uninformed traders who demand immediacy of execution for exogenous motives, and (iii) time-insensitive traders who are neither informed

⁴ A general justification of this literature can be found in Black (1986) and Shleifer and Summers (1990).

nor pressed to trade quickly. In this setup, time-sensitive traders use market orders due to the assumption of a sufficiently high preference for immediacy and informed traders submit market orders because that is the only way to exploit their information (since time-sensitive traders placing market orders create "noise" that allows informed traders to conceal their private information).

Jang and Jun (1989) study the choice between limit orders and market orders in security exchanges where a specialist acts as both dealer and broker. They show that sellers (buyers) placing a relatively low value on the security will trade via a market (limit) order and those placing a relatively high value on the security will trade via a limit (market) order. The trade-off between the gain (or loss) in transaction price and the loss (or gain) in trading probability is the key factor which determines the trader's decision.

Easley and O'Hara (1991) analyze the effects of price-contingent orders on security prices in a dealer market in which trading may involve either market orders or stop orders, which specify a price at which a quantity of stock is to be sold (bought). They show that an informed trader who checks the quote will always prefer to use a market order. The intuition is as follows. Suppose that the trader has received a bad signal and so wants to sell stock. She can sell via a market order at the current bid or she can place a stop-loss order at some price below the current bid. Selling at a higher price is obviously better so that she will use a market order. As a consequence, stop orders will only be used for non-information reasons such as price protection.

Black (1992) analyzes a model in which the traders' behavior is not restricted at all. Because his model is very general, he has been unable to give a full mathematical description of it so that it is very speculative. He argues that uninformed traders should use limit orders, informed traders should use market orders (so as to trade quickly), and that after a single trade the price should fully reflect the information which motivated it. To obtain these conjectures he assumes that informed traders are risk neutral.

Caballé (1992) demonstrates that when private information is very precise, informed traders in a regime with limit orders and automatic market clearing would prefer to switch to a regime with market orders in which there is no information sharing through prices. He does not analyze the informed traders' behavior in a model in which both limit and market orders are available. Rather, he studies two different mechanisms of price formation.

Angel (1994) and Foucault (1994) investigate the trade off between obtaining immediate execution by using market orders or achieving a better price by placing limit orders, which run execution risk. Foucault finds that traders with a high (low) exogenous willingness to trade use market (limit) orders. Angel assumes that the informed trader's

objective function is to acquire a fixed quantity of a security at least expected cost. He shows that informed investors usually prefer market orders and that limit orders are preferred when the bid-ask spread is wide.

Chakravarty and Holden (1994) extended the model of Glosten and Milgrom (1985) to analyze the choice between limit and market orders in a quote-driven system in which uninformed market makers post bid and ask prices before orders are submitted. In their model, there is no information sharing through prices, that is, market makers do not get to use limit orders on the book to extract any information. In contrast, I study the effect that the price impact of private information has on the choice between limit and market orders.

Biais, Hillion and Spatt (1994) analyze a dataset from the Paris Bourse. They study the dynamics of the limit order book and the order flow (order type, aggressiveness, etc.). Concerning the choice between market and limit orders, their empirical analysis suggests that the conditional probability that investors place limit orders is larger when the bid-ask spread is large or the order book is thin. Conversely, investors tend to place market orders when the spread is tight. However, they do not provide any insight into the effect of private information on the choice about the type of order.

In the chapter I of Medrano (1995), I analyzed the choice between limit orders and market orders in a noisy rational expectations competitive economy and in the chapter II the immediacy cost of limit orders was introduced. In both papers, a sector of risk neutral market makers received the order flow coming from a continuum of informed investors and a group of noise traders and set the price efficiently. In those setups, the incentives to submit limit orders were increasing in the precision of each small piece of information.

The paper is organized as follows. In section 2 the model is presented. Section 3 studies the competitive version of the model. The equilibria of the imperfectly competitive economy, with the insider submitting limit orders and market orders respectively, are analyzed in section 4. Section 5 compares the equilibria found in sections 4, and characterizes the optimal type of order from the insider's point of view. Conclusions are collected in section 6. An appendix containing all the proofs concludes the paper.

2. The Model

I consider an economy where a risky asset, with random fundamental value \tilde{v} , is traded against a riskless asset (the numéraire) whose return is normalized to zero. The risky asset is traded at a price p and thus generates return $\tilde{v}-p$. In the notation employed in this paper, a tilde distinguishes a random variable from its realization. For instance, \tilde{v} denotes

the random variable generating the liquidation value of the risky asset, and v is the liquidation value for a particular realization of \tilde{v} .

There are two rational traders: agent 1, the *insider* (informed trader), and agent 2, who is representative of the *outsiders* (uninformed traders)⁵. Furthermore, there are noise traders supplying an exogenous random quantity \tilde{z} , which is independent of all other variables in the economy.

The insider has access to some privileged information $\tilde{\theta}$ on the likely realization of the fundamental value v while the outsider only receives information via the market price (by placing a limit order). Both rational traders have exponential utilities in their terminal wealth, with risk aversion coefficients ρ_1 and ρ_2 respectively. That is, agent i takes a position x_i in the risky asset to maximize the utility function $U_i(\tilde{w}_i) = -\exp\{-\rho_i \tilde{w}_i\}$ of her terminal wealth $\tilde{w}_i = w_{0i} + (\tilde{v} - p)x_i$ where w_{0i} is agent i 's non-stochastic initial endowments.

I assume that, since the insider is the unique informed trader, she knows the relation between her demand of the asset and its price, that is, she has effective market power. On the other hand, the outsider is assumed to be price-taker, since she represents a (sufficiently large) number of uninformed rational traders. These simplifying assumptions make the model the simplest one with asymmetric information and imperfect competition. In contrast to other models of insider trading, in which no trader adds relevant information to the information possessed by the whole market, we analyze a market in which the presence of insider trading may lower fundamental risk (since the insider's information has new valuable information that the market might not otherwise infer).

Rational traders have two ways of placing orders: limit orders and market orders. I assume that the outsider submits limit orders (for sure) since she has no information to trade on. As it is shown in the Medrano (1995), a competitive uninformed trader is better off by placing limit orders provided that no cost is taken into account.

A limit order is a mapping from the set of private information to the space of demand schedules⁶. Given price p , let $X_1(\theta, p)$ be the demand function chosen by agent 1 when she has received the signal θ and decided to submit a limit order, and let $x_1 = X_1(\theta, p)$ be the quantity traded by agent 1 under the strategy rule X_1 .

⁵ It is well-known that in the CARA-Gaussian set-up competitive agents with the same information structure can be aggregated into one.

⁶ I will restrict myself to considering demand functions. See Kyle (1989) for an extension which allows for correspondences

A market order is a mapping from the set of private information to the space of quantities \mathfrak{R} , so that $x_i = X_i(\theta)$ will be the quantity traded by agent i when she has received the signal θ and decided to send a market order.

It is assumed that all random variables are normally distributed: \tilde{z} with zero mean and variance σ_z^2 , \tilde{v} with mean \bar{v} and variance σ_v^2 , and $\tilde{\theta}$ with mean \bar{v} and variance $\sigma_\theta^2 = \sigma_v^2 + \sigma_\eta^2$. That is, $\tilde{\theta} = \tilde{v} + \tilde{\eta}$ is a unbiased noisy signal of the true value \tilde{v} . We characterize the quality of the privileged information $\tilde{\theta}$ by the correlation coefficient between \tilde{v} and $\tilde{\theta}$, $r = \frac{\text{cov}[\tilde{v}, \tilde{\theta}]}{\sqrt{\sigma_v^2 \sigma_\theta^2}} = \sqrt{\frac{\sigma_v^2}{\sigma_\theta^2}}$, which establishes the following relations: $\sigma_\eta^2 = \left(\frac{1-r^2}{r^2}\right)\sigma_v^2$ and $\sigma_\theta^2 = \left(\frac{\sigma_v^2}{r^2}\right)$. Inside information is infinitely precise if $r^2=1$ or $\sigma_\eta^2 = 0$, and it is completely uninformative if $r^2=0$ or $\sigma_\eta^2 \rightarrow \infty$.

Although the price has no information to aggregate, it is still useful from the insider's point of view since it allows her to infer the exact amount of noise trading (and thus eliminate the price risk it creates).

3 The competitive version of the model

As a benchmark I first study the optimal choice between market and limit orders assuming that the informed agent behaves as a price taker. That is, in this section I assume that the insider takes the price as given although he has positive mass. This is an implausible assumption since the market clearing price obviously depends on the insider's demand in a non negligible way.

As it is well known, for any $\tilde{\varepsilon}$ normally distributed random variable $E[\exp\{\tilde{\varepsilon}\}] = \exp\{E[\tilde{\varepsilon}] + \text{var}[\tilde{\varepsilon}]/2\}$. Hence, agent i 's objective function given her information set I_i can be written as $E_i[U_i(\tilde{w}_i)] = E[-\exp\{-\rho_i \tilde{w}_i\} | I_i] = -\exp\left\{-\rho_i \left(E[\tilde{w}_i | I_i] - \frac{\rho_i}{2} \text{var}[\tilde{w}_i | I_i]\right)\right\}$ where ρ_i is agent i 's risk aversion coefficient. This expression follows because we restrict ourselves to linear equilibria, which keeps the normality of w_i conditional on I_i . Since $E[\tilde{w}_i | I_i] = x_i E[\tilde{v} - \tilde{p} | I_i]$ and $\text{var}[\tilde{w}_i | I_i] = x_i^2 \text{var}[\tilde{v} - \tilde{p} | I_i]$, maximizing with respect to x_i yields a demand function for the risky asset

$$x_i(I_i) = \frac{E[\tilde{v} - \tilde{p} | I_i]}{\rho_i \text{var}[\tilde{v} - \tilde{p} | I_i]} \quad [1]$$

which is linear in I_i since $\text{var}[\tilde{v} - \tilde{p} | I_i]$ is constant and $E[\tilde{v} - \tilde{p} | I_i]$ is linear due to the normality assumption.

Agent 2's information set is $I_2 = (\bar{p})$, and agent 1's information set is $I_1 = I_1^{LO} = (\tilde{\theta}, \bar{p})$ if she places a limit order and $I_1 = I_1^{MO} = (\tilde{\theta})$ if she submits a market order.

Price-taking insider and limit orders

The next proposition describes the rational expectations equilibrium when agent 1 uses limit orders to trade.

Proposition 3.1. *Suppose that agent 1 places limit orders. Then, for each $\rho_1 \neq 0$ and $r^2 \neq 1$ there exists a unique competitive linear rational expectations equilibrium characterized by*

$$x_1(\tilde{\theta}, p) = \alpha(\tilde{\theta} - p) + \beta_1(\bar{v} - p), \quad x_2(p) = \beta(\bar{v} - p), \quad p = \bar{v} + \frac{\alpha(\tilde{\theta} - \bar{v}) - \bar{z}}{\alpha + \beta_1 + \beta},$$

$$\text{where } \alpha = \frac{1}{\rho_1 \sigma_\eta^2} = \frac{r^2}{\rho_1(1-r^2)\sigma_v^2}, \quad \beta_1 = \frac{1}{\rho_1 \sigma_\varepsilon^2} \text{ and } \beta = \left[\rho_2 \sigma_v^2 + \frac{(\rho_1 + \rho_2)\sigma_v^2}{\rho_1^2 \sigma_z^2 \sigma_\eta^2} \right]^{-1}.$$

Given this equilibrium, the insider's ex ante (unconditional) expected utility is equal to

$$E[U_1(\tilde{W}_1)] = - \left\{ 1 + \frac{\text{var}[E(\tilde{v}|\tilde{\theta}) - p]}{\text{var}[\tilde{v}|\tilde{\theta}]} \right\}^{-1/2} = - \sqrt{\frac{\text{var}[\tilde{v}|\tilde{\theta}]}{\text{var}[\tilde{v} - p]}}$$

$$\text{where } \text{var}[\tilde{v}|\tilde{\theta}] = (1-r^2)\sigma_v^2 \text{ and } \text{var}[\tilde{v} - p] = \frac{(\beta_1 + \beta)^2 \sigma_v^2 + \alpha^2 \sigma_\eta^2 + \sigma_z^2}{(\alpha + \beta_1 + \beta)^2}.$$

Proof. See the Appendix.

Remarks: • The *insider's* demand for the risky asset can be expressed as a convex combination of the difference between her private information and the price (public information) and the difference between the prior expected liquidation value and the price,

$$x_1(\tilde{\theta}, p) = \frac{r^2(\tilde{\theta} - p) + (1-r^2)(\bar{v} - p)}{\rho_1 \text{var}[\tilde{v}|\tilde{\theta}]}. \text{ That is, she buys if her private information and/or the}$$

prior expected liquidation value are greater than the price and sells in the opposite case.

The weight put on the first difference, which can be defined as agent 1's *trading intensity*, is directly proportional to the precision of private information and both weights are inversely proportional to the insider's risk aversion and the residual volatility of the liquidation value. The weight put on the price, $\alpha + \beta_1 = \left(\rho_1 \text{var}[\tilde{v}|\tilde{\theta}] \right)^{-1}$, is increasing in both

the private information precision and the insider's risk tolerance, and is decreasing in the prior volatility of the liquidation return. Moreover, it is greater than the weight put on private information.

- The outsider just buys if the prior expected liquidation value is greater than the price, $x_2(p) = \left(1 - \frac{\text{cov}[\tilde{v}, p]}{\text{var}[p]}\right) \frac{(\bar{v} - p)}{\rho_2 \text{var}[\tilde{v}|p]}$. On the one hand, the outsider's *trading intensity* β is increasing in the informativeness of the price and her risk tolerance. But, on the other hand, the more informative the price, the closer it is to the liquidation value in expected terms, and thus the lower the expected return from the outsider's point of view. This second effect prevails so that the outsider's trading intensity is decreasing in the amount of information about the liquidation value⁷ r^2 . Obviously, it is decreasing in the amount of prior risk σ_v^2 and increasing in the amount of noise trading σ_z^2 .

- If the informed trader is perfectly informed about the liquidation value v , the market breaks down since the insider reacts too much to her private information, the price thus becomes fully revealing, and then no trader wants to absorb the supply shocks.

- If the insider is risk neutral, the unique possible equilibrium price is $p = E[v|\theta]$. Given this price, the outsider's demand equals zero and the insider absorbs the supply shocks, $x_1 = z$. But this equilibrium cannot be generated through linear demand functions and a market clearing price.

- We define the price precision as the inverse of the variance of the liquidation value given the information contained in the price. It is an index of the informativeness of the price about the liquidation value, v . The price contains information about v if and only if traders with fundamentals information trade on the basis of that information. Thus, it is natural to expect that the higher the traders' sensibility to fundamentals information, the more informative the price. This is true in equilibrium. The price precision, $\tau = \frac{1}{\text{var}[\tilde{v}|p]}$ $= \frac{1}{\sigma_v^2} + \frac{\alpha^2}{\alpha^2 \sigma_\eta^2 + \sigma_z^2}$, is decreasing in the fundamental risk σ_v^2 and the amount of noise trading σ_z^2 , and is increasing in the insider's trading intensity α .

- We can define the informational advantage of agent 1 over agent 2 as $q = \frac{\text{var}[\tilde{v}|p]}{\text{var}[\tilde{v}|\tilde{\theta}]}$.

It is a convex function of the precision of the insider's private information r^2 which achieves

⁷ Mathematically this is obvious since $\text{var}[\eta]$ is strictly decreasing in r^2 .

its maximum at $r^2 = \hat{r}^2 = \left[1 + \frac{1}{\rho_1 \sqrt{\sigma_v^2 \sigma_\varepsilon^2}} \right]^{-1}$. If $r^2 = 0$, the insider has no private information and, then, no informational advantage over the outsider, $q = 1$. If $r^2 = 1$, q equals 1 too because the price is fully revealing so that the insider's informational advantage disappears.

◦ Market depth, defined as the price impact of an unit increase in the noise affecting market price, can be measured by Λ , where Λ is equal to the aggregate trading intensity $\alpha + \beta_1 + \beta$. That is, the market is deep if traders react strongly to the price. Λ is a concave function of r^2 which achieves its minimum value at $r^2 = \hat{r}^2 = \frac{A}{1+A}$ if

$A = \frac{\rho_1^2 \sigma_\varepsilon^2}{(\rho_1 + \rho_2)} \left[\sqrt{\frac{(\rho_1 + \rho_2) \sigma_v^2}{\rho_1 \sigma_\varepsilon^2}} - \rho_2 \sigma_v^2 \right]$ is greater than zero, and at $r^2 = 0$ otherwise. Notice that the value of r^2 which minimizes market depth is lower than the value of r^2 which maximizes the insider's informational advantage⁸, that is, $\hat{r}^2 \leq \hat{r}^2$.

◦ The insider's ex ante (unconditional) expected utility is strictly increasing in both the return variance ($\text{var}[v-p]$) and the precision of agent I 's information in the estimation of the return, $1/\text{var}[v-p|\theta, p] = 1/\text{var}[v|\theta]$. Put another way, the insider's gains are high when the liquidation value is very different from the price, that is, when $\text{var}\{E[v|\theta] - p\}$ is high. On the other hand, she dislikes risk so that her expected utility decreases as the remaining fundamental risk ($\text{var}[v|\theta]$) increases.

It can be shown that the insider's ex ante expected utility can be written as

$$E[U_1] = -\left\{ 1 + \rho_1 (G_\theta + G_p) \right\}^{-1/2} \text{ where } G_\theta = C' \frac{r^2 \sigma_v^2}{\rho_1 (1-r^2) \sigma_v^2 + \lambda}, \quad G_p = \frac{C' \lambda^2 \sigma_\varepsilon^2}{\rho_1 (1-r^2) \sigma_v^2 + \lambda},$$

$C' = \frac{\rho_1 (1-r^2) \sigma_v^2}{\rho_1 (1-r^2) \sigma_v^2 + \lambda} < 1$ and $\lambda = 1/\beta$. Thus, this expected utility can be decomposed into

two terms: G_θ , which can be thought of as the utility level derived from trading on inside information, and G_p , which represents the utility level derived from the market making activity undertaken by the insider. G_θ represents the utility level derived from the money that the insider makes out of the outsider due to the informational advantage of the former over the latter. G_p can be written as $G_p = \left(\frac{\lambda}{\rho_1 (1-r^2) \sigma_v^2 + \lambda} \right) \frac{\sigma_\varepsilon^2}{\Lambda}$ where $\frac{\sigma_\varepsilon^2}{\Lambda}$ is the expected loss of noise traders and $\lambda / [\rho_1 (1-r^2) \sigma_v^2 + \lambda]$ is the marginal market share of the noise traders' demand z absorbed by the insider.

⁸ More exactly, $\hat{r}^2 < \hat{r}^2$ if $b > 0$, and $\hat{r}^2 = \hat{r}^2$ if $b = 0$.

Finally, the insider's ex ante expected utility is a concave function of r^2 . It achieves its minimum value $\left(E[U_1(\tilde{W}_1)] = -1\right)$ when inside information is perfect ($r^2=1$), since then the market is perfectly liquid and the return ($v-p$) is exactly equal to zero. On the other hand, it achieves its maximum value for some r^2 between \hat{r}^2 , which minimizes market depth, and \hat{r}^2 , which maximizes the insider's informational advantage.

Price-taking insider and market orders

The next proposition describes the rational expectations equilibrium when agent 1 uses market orders to trade.

Proposition 3.2. *Suppose that agent 1 places market orders. Then, for each $\rho_1 \neq 0$, there exists a unique competitive linear rational expectations equilibrium characterized by*

$$x_1(\tilde{\theta}) = \alpha(\tilde{\theta} - \bar{v}), \quad x_2(p) = \beta(\bar{v} - p), \quad p = \bar{e} + \frac{\alpha(\tilde{\theta} - \bar{v}) - \bar{z}}{\beta},$$

where α and β are implicitly defined by the two-equation system

$$\alpha = \frac{r^2}{\rho_1[(1-r^2)\sigma_v^2 + \lambda^2\sigma_z^2] + \lambda} \quad \beta = \frac{\alpha^2\sigma_v^2 + r^2\sigma_z^2}{\sigma_v^2\{\rho_2[\alpha^2(1-r^2)\sigma_v^2 + r^2\sigma_z^2] + \alpha r^2\}}$$

with $\lambda = 1/\beta$. Given this equilibrium, the insider's ex ante expected utility is equal to

$$E[U_1(\tilde{W}_1)] = -\left\{1 + \frac{\text{var}[E(\tilde{v} - p|\tilde{\theta})]}{\text{var}[\tilde{v} - p|\tilde{\theta}]}\right\}^{-1/2} = -\sqrt{\frac{\text{var}[\tilde{v} - p|\tilde{\theta}]}{\text{var}[\tilde{v} - p]}}$$

with $\text{var}[\tilde{v} - p|\tilde{\theta}] = \text{var}[\tilde{v}|\tilde{\theta}] + \frac{\sigma_z^2}{\beta^2}$ and $\text{var}[\tilde{v} - p] = \frac{(\beta - \alpha)^2\sigma_v^2 + \alpha^2\sigma_n^2 + \sigma_z^2}{\beta^2}$.

Proof. See the Appendix.

Remarks: • Now there is a well-defined equilibrium even if $r^2=1$. Since the insider bears the price risk introduced by the noise traders' demand, her trading intensity is bounded. Moreover, α depends on σ_z^2 . If σ_z^2 increases, the price risk goes up and, as a consequence, the insider's trading intensity decreases.

• Market depth is equal to the outsider's trading intensity since the insider's strategy does not depend upon the price. The outsider's trading intensity may be increasing in r^2 .

Nevertheless, if ρ_1 , ρ_2 or the product $\sigma_z^2 \sigma_v^2$ is sufficiently high, then β and the market depth are strictly decreasing in r^2 .

◦ Let q' denote the informational advantage of the insider over the outsider defined as the ratio between the precisions of both agents in the estimation of the return given their information sets⁹. That is, $q' = \text{var}(v - p|p) / \text{var}(v - p|\theta)$. Notice that q' may be lower than 1; that is, the outsider, who has no private information, can enjoy an informational advantage over the insider if the insider uses market orders. Obviously, θ is more informative than the price in the estimation of v , but the price may be more informative than θ in the estimation of the return. We can prove that: (i) if the outsider is risk neutral, $q' > 1$; (ii) if ρ_2 is greater than zero, q^2 is lower than 1 for r^2 sufficiently low; and (iii) if ρ_2 is sufficiently greater than ρ_1 , q' is lower¹⁰ than 1 for all r^2 . Finally, although q' may be decreasing in r^2 (for r^2 close to one), we can prove that q' is strictly increasing in r^2 if ρ_1 , ρ_2 or the product $\sigma_z^2 \sigma_v^2$ is sufficiently high.

◦ The insider's ex ante expected utility can be written as $E[U_1] = -\{1 + \rho_1 G_\theta\}^{-1/2}$ where

$$G_\theta = \frac{C'' r^2 \sigma_v^2}{\rho_1 (1 - r^2) \sigma_v^2 + \rho_1 \lambda^2 \sigma_z^2 + \lambda}, \quad C'' = \left[\frac{\rho_1 (1 - r^2) \sigma_v^2 + \rho_1 \lambda^2 \sigma_z^2}{\rho_1 (1 - r^2) \sigma_v^2 + \rho_1 \lambda^2 \sigma_z^2 + \lambda} \right] < 1 \text{ and } \lambda = 1/\beta. \quad G_\theta$$

can be interpreted as an index of the gains coming from insider trading. Since agent I 's strategy does not depend on the price, she does not make the market, that is, $G_p = 0$. The insider's expected utility tends to increase if her informational advantage goes up or market depth goes down. We can show that the value of r^2 which maximizes the insider's expected utility is greater when the insider places market orders. Moreover, if ρ_1 , ρ_2 , σ_z^2 or σ_v^2 is sufficiently high, $E[U_1(\tilde{W}_1)]$ is strictly increasing in the precision of the inside information.

Optimal choice about the type of order

In the next proposition we compare the two equilibria characterized by propositions 3.1 and 3.2, and explain agent I 's optimal choice about the type of order.

Proposition 3.3. (i) $\alpha^{LO} > \alpha^{MO}$, (ii) $\beta^{LO} < \beta^{MO}$, (iii) $\text{var}[\tilde{v}|p^{LO}] < \text{var}[\tilde{v}|p^{MO}]$ ($\tau^{LO} > \tau^{MO}$), (iv) If r^2 is sufficiently low or sufficiently high, then $\Lambda^{LO} > \Lambda^{MO}$ and

⁹ I denote this informational advantage q' to distinguish it from $q = \text{var}[v|p] / \text{var}[v - p|\theta]$. In the equilibrium with market orders, q is strictly increasing in r^2 .

¹⁰ For instance, if $\sigma_z^2 = \sigma_v^2 = \rho_1 = 1$, then q' is lower than 1 for all r^2 if ρ_2 is greater than 0.55. In particular, if ρ_2 is equal to 1, q' is lower than 0.603 for all r^2 ; that is, price precision is (almost) twice the precision of inside information even if $r^2 = 1$.

$\text{var}[\tilde{v} - p^{LO}] < \text{var}[\tilde{v} - p^{MO}]$, and (v) if r^2 is sufficiently low, then $E[U_1^{LO}] > E[U_1^{MO}]$; and if r^2 is sufficiently high, then $E[U_1^{LO}] < E[U_1^{MO}]$.

Proof. See the Appendix.

The last result characterizes the insider's optimal choice about the type of order. It says that the insider will choose market orders if her private information is very precise and she will choose limit orders otherwise. Moreover, in numerical simulations it appears that the incentives to use market orders are increasing in the private information precision¹¹ and that there exists $\bar{r}^2 \in (0,1)$ such that if $r^2 < \bar{r}^2$, the insider chooses limit orders and if $r^2 > \bar{r}^2$, she uses market orders.

The insider faces a trade off between maximizing her insider trading gains by using market orders or maximizing her market making gains by placing limit orders. If inside information is not too precise, the market making activity is very profitable (since market depth is low) while the insider trading gains are small (since the informational advantage of the insider is low). Thus, the insider should choose limit orders in order to make the market.

At the other extreme, if inside information is very precise and agent I uses limit orders, the market making gains and the insider trading gains are small. Since agents I 's demand has too much sensitivity to inside information, the price precision is very high¹². As a result, the insider's informational advantage is low and the market is very liquid. On the contrary, if agent I uses market orders, she restrains her trading intensity and, as a consequence, she preserves some informational advantage since the price is not too informative. Thus, market orders are optimal from the insider's point of view if θ is sufficiently precise. In this setup, using market orders is a sensible way to ensure that she will not react excessively to her private information since she is willing to accept the price risk introduced by noise traders.

4. Imperfectly competitive insider

We now analyze the fully rational situation in which the insider recognizes and exploits her ability to affect the market price, and (therefore) the outsider's beliefs.

¹¹ However, this result is hard to prove since the ratio $E[U_1^{LO}]/E[U_1^{MO}]$ is not monotone with respect to r^2 and (furthermore) it depends on some endogenous parameters which are implicitly defined.

¹² In fact, if the insider submits limit orders, the price is informationally equivalent to the inside information in the limit as r^2 tends to 1.

Imperfectly competitive insider and limit orders

We first introduce the appropriate concept of equilibrium, which is similar to the rational expectations equilibrium with imperfect competition defined by Kyle (1989).

Definition: An imperfectly competitive rational expectations equilibrium is defined as the set of functions $\{P(\tilde{\theta}, \tilde{z}), X_1(\tilde{\theta}, \tilde{p}), X_2(\tilde{p})\}$ such that:

- the price $\tilde{p} = P(\tilde{\theta}, \tilde{z})$ clears the market (with probability one), $X_1(\tilde{\theta}, \tilde{p}) + X_2(\tilde{p}) = \tilde{z}$,
- $X_1(\tilde{\theta}, \tilde{p})$ is agent 1's optimal strategy subject to the constraint $X_1(\tilde{\theta}, \tilde{p}) + X_2(\tilde{p}) = \tilde{z}$, that is,

$$\forall X_1' \text{ such that } (X_1' \neq X_1) \quad E\left[U_1\left\{(\tilde{v} - \tilde{p})X_1(\tilde{\theta}, \tilde{p})\right\}\right] \geq E\left[U_1\left\{(\tilde{v} - \tilde{p})X_1'(\tilde{\theta}, \tilde{p})\right\}\right]$$

- $X_2(\tilde{p})$ is agent 2's optimal strategy, taking the market clearing price \tilde{p} as given, that is,

$$\forall X_2' \text{ such that } (X_2' \neq X_2) \quad E\left[U_2\left\{(\tilde{v} - \tilde{p})X_2(\tilde{p})\right\}\right] \geq E\left[U_2\left\{(\tilde{v} - \tilde{p})X_2'(\tilde{p})\right\}\right].$$

From the market clearing condition, equilibrium price depends on the strategies of speculators. To emphasize this dependence, let us write $p = P(X_1, X_2, z)$, $x_1 = x_1(X_2, z)$ and $x_2 = x_2(X_1, z)$. Given this notation, the first condition of the above definition becomes: for every $X_1' \neq X_1$, $E\left[U_1\left\{[\tilde{v} - P(X_1, X_2, z)]x_1(X_2, z)\right\}\right] \geq E\left[U_1\left\{[\tilde{v} - P(X_1', X_2, z)]x_1'(X_2, z)\right\}\right]$, which clearly shows the imperfectly competitive behavior of agent 1.

The insider's maximization problem is equivalent to the monopsonist's problem of maximizing against the residual supply implicitly defined by $x_2(p) + x_1 = \tilde{z}$. Since we restrict attention to linear equilibria, we can express the strategies of the rational traders and the insider's residual supply as

$$x_1(\tilde{\theta}, p) = \alpha(\tilde{\theta} - p) + \beta_1(\tilde{v} - p) \quad x_2(p) = \beta(\tilde{v} - p) \quad p = (\tilde{v} - \lambda\tilde{z}) + \lambda x_1$$

where the slope λ is just the inverse of the outsider's trading intensity β , $\lambda = 1/\beta$. That is, the more aggressive the outsider behaves, the smaller the slope of the insider's residual supply. Alternatively, given agent 2's optimal demand, $X_2(p) = \frac{E[\tilde{v}|p] - p}{\rho_2 \text{var}[\tilde{v}|p]}$, λ can be

written as $\lambda = \rho_2 \text{var}[\tilde{v}|p](1 - \text{cov}[\tilde{v}, p]/\text{var}[p])^{-1}$. Therefore, the slope λ is increasing in the outsider's risk aversion ρ_2 , the residual (after trading takes place) fundamental risk, $\text{var}[\tilde{v}|p]$, and the marginal effect of a change in the price (due to a variation in the insider's demand) on the expectation of the liquidation value from the outsider's point of view.

Now, given the distribution of the insider's terminal wealth conditional on her information set, which is characterized by $E[W_1|p, \tilde{\theta}] = (E[\tilde{v}|\tilde{\theta}] - p)x_1$ and $\text{var}[W_1|p, \tilde{\theta}] = x_1^2 \text{var}[\tilde{v}|\tilde{\theta}]$, we can state the insider's maximization problem as

$$\begin{aligned} \underset{x_1}{\text{Max}} \quad & (E[\tilde{v}|\tilde{\theta}] - p)x_1 - \frac{\rho_1}{2} x_1^2 \text{var}[\tilde{v}|\tilde{\theta}] \\ \text{s.t.} \quad & p = (\bar{v} - \lambda \bar{z}) + \lambda x_1 \end{aligned}$$

If the second order condition holds $2\lambda + \rho_1 \text{var}[\tilde{v}|\tilde{\theta}] > 0$, then the insider has the well defined demand function

$$x_1(p; \tilde{\theta}) = \frac{E[\tilde{v}|\tilde{\theta}] - p}{\rho_1 \text{var}[\tilde{v}|\tilde{\theta}] + \lambda}. \quad [2]$$

Agent 1 restricts her speculative position so as to exploit her market power. As one would expect, the greater λ , the greater the reduction in the insider's demand for the risky asset. As in Kyle (1989) the monopsonist insider has a demand curve. The price-quantity chosen by the insider is obtained by equating marginal cost to marginal value. The insider's marginal valuation curve is given by $E[v|\theta]$ while the marginal cost schedule is given by $MC(x_1) = \bar{v} - \lambda z + m x_1$, where the slope m is twice the slope of the insider's residual supply plus the marginal cost of risk per unit of asset holding from the insider's point of view, $m = 2\lambda + \rho_1 \text{var}[v|\theta]$.

The next proposition establishes existence and uniqueness of equilibrium.

Proposition 4.1: *There is a unique linear imperfectly competitive rational expectations equilibrium. It is given by*

$$x_1(\tilde{\theta}, p) = \alpha(\tilde{\theta} - p) + \beta_1(\bar{v} - p) \quad x_2(p) = \beta(\bar{v} - p) \quad p = \bar{v} + \Lambda^{-1}[\alpha(\tilde{\theta} - \bar{v}) - \bar{z}]$$

with $\alpha = r^2 / (\rho_1 \text{var}[\tilde{v}|\tilde{\theta}] + \lambda)$, $\beta_1 = (1 - r^2)\alpha / r^2$, $\beta = 1/\lambda$, $\Lambda = \alpha + \beta_1 + \beta$, $\text{var}[\tilde{v}|\tilde{\theta}] = (1 - r^2)\sigma_v^2$, and where the equilibrium value of λ is implicitly defined by

$$\lambda = \rho_2 \sigma_v^2 + \frac{(\sigma_v^2 - \text{var}[\tilde{v}|\tilde{\theta}])}{\sigma_z^2} \frac{(\rho_1 + \rho_2) \text{var}[\tilde{v}|\tilde{\theta}] + \lambda}{(\rho_1 \text{var}[\tilde{v}|\tilde{\theta}] + \lambda)^2}$$

The insider's ex ante expected utility is given by

$$E[U_1(\tilde{W}_1)] = - \left\{ 1 + C \frac{\text{var}[E(\tilde{v}|\tilde{\theta}) - p]}{\text{var}[\tilde{v}|\tilde{\theta}]} \right\}^{-1/2} = - \left\{ 1 + \frac{\rho_1(r^2\sigma_v^2 + \lambda^2\sigma_z^2)}{m} \right\}^{-1/2}$$

where $C = 1 - \lambda^2 / (\rho_1 \text{var}[\tilde{v}|\tilde{\theta}] + \lambda)^2$ and $m = \rho_1 \text{var}[\tilde{v}|\tilde{\theta}] + 2\lambda$.

Proof. See the Appendix.

Remarks: • The market price is informationally equivalent to $\alpha(\tilde{\theta} - \bar{v}) - \bar{z}$ and to $\tilde{\gamma} = E[\tilde{v}|\tilde{\theta}] - \left\{ \rho_1 \text{var}[\tilde{v}|\tilde{\theta}] + \lambda \right\} \bar{z}$. Moreover, it is in the interval $[\bar{v}, \gamma]$ for all (θ, z) .

• The insider's trading intensity α , depends positively (ceteris paribus) on the quality of the privileged information r^2 , and negatively on the degree of risk aversion, prior volatility of the liquidation value, and the slope of the residual supply λ . Now, trading intensity depends on the outsider's risk aversion via λ . Obviously, α is now lower than in the competitive case. Moreover, in contrast to the competitive case, the insider's trading intensity depends on the amount of noise trading (σ_z^2). An increase in noise trading increases the conditional expected return ($E[v|\theta] - p$) without increasing risk ($\text{var}[v|\theta]$), and furthermore makes the insider's residual supply smoother. Both effects work in the same direction: making the insider more aggressive.

• The outsider's trading intensity, which may be written as $\beta = \sigma_z^2 / \left\{ \sigma_v^2 [\rho_2 (\alpha^2 \sigma_\eta^2 + \sigma_z^2) + \alpha] \right\}$, is decreasing in the insider's trading intensity α , the fundamental risk, and the outsider risk aversion ρ_2 .

• The insider's expected utility can be decomposed into two independent terms related to her two sources of information. Inside information generates an expected profit proportional to $r^2 \sigma_v^2$, which measures the reduction in fundamental risk due to private information, $r^2 \sigma_v^2 = \sigma_v^2 - \text{var}[v|\theta]$. Using limit orders, which is informationally equivalent to observing the price, allows the insider to infer the supply shock due to the noise traders (since (θ, p) is informationally equivalent to (θ, z)). This generates an additional expected profit proportional to $\lambda^2 \sigma_z^2$. To obtain these profits, the insider incurs two kinds of costs related to the residual risk ($\text{var}[v|\theta]$) and to the effect of the insider's marginal demand on the price paid by her inframarginal position (2λ). Finally, notice that, in sharp contrast to the competitive setup, the insider's ex ante expected utility is strictly increasing in the precision of her private information. As r^2 goes up, the informational advantage of the insider and her marginal market share go up, and market depth goes down. Both effects tend to increase her ex ante expected utility.

Imperfectly competitive insider and market orders

Now we study the equilibrium which prevails when the insider uses market orders. To do this, we have to replace $X_1(\theta, p)$ by $X_1(\theta)$ in the definition of an imperfectly competitive rational expectations equilibrium. Moreover, the insider's information set is $\{\theta\}$ instead of $\{\theta, p\}$. Therefore, if the second order condition $2\lambda + \rho_1 \text{var}[\tilde{v} - p|\tilde{\theta}] > 0$ holds, the

insider's optimal market order becomes $x_1(\tilde{\theta}) = \frac{E[\tilde{v} - p|\tilde{\theta}]}{\rho_1 \text{var}[\tilde{v} - p|\tilde{\theta}] + \lambda}$, where λ is the slope of the insider's residual supply.

The next proposition establishes existence and uniqueness of equilibrium.

Proposition 4.2: *There is a unique linear imperfectly competitive rational expectations equilibrium. It is given by*

$$x_1(\tilde{\theta}) = \alpha(\tilde{\theta} - \bar{v}), \quad x_2(p) = \beta(\bar{v} - p), \quad \text{and} \quad p = \bar{v} + \lambda[\alpha(\tilde{\theta} - \bar{v}) - \tilde{z}]$$

with $\alpha = r^2 / [\rho_1 \text{var}(v - p|\theta) + 2\lambda]$, $\beta = 1/\lambda$, $\text{Var}(v - p|\theta) = (1 - r^2)\sigma_v^2 + \lambda^2\sigma_z^2$, and where the equilibrium value of λ is implicitly defined by

$$\lambda = \rho_2 \sigma_v^2 + \frac{(\sigma_v^2 - \text{var}[\tilde{v}|\tilde{\theta}]) \left([\rho_1 + \rho_2] \text{var}[\tilde{v}|\tilde{\theta}] + \lambda + \rho_1 \lambda^2 \sigma_z^2 \right)}{\sigma_z^2 \left(\rho_1 \text{var}[\tilde{v}|\tilde{\theta}] + 2\lambda + \rho_1 \lambda^2 \sigma_z^2 \right)^2}.$$

The insider's ex ante expected utility is given by

$$E[U_1(\tilde{W}_1)] = - \left\{ 1 + C \frac{\text{var}[E(\tilde{v} - p|\tilde{\theta})]}{\text{var}[\tilde{v}|\tilde{\theta}]} \right\}^{-1/2} = - \left\{ 1 + \tilde{v} \frac{r^2 \sigma_v^2}{m} \right\}^{-1/2}$$

$$\text{with } C = \frac{\rho_1 \text{var}[\tilde{v}|\tilde{\theta}] \left(\rho_1 \text{var}[\tilde{v} - p|\tilde{\theta}] + 2\lambda \right)}{\left(\rho_1 \text{var}[\tilde{v} - p|\tilde{\theta}] + \lambda \right)^2} \text{ and } m = \rho_1 \text{var}[\tilde{v}|\tilde{\theta}] + 2\lambda + \rho_1 \lambda^2 \sigma_z^2.$$

Proof. See the Appendix.

Remarks: • Now, the insider bears a greater residual risk since she does not observe the information contained in the price; that is, $\text{Var}(v - p|\theta) = \text{Var}(v - p|p, \theta) + \lambda^2 \sigma_z^2$.

◦ The outsider, whose trading intensity becomes $\beta = \frac{\sigma_z^2 + \alpha^2(\sigma_v^2 + \sigma_\eta^2)}{\sigma_v^2[\rho_2(\alpha^2\sigma_\eta^2 + \sigma_z^2) + \alpha]}$, is

expected to trade more aggressively. Since the insider does not absorb any of the liquidity trading, the order flow received by the outsider ($z-x_1$) is less likely to reflect the insider's private information and, as a result, the outsider should become more willing to trade.

◦ The insider's informational advantage $q' = \text{var}[\tilde{v} - \tilde{p}|\tilde{p}]/\text{var}[\tilde{v} - \tilde{p}|\tilde{\theta}]$ changes greatly. For instance, if the inside information is perfect ($r^2 = 1$), the insider's informational advantage is bounded (since $\text{Var}(v - p|\theta) = \lambda^2\sigma_z^2 > 0$) while it would be infinite if the insider placed limit orders.

5. Limit versus market orders

In this section we compare the two equilibria characterized by propositions 4.1 and 4.2, and explain the insider's optimal choice about the type of order. Obviously, the insider will choose a limit order (market order) if and only if $E[U_1^{LO}] > (<) E[U_1^{MO}]$.

If the insider were forced to publicly announce her inside information before trading, she would never use market orders. In this case, the market makers' information set would be (p, θ) so that they would enjoy an informational advantage over the insider (if she herself placed market orders). Thus, the insider's gains G_p would be equal to zero and G_θ would be strictly lower than zero. On the contrary, if the insider submitted limit orders, her gains G_p would be strictly greater than zero and G_θ would be equal to zero, since she would have the same information set than the outsider.

The next proposition presents the main effects of order form on security prices and market performance.

Proposition 5.1. (i) $\lambda^{LO} > \lambda^{MO}$ and $\beta^{LO} < \beta^{MO}$, (ii) $\alpha^{LO} > \alpha^{MO}$, (iii) $\tau^{LO} > \tau^{MO}$, (iv) $r^2 \rightarrow 1 \Rightarrow q^{LO}/q^{MO} \rightarrow \infty$; and $r^2 \rightarrow 0 \Rightarrow q^{LO}/q^{MO} > 1$, and (v) If $\rho_1 = 0$, then $1 \leq (\Lambda^{LO}/\Lambda^{MO}) \leq 2$.

Proof. See the Appendix.

Remarks: ◦ The insider reacts more to her private information when she trades via limit orders. Two reasons explain this result. On the one hand, she feels a lower risk because she has more information, $\text{var}[v-p|\theta, p] < \text{var}[v-p|\theta]$. On the other hand, she obtains a greater

return conditional on her information set, $\left| E[\tilde{v} - p | \tilde{\theta}] \right| = \left| E[\tilde{v} - p | \tilde{\theta}, p] \right| - \lambda |\bar{z}| \leq \left| E[\tilde{v} - p | \tilde{\theta}, p] \right|$. Moreover, if the insider is risk neutral, then $(\alpha^{LO}/\alpha^{MO}) \in [1, 2]$.

- The price conveys information about the liquidation value just because agent I , who is the unique informed agent, trades on her private information. Thus, it is natural to expect that the informativeness of the price will be increasing in the weight put by agent I on her private information α . As a direct consequence of the above result, the price precision is higher when agent I chooses limit orders. Moreover, the insider's informational advantage is greater when she submits limit orders although the outsider is better informed.

- If the insider uses limit orders, the outsider will trade less aggressively. On one hand, the outsider is better informed when the insider places limit orders, since $\tau^{LO} > \tau^{MO}$. On the other hand, as the price precision goes up, the price gets close to the asset liquidation value so that the expected return from the outsider's point of view $E[v-p|p]$ is lower. These two effects work in opposite directions and the latter outweighs the former. As a consequence, the slope of the insider's residual supply is greater when she places limit orders. Moreover, if the insider is risk neutral, then $(\lambda^{LO}/\lambda^{MO})$ and $(\beta^{MO}/\beta^{LO}) \in [1, 2]$.

- If the insider is risk neutral, then $(\Lambda^{LO}/\Lambda^{MO}) \in [1, 2]$, so that the market is deeper when the insider chooses limit orders. As mentioned above, market depth is equal to the trader's aggregate price sensibility. If the insider places limit orders, her strategy is price sensitive, which directly increases market depth and (more than) offsets the decrease in the outsider's price sensibility.

- As in Kyle (1989), let us introduce some parameters which have an intuitive interpretation. Denote by ζ the "informational incidence parameter" measuring the number of dollars by which the market price goes up when the insider's valuation of the asset goes up by one dollar as a result of a larger realization of her private signal $\tilde{\theta}$. That is,

$$\zeta = \left(\frac{dp}{d\theta} \right) / \left(\frac{dE(\tilde{v}/\theta)}{d\theta} \right) = \left(\frac{\alpha}{\Lambda r^2} \right) = \frac{\lambda}{m}.$$

And denote by ξ_i the "marginal market share of the quantity traded by noise traders going to agent i ", in the sense that when the realization of z goes up by one dollar, the quantity traded by agent i goes up by ξ_i units. That is,

$$\xi_i = \frac{dx_i}{dp} \frac{dp}{dz}.$$

Obviously, from the market clearing condition, the identity $\xi_1 + \xi_2 = 1$ must be satisfied. Notice that the marginal market share for agent i is just the ratio between the price sensibility of her demand (dx_i/dp) and the market depth $(\Lambda^{-1} = dp/dz)$.

Endogenous choice between market and limit orders

The insider's optimal choice about the type of order is driven by the comparison between her ex ante expected utilities attached to the optimal limit order and market order respectively. From propositions 4.1 and 4.2, these expected utilities are given by

$$E[U_1^j] = -\left\{1 + \rho_1(G_\theta^j + G_p^j)\right\}^{-1/2} \quad j=LO, MO: \text{ where } G_p^j = \frac{\xi_1^j}{\xi_2^j} \frac{\sigma_v^2}{\Lambda^j} \text{ and } G_\theta^j = \alpha^j(1 - \xi_1^j)\sigma_v^2. \text{ If}$$

the insider uses limit orders ($j=LO$), then the informational incidence parameter is equal to the marginal market share for the insider $\xi_1^{LO} = \zeta^{LO}$ and $\xi_1^{LO} \leq 1/2$, since $\xi_2^{LO} = \beta^{LO}/\Lambda^{LO} = [\rho_1 \text{var}(v|\theta) + \lambda^{LO}] / [\rho_1 \text{var}(v|\theta) + 2\lambda^{LO}] \geq 1/2$. The outsider enjoys a greater marginal market share because the insider restricts her demand. On the other hand, if the insider submits market orders, $\xi_1^{MO} = 0$ and $\xi_2^{MO} = 1$, since she does not make market.

The insider's ex ante expected utility can be decomposed into the term G_θ , which measures the utility level derived from trading on the inside information, and G_p , which represents the utility coming from the market making activity of the insider. We will call G_θ "insider trading gains" and G_p "market making gains". As shown in propositions 4.1 and 4.2, both gains are decreasing in the insider's marginal cost m .

The inside information allows the insider to make money out of the market makers. Insider trading gains G_θ are increasing (*ceteris paribus*) in the insider's trading intensity and prior volatility of the asset liquidation value, and are decreasing in the marginal market share for the insider and the informational incidence of inside information. Alternatively, G_θ is proportional to $r^2\sigma_v^2$, which is an index of the return volatility conditional on the insider's information set due to her private information.

As mentioned above, a trader submitting limit orders is an effective market maker. The insider's market making gains are equal to the ratio between the marginal market shares of agents 1 and 2 times the expected loss of noise traders. Alternatively, G_p is proportional to $\lambda^2\sigma_v^2$, which measures the return volatility conditional on (θ, p) due to the price. Of course, if the insider submits market orders, then her market making gains equal zero since her demand does not depend upon the price. Therefore, considering only market making gains, it is obvious that the insider's optimal choice would be to place a limit order.

Before characterizing the insider's (ex ante) optimal choice it is instructive to look at the insider's expected utility conditional on her private information. Depending on the type of order chosen this expected utility will be given by¹³

$$E\left[U_i^{LO}|\tilde{\theta}\right] = -\left\{1 + G_p^{LO}\right\}^{-1/2} \exp\left\{-\frac{\rho_1}{2m^{LO}\left[1 + \rho_1 G_p^{LO}\right]} r^4 (\tilde{\theta} - \bar{v})^2\right\}$$

if the insider places limit orders, or by

$$E\left[U_i^{MO}|\tilde{\theta}\right] = -\exp\left\{-\frac{\rho_1}{2m^{MO}} r^4 (\tilde{\theta} - \bar{v})^2\right\}$$

if the insider submits market orders; where $G_p^{LO} = \frac{(\lambda^{LO})^2 \sigma_z^2}{m^{LO}}$, $m^{LO} = \rho_1(1-r^2)\sigma_v^2 + 2\lambda^{LO}$, and $m^{MO} = \rho_1(1-r^2)\sigma_v^2 + 2\lambda^{MO} + \rho_1(\lambda^{MO})^2 \sigma_z^2$. Alternatively, the above expressions may be written as

$$E\left[U_i^{LO}|\tilde{\theta}\right] = [CMMG^{LO}][CITG^{LO}(\tilde{\theta} - \bar{v})] \quad \text{and} \quad E\left[U_i^{MO}|\tilde{\theta}\right] = CITG^{MO}(\tilde{\theta} - \bar{v}),$$

where $CMMG^{LO} = \left\{1 + \frac{\rho_1(\lambda^{LO})^2 \sigma_z^2}{\rho_1(1-r^2)\sigma_v^2 + 2\lambda^{LO}}\right\}^{-1/2}$ and

$$CITG^j(\tilde{\theta} - \bar{v}) = -\exp\left\{-\frac{\rho_1 r^4 (\tilde{\theta} - \bar{v})^2}{2\left[\rho_1(1-r^2)\sigma_v^2 + 2\lambda^j + \rho_1(\lambda^j)^2 \sigma_z^2\right]}\right\} \quad (j = LO, MO).$$

I define the *conditional insider trading gains* (CITG) as the function $CITG^j(\tilde{\theta} - \bar{v})$, where the superscript j refers to the type of order chosen by the insider ($j = LO, MO$). It is obvious that these gains are different from zero ("CITG=-1" means zero gains) if and only if the inside information differs from the prior expected liquidation value and it is correlated with the asset liquidation value (otherwise it would be just noise), so that the above function is a natural measure of the gains coming from insider trading.

¹³ It is shown in the proof of the proposition 4.1 that

$$E\left[U_i^{LO}(\tilde{W}_1)|\tilde{z}, \tilde{\theta}\right] = -\exp\left\{-\frac{\rho_1}{2m^{LO}} \left[r^2(\tilde{\theta} - \bar{v}) + \lambda\tilde{z}\right]^2\right\}. \quad \text{Taking } \tilde{\chi} = \left(\frac{\rho_1}{2m^{LO}}\right)^{1/2} \left[r^2(\tilde{\theta} - \bar{v}) + \lambda\tilde{z}\right]$$

and applying Rao's formula, we get the desired expression for $E\left[U_i^{LO}|\tilde{\theta}\right]$. On the other hand, it can be

directly derived from proposition 4.4 that $E\left[U_i^{MO}(\tilde{W}_1)|\tilde{\theta}\right] = -\exp\left\{-\frac{\rho_1}{2m^{MO}} \left[r^2(\tilde{\theta} - \bar{v})\right]^2\right\}$.

When the insider places limit orders, she provides liquidity to the market (like any other market maker) and, consequently, she obtains some market making gains¹⁴. Analytically, these gains are given by the term $CMMG^{LO} = \{1 + G_p^{LO}\}^{-1/2}$, to which I refer as the insider's *conditional (on θ) market making gains*. If the insider places market orders, these gains are equal to zero. Therefore, it is clear that the *conditional market making gains* are higher when the insider submits market orders.

Since $\lambda^{LO} > \lambda^{MO}$, the *conditional insider trading gains* are higher when the insider submits market orders. To understand this result it may be interesting to look at the expected return conditional on the inside information. Whatever the type of order chosen by the insider this expected return may be written as¹⁵

$$E[\tilde{v} - p|\tilde{\theta}] = r^2(1 - \zeta)(\tilde{\theta} - \bar{v})$$

where ζ is the informational incidence parameter. From the insider's point of view, the expected return after observing her private information is equal to the product of three terms: the correlation coefficient between the liquidation value and the inside information, the deviation of this information from the expected liquidation value, and one minus the informational incidence parameter. The above conditional expected return may be interpreted as an index of the value of the inside information in the sense that this information has value if and only if (i) it is correlated with the liquidation value (that is, $r^2 \neq 0$), (ii) it is not fully revealed by the security price (that is, $\zeta \neq 1$), and (iii) its realization differs from the prior expected liquidation value (that is, $\tilde{\theta} \neq \bar{v}$). If any of these conditions is not satisfied, the inside information is worthless. Alternatively, the conditional expected return may be seen as an index of the insider trading gains since the higher the conditional expected return, the higher the insider's gains coming from her private information.

In the above expression the unique variable which depends upon the type of order chosen is the informational incidence parameter. Insider trading gains are decreasing in the

¹⁴ Note that these gains are different from zero even if the private signal does not contain any information ($r^2=0$) or it is equal to the prior expected liquidation value ($\tilde{\theta} = \bar{v}$). Therefore, they are independent of the possession of inside information.

¹⁵ From propositions 4.1 and 4.2, the security price may be written as $p = \bar{v} + \Lambda^{-1}[\alpha(\tilde{\theta} - \bar{v}) - \tilde{z}]$, so that the expected return conditional on the realization of the inside information is given by $E[\tilde{v} - p|\tilde{\theta}] = E[(\tilde{v} - \bar{v})|\tilde{\theta}] - \Lambda^{-1}\alpha(\tilde{\theta} - \bar{v})$ since $E[\tilde{z}|\tilde{\theta}] = 0$. Taking into account that $E[(\tilde{v} - \bar{v})|\tilde{\theta}] = r^2(\tilde{\theta} - \bar{v})$ and that $\zeta = \alpha/(\Lambda r^2)$, we have the desired expression the conditional expected return.

informational incidence parameter, and this parameter is higher when the insider uses limit orders because the insider reacts more to her private information. As a direct consequence, the expected return conditional on the inside information and the insider trading gains are higher when the insider uses market orders. This is a very intuitive result: the informed trader maximizes her insider trading gains by using market orders, since these orders reveal less information than limit orders.

From the above discussion we find that the insider faces a trade off between maximizing her conditional insider trading gains by placing market orders or maximizing her conditional market making gains by submitting limit orders. The result of this trade off crucially depends on the realization of the inside information. Provided that the precision of the inside information is strictly greater than zero¹⁶, there exists a real value $\hat{\theta}$ implicitly defined by $E[U_1^{LO}|\hat{\theta}] = E[U_1^{MO}|\hat{\theta}]$ such that (i) $E[U_1^{LO}|\hat{\theta}] > E[U_1^{MO}|\hat{\theta}]$ for all the realizations θ such that $|\theta - \bar{v}| < |\hat{\theta} - \bar{v}|$ and (ii) $E[U_1^{LO}|\hat{\theta}] < E[U_1^{MO}|\hat{\theta}]$ for all the realizations θ such that $|\theta - \bar{v}| > |\hat{\theta} - \bar{v}|$. Analytically, $\hat{\theta}$ is given by

$$\hat{\theta} = \bar{v} + \left\{ \frac{1}{\rho_1 r^4} \left(\frac{1}{m^{MO}} - \frac{1}{m^{LO} [1 + \rho_1 G_p^{LO}]} \right) \ln [1 + \rho_1 G_p^{LO}] \right\}^{1/2},$$

or by

$$\hat{\theta} = \bar{v} + \left\{ \frac{\ln \left[1 + \frac{\rho_1 (\lambda^{LO})^2 \sigma_z^2}{\rho_1 (1-r^2) \sigma_v^2 + 2\lambda^{LO}} \right]}{\rho_1 r^4 \left(\frac{1}{\rho_1 (1-r^2) \sigma_v^2 + 2\lambda^{MO} + \rho_1 (\lambda^{MO})^2 \sigma_z^2} - \frac{1}{\rho_1 (1-r^2) \sigma_v^2 + 2\lambda^{LO} + \rho_1 (\lambda^{LO})^2 \sigma_z^2} \right)} \right\}^{1/2}$$

That is, placing limit orders is ex-post (conditional on θ) optimal for realizations of the inside information which are close to the prior expected liquidation value while placing market orders is ex-post optimal for realizations of θ which are far away from the prior expected liquidation value. This is very intuitive: if the realization of the inside information is close to the prior expected liquidation value, this information is (almost) worthless (the insider trading gains are close to zero whatever the type of order chosen) and, therefore, it is optimal to place limit orders so as to maximize market making gains.

¹⁶ If the precision of the inside information equals zero, placing limit orders would be optimal for all realizations of θ since the inside information would be worthless and, as a direct consequence, the insider trading gains would be equal to zero. That is, $E[U_1^{LO}|\tilde{\theta}] > E[U_1^{MO}|\tilde{\theta}] = -1$.

Let ϕ^{MO} denote the probability that the insider's expected utility conditional on her private information is higher if she chooses market orders. That is, ϕ^{MO} denotes the probability that market orders are ex-post (conditional on θ) optimal. Since $\tilde{\theta} \sim N(\bar{v}, \sigma_v^2/r^2)$, it is obvious that $\phi^{MO} = \text{Pr ob}\{|\theta - \bar{v}| > |\hat{\theta} - \bar{v}|\} = 2\Phi\left[-\sqrt{r^2/\sigma_v^2}(\hat{\theta} - \bar{v})\right]$, where $\Phi[\circ]$ denotes the probability distribution function of the standard normal variable.

The next proposition characterizes the insider's (ex ante) optimal choice between market and limit orders. Basically, it states that placing limit orders is ex ante optimal from the insider's point of view whatever the precision of the inside information.

Proposition 5.2. (v) If $\rho_1 \neq 0$ or $\rho_2 \neq 0$, then $E[U_1^{LO}] > E[U_1^{MO}] \forall r^2$; and $E[U_1^{LO}] = E[U_1^{MO}] \forall r^2$ if and only if $\rho_1 = \rho_2 = 0$.

Proof. See the Appendix.

From the previous discussion, we know that placing market orders is ex-post optimal for realizations of θ which are far away from the prior expected liquidation value. However, since these realizations are very unlikely, placing limit orders is ex ante optimal whatever the precision of the inside information. Analytically, the probability that market orders are ex-post (conditional on θ) optimal ϕ^{MO} is always (much) lower than .5 and, moreover, when the realization of θ is close to the prior expected liquidation value (that is, when limit orders are ex-post optimal), the *conditional market making gains* are much higher than the *conditional insider trading gains*. As a result, the insider will never choose to place market orders (assuming that the choice is taken before observing the realization of the inside information).

Alternatively, we can compare G_θ^{LO} and G_θ^{MO} . G_θ^{LO} is greater (lower) than G_θ^{MO} if and only if m^{LO} is lower (greater) than m^{MO} . The insider's marginal cost can be decomposed into the term 2λ , which measures the effect of the insider's marginal demand on the return, and the term $\rho_1 \text{Var}[v - p|I_1]$ related to the residual risk born by the insider. If the precision of θ is low, G_θ^{LO} is greater than G_θ^{MO} , because the information contained in the price provides valuable insurance gains while the risk born in case the insider uses market orders is too high. Mathematically, $\text{Var}[v - p^{MO}|\theta] \gg \text{Var}[v - p^{LO}|\theta, p^{LO}]$ and $m^{LO} < m^{MO}$, so that $G_\theta^{LO} > G_\theta^{MO}$. On the contrary, if the precision of θ is sufficiently high and the volatility of the noise trader's demand is not too high, G_θ^{MO} is greater than G_θ^{LO} . When the insider chooses limit orders, she absorbs part of the trades of liquidity traders. Then, the order flow received by market makers is more likely to contain fundamentals information, so that they are less

willing to trade¹⁷. This tends to increase the price impact of the insider's marginal demand. Since the residual risk born by the insider is (in this case) low whatever the type of order used, the insider's marginal cost would be greater if the insider used limit orders. Mathematically, if r^2 is high and σ_θ^2 is not too high, then $\text{var}[v - p^{MO} | \theta]$ and $\text{var}[v - p^{LO} | \theta, p^{LO}]$ are small and $\lambda^{LO} \gg \lambda^{MO}$, so that $m^{LO} > m^{MO}$ and, as a consequence, $G_\theta^{LO} < G_\theta^{MO}$.

In proposition 5.2, it is shown that the insider's optimal choice is to place limit orders whatever the value of r^2 . From the above discussion, it is obvious that if r^2 is low, the insider will use limit orders because both G_θ and G_p are higher. If r^2 is sufficiently high, the insider maximizes her market making gains by using a limit order while she maximizes her insider trading gains by placing market orders. Proposition 5.2 establishes that the former effect dominates the latter. In the competitive version of the model, limit orders were optimal (for r^2 sufficiently high) because the insider's market making gains went to zero since the market was perfectly liquid due to the excessive responsiveness of the insider to her private information. When the insider acts strategically, she restrains her trades so that market depth is low and market making gains are potentially high.

6. Conclusions

In this paper we have analyzed the optimal choice between market and limit orders taken by a single insider, who enjoys some market power, and the consequences of this choice on the liquidity of the market. Concerning the second issue, we have found that the price precision and the market depth are greater when the insider submits limit orders. The insider reacts more to her private information when she trades through limit orders. As a direct consequence, the price is more informative about the liquidation value. Finally, if the insider places limit orders, her strategy is price sensitive, which directly increases market depth and (more than) offsets the decrease in the outsider's price sensibility.

With respect to the choice between market and limit orders, we have proved that the insider will prefer to use limit orders. Considering only the insider trading gains, her optimal choice would be to place a limit order if private information was not too precise and to submit a market order otherwise. On the other hand, considering only the market making gains, the insider's optimal choice is to place a limit order, since these gains would be equal to zero if she placed market orders.

It is obvious that, if the precision of θ is low, the insider will use limit orders because both her market making gains and her insider trading gains are higher. On the other hand, if

¹⁷ Mathematically, β^{MO} is greater than β^{LO} and, thus, λ^{LO} is greater than λ^{MO} .

the precision of θ is high, the insider maximizes her market making gains by using a limit order while she maximizes her insider trading gains by placing market orders. We have proved that the former effect dominates the latter.

I have studied an order-driven system in which a strategic informed trader chooses her optimal type of order to exploit her information. This trader knows that her choice affects the informativeness of the price and, consequently, the beliefs and trades of other investors. To make the model tractable, some limitations have been introduced: (i) the insider is not permitted to use both market and limit orders, (ii) all orders are executed at the same time in a single centralized auction, (iii) limit orders are modeled as linear demand schedules covering all prices, and (iv) liquidity traders are assumed to demand a fixed exogenous quantity. Further research should remove these limitations. For instance, a straight forward extension would be a multi-period version. In such extension, informed traders could find it advantageous to spread their trades over time in order to minimize the price impact of their private information. Moreover, a multi-period market would allow us to model the (relative) lack of immediacy of limit orders. Another extension would be to model the preferences of the liquidity traders. An important shortcoming of the noisy rational expectations models is the lack of rationale for the behavior of the liquidity traders, since it prevents from making an appropriate welfare analysis.

Appendix

Rao's formula: Let $\tilde{\chi} \approx N(\bar{\chi}, \sigma_{\tilde{\chi}}^2)$. Then, $E[\exp\{-\tilde{\chi}^2\}] = \frac{1}{\sqrt{1+2\sigma_{\tilde{\chi}}^2}} \exp\left\{\frac{-\bar{\chi}^2}{1+2\sigma_{\tilde{\chi}}^2}\right\}$.

Proof of proposition 3.1: Let us assume that $\rho_1 > 0$ and $r^2 \neq 1$.

Consider the general linear strategies $x_1(\tilde{\theta}, p) = \alpha(\tilde{\theta} - p) + \beta_1(\bar{v} - p)$ and $x_2(p) = \beta(\bar{v} - p)$. From the market clearing condition, $x_1(p, \tilde{\theta}) + x_2(p) = \bar{z}$, we get $p = \bar{v} + \frac{\alpha(\tilde{\theta} - \bar{v}) - \bar{z}}{\alpha + \beta_1 + \beta}$. Given this price function, from standard normal theory, we obtain

$$E[\tilde{v} - p | \tilde{\theta}, p] = r^2(\tilde{\theta} - \bar{v}) + \bar{v} - p \quad E[\tilde{v} - p | p] = \left[1 - \frac{\alpha\sigma_v^2(\alpha + \beta_1 + \beta)}{\alpha^2(\sigma_v^2 + \sigma_\eta^2) + \sigma_z^2}\right](\bar{v} - p)$$

$$\text{var}[\tilde{v} - p | \tilde{\theta}, p] = (1 - r^2)\sigma_v^2 \quad \text{var}[\tilde{v} - p | p] = \frac{\sigma_v^2(\alpha^2\sigma_\eta^2 + \sigma_z^2)}{\alpha^2(\sigma_v^2 + \sigma_\eta^2) + \sigma_z^2}.$$

Then, according to [1], the optimal portfolios of agent 1 and 2 are given by

$$x_1(\tilde{\theta}, p) = \frac{r^2(\tilde{\theta} - p) + (1 - r^2)(\bar{v} - p)}{\rho_1 \text{var}[\tilde{v} | \tilde{\theta}]} \quad x_2(p) = \frac{\alpha^2\sigma_\eta^2 + \sigma_z^2 - \alpha\sigma_v^2(\beta_1 + \beta)}{\rho_2\sigma_v^2(\alpha^2\sigma_\eta^2 + \sigma_z^2)}(\bar{v} - p).$$

By equating these functions with the general strategies initially conjectured, we find that there is only one equilibrium characterized by $\alpha = 1/(\rho_1\sigma_\eta^2)$, $\beta_1 = 1/(\rho_1\sigma_\epsilon^2)$ and $\beta = \frac{\alpha^2\sigma_\eta^2 + \sigma_z^2 - \alpha\sigma_v^2(\beta_1 + \beta)}{\rho_2\sigma_v^2(\alpha^2\sigma_\eta^2 + \sigma_z^2)}$. If we substitute the value of α into the last expression, we directly obtain the expression for β shown in the statement of the proposition.

Conditional on agent 1's information set (θ, p) , her expected utility is

$$E_1[U_1(\tilde{w}_1)] = E[-\exp\{-\rho_1\tilde{w}_1\} | I_1] = -\exp\left\{-\rho_1\left(E[\tilde{w}_1 | I_1] - \frac{\rho_1}{2}\text{var}[\tilde{w}_1 | I_1]\right)\right\}$$

where $E[\tilde{w}_1 | I_1] = x_1 E[\tilde{v} - \tilde{p} | I_1]$ and $\text{var}[\tilde{w}_1 | I_1] = x_1^2 \text{var}[\tilde{v} - \tilde{p} | I_1]$. By substituting

$$x_1(\tilde{\theta}, p) = \frac{E[\tilde{v} | \tilde{\theta}, p] - p}{\rho_1 \text{var}[\tilde{v} | \tilde{\theta}]}, \text{ one gets } E_1[U_1(\tilde{W}_1)] = -\exp\left\{-\frac{[E(\tilde{v} | \tilde{\theta}) - p]^2}{2 \text{var}[\tilde{v} | \tilde{\theta}]}\right\}.$$

To obtain agent 1's ex ante (unconditional) expected utility it suffices to apply Rao's formula by taking $\tilde{\chi} = [E(\tilde{v} | \tilde{\theta}) - p] / \sqrt{2 \text{var}[\tilde{v} | \tilde{\theta}]}$. Moreover, from the decomposition $\text{var}[\tilde{v} - p] =$

$\text{var}\left[E(\tilde{v} - p|\tilde{\theta}, p)\right] + E\left\{\text{var}[\tilde{v} - p|\tilde{\theta}, p]\right\}$ where $\text{var}[\tilde{v} - p|\tilde{\theta}, p] = \text{var}[\tilde{v}|\tilde{\theta}]$ is non random, agent I 's ex ante expected utility may be written as $E[U_1(\tilde{W}_1)] = -\sqrt{\frac{\text{var}[\tilde{v}|\tilde{\theta}]}{\text{var}[\tilde{v} - p]}}$.

####

Proof of proposition 3.2: Let us assume that $\rho_1 > 0$.

Consider the general linear strategies $x_1(\tilde{\theta}) = \alpha(\tilde{\theta} - \bar{v})$ and $x_2(p) = \beta(\bar{v} - p)$. From the market clearing condition, $x_1(p, \tilde{\theta}) + x_2(p) = \bar{z}$, we get $p = \bar{v} + \frac{\alpha(\tilde{\theta} - \bar{v}) - \bar{z}}{\beta}$. Given this price function, the return can be written as $\tilde{v} - p = \tilde{v} - \bar{v} - \lambda[\alpha(\tilde{\theta} - \bar{v}) - \bar{z}]$ where $\lambda = 1/\beta$. Then, by applying standard normal theory, we obtain

$$E[\tilde{v} - p|\tilde{\theta}] = (r^2 - \lambda\alpha)(\tilde{\theta} - \bar{v}) \quad \text{var}[\tilde{v} - p|\tilde{\theta}] = (1 - r^2)\sigma_v^2 + \lambda^2\sigma_z^2$$

$$E[\tilde{v} - p|p] = \left[1 - \frac{\alpha\sigma_v^2\beta}{\alpha^2(\sigma_v^2 + \sigma_\eta^2) + \sigma_z^2}\right](\bar{v} - p) \quad \text{var}[\tilde{v} - p|p] = \frac{\sigma_v^2(\alpha^2\sigma_\eta^2 + \sigma_z^2)}{\alpha^2(\sigma_v^2 + \sigma_\eta^2) + \sigma_z^2}.$$

According to [1], the optimal portfolios of agents 1 and 2 are given by

$$x_1(\tilde{\theta}) = \frac{(r^2 - \lambda\alpha)}{\rho_1[(1 - r^2)\sigma_v^2 + \lambda^2\sigma_z^2]}(\tilde{\theta} - \bar{v}) \quad x_2(\tilde{p}) = \frac{\alpha(\alpha - \beta)\sigma_v^2 + \alpha^2\sigma_\eta^2 + \sigma_z^2}{\rho_2\sigma_v^2[\alpha^2\sigma_\eta^2 + \sigma_z^2]}(\bar{v} - \tilde{p}).$$

By equating these functions with the general strategies initially conjectured, and solving for α and β , we get $\alpha = \frac{r^2}{\rho_1[(1 - r^2)\sigma_v^2 + \lambda^2\sigma_z^2] + \lambda}$ and

$$\beta = \frac{\alpha^2\sigma_v^2 + r^2\sigma_z^2}{\sigma_v^2\{\rho_2[\alpha^2(1 - r^2)\sigma_v^2 + r^2\sigma_z^2] + \alpha r^2\}}.$$

Substituting the value of α into the last expression yields $\lambda = \frac{1}{\beta} = \rho_2\sigma_v^2 + \frac{r^2\sigma_v^2[(\rho_1 + \rho_2)(1 - r^2)\sigma_v^2 + \rho_1\lambda^2\sigma_z^2]}{\sigma_z^2[\rho_1(1 - r^2)\sigma_v^2 + \rho_1\lambda^2\sigma_z^2 + \lambda]}$. There is one equilibrium for

each fixed point of $f(\lambda) = \rho_2\sigma_v^2 + \frac{r^2\sigma_v^2[(\rho_1 + \rho_2)(1 - r^2)\sigma_v^2 + \rho_1\lambda^2\sigma_z^2]}{\sigma_z^2[\rho_1(1 - r^2)\sigma_v^2 + \rho_1\lambda^2\sigma_z^2 + \lambda]}$, which is strictly

greater than zero and decreasing for every λ . Thus, there is only one equilibrium.

The rest of the proof is similar to the proof of proposition 3.1. Given

$$x_1(\tilde{\theta}) = \frac{E[\tilde{v} - \rho l \tilde{\theta}]}{\rho_1 \text{var}[\tilde{v} - \rho l \tilde{\theta}]}, \text{ agent } l\text{'s expected utility conditional on her information set } (\theta) \text{ is}$$

$$\text{given by } E_l[U_1(\tilde{W}_l)] = -\exp\left\{-\frac{[E(\tilde{v} - \rho l \tilde{\theta})]^2}{2 \text{var}[\tilde{v} - \rho l \tilde{\theta}]}\right\}. \text{ To obtain agent } l\text{'s ex ante (unconditional)}$$

expected utility it suffices to apply Rao's formula with $\tilde{\chi} = E(\tilde{v} - \rho l \tilde{\theta}) / \sqrt{2 \text{var}[\tilde{v} - \rho l \tilde{\theta}]}$.

Moreover, from the decomposition $\text{var}[\tilde{v} - \rho] = \text{var}[E(\tilde{v} - \rho l \tilde{\theta})] + E\{\text{var}[\tilde{v} - \rho l \tilde{\theta}]\}$, agent

l 's ex ante expected utility may be written as $E[U_1(\tilde{W}_l)] = -\sqrt{\text{var}[\tilde{v} - \rho l \tilde{\theta}] / \text{var}[\tilde{v} - \rho]}$.

####

Proof of proposition 3.3: (i) From propositions 3.1 and 3.2, $\alpha^{LO} = \frac{1}{\rho_1 \sigma_\eta^2}$ and

$$\alpha^{MO} = \left[\rho_1 \sigma_\eta^2 + \frac{(\sigma_v^2 + \sigma_\eta^2)(\beta + \rho_1 \sigma_z^2)}{\beta^2 \sigma_v^2} \right]^{-1}; \text{ so that it is obvious that } \alpha^{LO} > \alpha^{MO}.$$

(ii) Agent 2's trading intensities may be written as the following functions of α

$$\beta^{LO} = \frac{\sigma_z^2}{\sigma_v^2 [\alpha^{LO} + \rho_2 ((\alpha^{LO})^2 \sigma_\eta^2 + \sigma_z^2)]} \text{ and } \beta^{MO} = \frac{\sigma_z^2 + (\alpha^{MO})^2 (\sigma_v^2 + \sigma_\eta^2)}{\sigma_v^2 [\alpha^{MO} + \rho_2 ((\alpha^{MO})^2 \sigma_\eta^2 + \sigma_z^2)]}.$$

And from the result (i) we get $\beta^{LO} < \frac{\sigma_z^2}{\sigma_v^2 [\alpha^{MO} + \rho_2 ((\alpha^{MO})^2 \sigma_\eta^2 + \sigma_z^2)]} < \beta^{MO}$.

(iii) From $\tau = \frac{1}{\sigma_v^2} + \frac{\alpha^2}{\alpha^2 \sigma_\eta^2 + \sigma_z^2}$ and (i), the result $\tau^{LO} > \tau^{MO}$ is directly derived.

(iv) and (v): If r^2 equals 0 and agent l places limit orders, the rational expectations equilibrium is characterized by (see proposition 3.1) $x_1^{LO}(p) = \frac{(\bar{v} - p)}{\rho_1 \sigma_v^2}$, $x_2^{LO}(p) = \frac{(\bar{v} - p)}{\rho_2 \sigma_v^2}$,

$$p^{LO} = \bar{v} - \left(\frac{1}{\rho_1} + \frac{1}{\rho_2} \right)^{-1} \sigma_v^2 z, \quad \Lambda^{LO} = \left(\frac{1}{\rho_1} + \frac{1}{\rho_2} \right) \frac{1}{\sigma_v^2}, \quad \tau^{LO} = 1 / \sigma_v^2, \quad \text{Var}(p^{LO}) = \frac{\rho_1^2 \rho_2^2 \sigma_v^4 \sigma_z^2}{(\rho_1 + \rho_2)^2},$$

$\text{Var}(v - p^{LO}) = \sigma_v^2 + \frac{\rho_1^2 \rho_2^2 \sigma_v^4 \sigma_z^2}{(\rho_1 + \rho_2)^2}$, and $E[U_1^{LO}(W_1)] = -\left[1 + \frac{\rho_1^2 \rho_2^2 \sigma_z^2 \sigma_v^2}{(\rho_1 + \rho_2)^2} \right]^{-1} > -1$. On the other

hand, if r^2 equals 0 and agent l places market orders, the rational expectations equilibrium is

given by (see proposition 3.2) $x_1^{MO} = 0$, $x_2^{MO}(p) = \frac{(\bar{v} - p)}{\rho_2 \sigma_v^2}$, $p^{MO} = \bar{v} - \rho_2 \sigma_v^2 z$,

$$\Lambda^{MO} = \frac{1}{\rho_2 \sigma_v^2}, \quad \tau^{MO} = 1 / \sigma_v^2, \quad \text{Var}(p^{MO}) = \rho_2^2 \sigma_v^4 \sigma_z^2, \quad \text{Var}(v - p^{MO}) = \sigma_v^2 + \rho_2^2 \sigma_v^4 \sigma_z^2,$$

$E[U_1^{MO}(W_1)] = -1$. Consequently, $\Lambda^{LO} > \Lambda^{MO}$, $\text{Var}(p^{LO}) < \text{Var}(p^{MO})$,

$\text{Var}(v - p^{LO}) < \text{Var}(v - p^{MO})$ and $E[U_1^{LO}(W_1)] > E[U_1^{MO}(W_1)]$. By continuity these results are true for r^2 small.

If r^2 tends to 1, then α^{LO} and Λ^{LO} tend to infinity, β^{LO} and $\text{Var}(v - p^{LO})$ tend to 0 and $E[U_1^{LO}(W_1)]$ tends to -1. On the other hand, α^{MO} and β^{MO} are strictly greater than zero and finite, and the same is true for Λ^{MO} and $\text{Var}(v - p^{MO})$. Furthermore, $\text{Var}(v - p|\theta)$ and agent I 's ex ante expected utility tend to $\sigma_z^2 / (\beta^{MO})^2$ and

$$-\sqrt{\frac{\sigma_z^2}{(\beta^{MO} - \alpha^{MO})^2 \sigma_v^2 + \alpha^{MO} \sigma_z^2 + \sigma_z^2}} > -1 \text{ respectively. Thus, if } r^2 \rightarrow 1,$$

$\text{Var}(v - p^{MO}) > \text{Var}(v - p^{LO})$, $\Lambda^{LO} > \Lambda^{MO}$, $\text{Var}(v - p^{MO}|\theta) > \text{Var}(v - p^{LO}|\theta, p^{LO}) \rightarrow 0$ and $E[U_1^{LO}] < E[U_1^{MO}]$. By continuity these results are true for r^2 large (sufficiently close to 1).

####

Proof of proposition 4.1: Consider the general linear strategies

$x_1(\tilde{\theta}, p) = \alpha(\tilde{\theta} - p) + \beta_1(\bar{v} - p)$ and $x_2(p) = \beta(\bar{v} - p)$. From the market clearing condition,

$x_1(p, \tilde{\theta}) + x_2(p) = \tilde{z}$, the market clearing price is given by $p = \bar{v} + \frac{\alpha(\tilde{\theta} - \bar{v}) - \tilde{z}}{\alpha + \beta_1 + \beta}$ and the

insider's residual supply is given by $p = \bar{v} + \lambda(x_1 - \tilde{z})$ where $\lambda = 1/\beta$. And given these functions, by applying standard normal theory we obtain

$$E[\tilde{v}|\tilde{\theta}] = r^2(\tilde{\theta} - \bar{v}) + \bar{v} \quad E[\tilde{v} - p|p] = \left[1 - \frac{\alpha \sigma_v^2 (\alpha + \beta_1 + \beta)}{\alpha^2 (\sigma_v^2 + \sigma_\eta^2) + \sigma_z^2} \right] (\bar{v} - p)$$

$$\text{var}[\tilde{v}|\tilde{\theta}] = (1 - r^2) \sigma_v^2 \quad \text{var}[\tilde{v} - p|p] = \frac{\sigma_v^2 (\alpha^2 \sigma_\eta^2 + \sigma_z^2)}{\alpha^2 (\sigma_v^2 + \sigma_\eta^2) + \sigma_z^2}.$$

Then, according to [1] and [2], the optimal strategies of agents 1 and 2 are given by

$$x_1(p, \tilde{\theta}) = \frac{r^2(\tilde{\theta} - p) + (1 - r^2)(\bar{v} - p)}{\rho_1 \text{var}[\tilde{v}|\tilde{\theta}] + \lambda} \quad x_2(p) = \frac{\alpha^2 \sigma_\eta^2 + \sigma_z^2 - \alpha \sigma_v^2 (\beta_1 + \beta)}{\rho_2 \sigma_v^2 (\alpha^2 \sigma_\eta^2 + \sigma_z^2)} (\bar{v} - p).$$

By equating these functions with the general strategies initially conjectured, we find that $\alpha = r^2 / (\rho_1 \text{var}[\tilde{v}|\tilde{\theta}] + \lambda)$, $\beta_1 = (1 - r^2) \alpha / r^2$ and, after substituting α and simplifying,

$\beta = \sigma_z^2 / \left\{ \sigma_v^2 \left[\rho_2 (\alpha^2 \sigma_n^2 + \sigma_z^2) + \alpha \right] \right\}$. Substituting again the value of α into the last expression and taking into account that $\lambda = 1/\beta$ lead to the equation

$$\lambda = \rho_2 \sigma_v^2 + \frac{(\sigma_v^2 - \text{var}[\tilde{v}|\tilde{\theta}]) \left((\rho_1 + \rho_2) \text{var}[\tilde{v}|\tilde{\theta}] + \lambda \right)}{\sigma_z^2 \left(\rho_1 \text{var}[\tilde{v}|\tilde{\theta}] + \lambda \right)^2}.$$

That is, there is one equilibrium for each fixed point of the function

$$f(\lambda) = \rho_2 \sigma_v^2 + \frac{(\sigma_v^2 - \text{var}[\tilde{v}|\tilde{\theta}]) \left((\rho_1 + \rho_2) \text{var}[\tilde{v}|\tilde{\theta}] + \lambda \right)}{\sigma_z^2 \left(\rho_1 \text{var}[\tilde{v}|\tilde{\theta}] + \lambda \right)^2}$$
 that satisfies the second order

condition $(\rho_1 \text{var}[\tilde{v}|\tilde{\theta}] + 2\lambda) > 0$. It is easy to show that there is no equilibrium for λ lower than zero. A necessary condition for $f(\lambda)$ lower than zero is $\lambda < -(\rho_1 + \rho_2) \text{var}[\tilde{v}|\tilde{\theta}]$. But then the second order condition is not satisfied, since $2\lambda + \rho_1 \text{var}[\tilde{v}|\tilde{\theta}] <$

$$(-\rho_1 - 2\rho_2) \text{var}[\tilde{v}|\tilde{\theta}] < 0. \text{ On the other hand, } \forall \lambda > 0, f(\lambda) \in \left[\rho_2 \sigma_v^2, \rho_2 \sigma_v^2 + \frac{(\rho_1 + \rho_2) r^2}{\rho_1^2 (1 - r^2) \sigma_z^2} \right]$$

and $f(\lambda)$ is strictly decreasing. Thus, there is only one strictly positive fixed point, which obviously satisfies $(\rho_1 \text{var}[\tilde{v}|\tilde{\theta}] + 2\lambda) > 0$. This fixed point characterizes the unique rational expectations equilibrium.

Conditional on I_1 , agent I 's expected utility is

$$E_1[U_1(\tilde{w}_1)] = -\exp \left\{ -\rho_1 \left(E[\tilde{w}_1|I_1] - \frac{\rho_1}{2} \text{var}[\tilde{w}_1|I_1] \right) \right\} \text{ where } E[\tilde{w}_1|I_1] = x_1 E[\tilde{v} - \tilde{p}|I_1] \text{ and}$$

$$\text{var}[\tilde{w}_1|I_1] = x_1^2 \text{var}[\tilde{v} - \tilde{p}|I_1]. \text{ Substituting } x_1(\tilde{\theta}, p) = \frac{E[\tilde{v}|\tilde{\theta}] - p}{\rho_1 \text{var}[\tilde{v}|\tilde{\theta}] + \lambda} \text{ into the above}$$

$$\text{expression yields } E[U_1(\tilde{W}_1)|p, \tilde{\theta}] = -\exp \left\{ -\rho_1 \left(\frac{\rho_1}{2} \text{var}[\tilde{v}|\tilde{\theta}] + \lambda \right) \left(\frac{E[\tilde{v}|\tilde{\theta}] - p}{\rho_1 \text{var}[\tilde{v}|\tilde{\theta}] + \lambda} \right)^2 \right\} \text{ or,}$$

$$\text{equivalently, } E[U_1(\tilde{W}_1)|\tilde{z}, \tilde{\theta}] = -\exp \left\{ -\frac{\rho_1}{2m} \left[r^2 (\tilde{\theta} - \bar{v}) + \lambda z \right]^2 \right\}, \text{ where } m = \rho_1 \text{var}[\tilde{v}|\tilde{\theta}] + 2\lambda.$$

$$\text{Taking } \tilde{\chi} = \sqrt{\rho_1 \left(\frac{\rho_1}{2} \text{var}[\tilde{v}|\tilde{\theta}] + \lambda \right)} \left(\frac{E[\tilde{v}|\tilde{\theta}] - p}{\rho_1 \text{var}[\tilde{v}|\tilde{\theta}] + \lambda} \right) = \left(\frac{\rho_1}{2m} \right)^{1/2} \left[r^2 (\tilde{\theta} - \bar{v}) + \lambda z \right] \text{ and}$$

applying the Rao's formula, agent I 's ex ante expected utility is given by

$$E[U_1(\tilde{W}_1)] = - \left\{ 1 + C \frac{\text{var} \left[E[\tilde{v}|\tilde{\theta}] - p \right]}{\text{var}[\tilde{v}|\tilde{\theta}]} \right\}^{-1/2} = - \left\{ 1 + \frac{\rho_1 (r^2 \sigma_v^2 + \lambda^2 \sigma_z^2)}{m} \right\}^{-1/2}$$

where $C = \frac{\rho_1 \text{var}[\tilde{v}|\tilde{\theta}](\rho_1 \text{var}[\tilde{v}|\tilde{\theta}] + 2\lambda)}{(\rho_1 \text{var}[\tilde{v}|\tilde{\theta}] + \lambda)^2} = 1 - \frac{\lambda^2}{(\rho_1 \text{var}[\tilde{v}|\tilde{\theta}] + \lambda)^2}$ ($0 < C < 1$).

####

Proof of proposition 4.2: This is similar to the proof of proposition 4.1. We only have to substitute $E[\tilde{v}|\tilde{\theta}] - p$ for $E[\tilde{v} - p|\tilde{\theta}]$ and $\rho_1 \text{var}[\tilde{v}|\tilde{\theta}] + \lambda$ for $\rho_1 \text{var}[\tilde{v} - p|\tilde{\theta}] + \lambda$.

For example, the equation which characterizes the equilibrium values of λ will be

$$\lambda = \rho_2 \sigma_v^2 + \frac{(\sigma_v^2 - \text{var}[\tilde{v}|\tilde{\theta}]) \left((\rho_1 + \rho_2) \text{var}[\tilde{v}|\tilde{\theta}] + \lambda + \rho_1 \lambda^2 \sigma_z^2 \right)}{\sigma_z^2 \left(\rho_1 \text{var}[\tilde{v}|\tilde{\theta}] + 2\lambda + \rho_1 \lambda^2 \sigma_z^2 \right)^2}$$

which has one unique positive solution satisfying $(\rho_1 \text{var}[\tilde{v} - p|\tilde{\theta}] + 2\lambda) > 0$.

In a similar way, agent I 's expected utility conditional on her information set (θ) is

$$E[U_1(\tilde{W}_1)|\tilde{\theta}] = -\exp \left\{ -\rho_1 \left(\frac{\rho_1}{2} \text{var}[\tilde{v} - p|\tilde{\theta}] + \lambda \right) \left(\frac{E[\tilde{v} - p|\tilde{\theta}]}{\rho_1 \text{var}[\tilde{v} - p|\tilde{\theta}] + \lambda} \right)^2 \right\}, \text{ and applying}$$

Rao's formula, we get the desired expressions for agent I 's ex ante expected utility.

####

Proof of proposition 5.1.: (i) λ^{LO} is a fixed point of

$$f(\lambda) = \rho_2 \sigma_v^2 + \frac{r^2 \sigma_v^2 \left((\rho_1 + \rho_2)(1-r^2)\sigma_v^2 + \lambda \right)}{\sigma_z^2 \left(\rho_1(1-r^2)\sigma_v^2 + \lambda \right)^2} \text{ and } \lambda^{MO} \text{ is implicitly defined by}$$

$$\lambda^{MO} = \rho_2 \sigma_v^2 + \frac{r^2 \sigma_v^2 \left((\rho_1 + \rho_2)(1-r^2)\sigma_v^2 + \lambda^{MO} + \rho_1 (\lambda^{MO})^2 \sigma_z^2 \right)}{\sigma_z^2 \left(\rho_1(1-r^2)\sigma_v^2 + 2\lambda^{MO} + \rho_1 (\lambda^{MO})^2 \sigma_z^2 \right)^2}. \text{ Since } f(\lambda) \text{ is strictly}$$

decreasing, we know that $\lambda' - f(\lambda') > (<=) 0 \Leftrightarrow \lambda' > (<=) \lambda^{LO}$. Thus, it suffices to

demonstrate that $\lambda^{MO} - f(\lambda^{MO}) < 0$. Using the implicit definition of λ^{MO} , we get

$$\begin{aligned} \lambda^{MO} - f(\lambda^{MO}) &= \frac{r^2 \sigma_v^2}{\sigma_z^2} \left\{ \frac{\left((\rho_1 + \rho_2)(1-r^2)\sigma_v^2 + \lambda^{MO} + \rho_1 (\lambda^{MO})^2 \sigma_z^2 \right)}{\left(\rho_1(1-r^2)\sigma_v^2 + 2\lambda^{MO} + \rho_1 (\lambda^{MO})^2 \sigma_z^2 \right)^2} \right\} - \frac{\left((\rho_1 + \rho_2)(1-r^2)\sigma_v^2 + \lambda^{MO} \right)}{\left(\rho_1(1-r^2)\sigma_v^2 + \lambda^{MO} \right)^2} = \\ &= \frac{r^2 \sigma_v^2}{\sigma_z^2} \left[\rho_1(1-r^2)\sigma_v^2 + 2\lambda^{MO} + \rho_1 (\lambda^{MO})^2 \sigma_z^2 \right]^{-2} \left[\rho_1(1-r^2)\sigma_v^2 + \lambda^{MO} \right]^2 - \\ &\quad \left\{ \left[(\rho_1 + \rho_2)(1-r^2)\sigma_v^2 + \lambda^{MO} + \rho_1 (\lambda^{MO})^2 \sigma_z^2 \right] \left[\rho_1(1-r^2)\sigma_v^2 + \lambda^{MO} \right]^2 - \right. \\ &\quad \left. - \left[(\rho_1 + \rho_2)(1-r^2)\sigma_v^2 + \lambda^{MO} \right] \left[\rho_1(1-r^2)\sigma_v^2 + 2\lambda^{MO} + \rho_1 (\lambda^{MO})^2 \sigma_z^2 \right]^2 \right\} \end{aligned}$$

Therefore, $\lambda' - f(\lambda') < 0$ if and only if the expression in the brackets is negative. But this can be decomposed as

$$\begin{aligned}
\{ \} &= \left[\rho_1(1-r^2)\sigma_v^2 + \lambda^{MO} + \rho_1(\lambda^{MO})^2 \sigma_z^2 \right] \left[\rho_1(1-r^2)\sigma_v^2 + \lambda^{MO} \right]^2 \\
&\quad - \rho_2(1-r^2)\sigma_v^2 \left[\rho_1(1-r^2)\sigma_v^2 + \lambda^{MO} \right]^2 - \\
&\quad - \left[\rho_1(1-r^2)\sigma_v^2 + \lambda^{MO} \right] \left[\rho_1(1-r^2)\sigma_v^2 + \lambda^{MO} + \rho_1(\lambda^{MO})^2 \sigma_z^2 \right] \left[\rho_1(1-r^2)\sigma_v^2 + 2\lambda^{MO} + \rho_1(\lambda^{MO})^2 \sigma_z^2 \right] - \\
&\quad - \rho_2(1-r^2)\sigma_v^2 \left[\rho_1(1-r^2)\sigma_v^2 + 2\lambda^{MO} + \rho_1(\lambda^{MO})^2 \sigma_z^2 \right]^2 - \\
&\quad - \left[(\rho_1 + \rho_2)(1-r^2)\sigma_v^2 + \lambda^{MO} \right] \left[\rho_1(1-r^2)\sigma_v^2 + 2\lambda^{MO} + \rho_1(\lambda^{MO})^2 \sigma_z^2 \right] \lambda^{MO} = \\
&\quad = - \left[\rho_1(1-r^2)\sigma_v^2 + 2\lambda^{MO} + \rho_1(\lambda^{MO})^2 \sigma_z^2 \right] \left[\rho_1(1-r^2)\sigma_v^2 + \lambda^{MO} \right] \left[\lambda^{MO} + \rho_1(\lambda^{MO})^2 \sigma_z^2 \right] \\
&\quad - \rho_2(1-r^2)\sigma_v^2 \left\{ 3(\lambda^{MO})^2 + 2\rho_1(1-r^2)\sigma_v^2 \lambda^{MO} + \rho_1(\lambda^{MO})^2 \sigma_z^2 \left[\rho_1(1-r^2)\sigma_v^2 + 2\lambda^{MO} + \rho_1(\lambda^{MO})^2 \sigma_z^2 \right] \right\} - \\
&\quad - \lambda^{MO} \left[(\rho_1 + \rho_2)(1-r^2)\sigma_v^2 + \lambda^{MO} \right] \left[\rho_1(1-r^2)\sigma_v^2 + 2\lambda^{MO} + \rho_1(\lambda^{MO})^2 \sigma_z^2 \right] < 0.
\end{aligned}$$

$\lambda = 1/\beta$ so that $\lambda^{LO} > \lambda^{MO}$ directly implies that $\beta^{LO} < \beta^{MO}$.

$$\begin{aligned}
\text{(ii) } \alpha^{LO} > \alpha^{MO} &\Leftrightarrow \rho_1 \text{ var}(v|\theta) + 2\lambda^{MO} + \rho_1(\lambda^{MO})^2 \sigma_z^2 > \rho_1 \text{ var}(v|\theta) + \lambda^{MO} \\
&\Leftrightarrow \lambda^{LO} < 2\lambda^{MO} + \rho_1(\lambda^{MO})^2 \sigma_z^2. \text{ Thus, as in part (i), it suffices to demonstrate that} \\
&\quad \left[2\lambda^{MO} + \rho_1(\lambda^{MO})^2 \sigma_z^2 \right] - f \left[2\lambda^{MO} + \rho_1(\lambda^{MO})^2 \sigma_z^2 \right] > 0.
\end{aligned}$$

The right-hand side of this inequality is equal to

$$\begin{aligned}
&2\lambda^{MO} + \rho_1(\lambda^{MO})^2 \sigma_z^2 - \rho_2 \sigma_v^2 - \frac{r^2 \sigma_v^2 \left[(\rho_1 + \rho_2)(1-r^2)\sigma_v^2 + 2\lambda^{MO} + \rho_1(\lambda^{MO})^2 \sigma_z^2 \right]}{\sigma_z^2 \left[\rho_1(1-r^2)\sigma_v^2 + 2\lambda^{MO} + \rho_1(\lambda^{MO})^2 \sigma_z^2 \right]^2} = \\
&= \rho_1(\lambda^{MO})^2 \sigma_z^2 + 2\rho_2 \sigma_v^2 + 2 \frac{r^2 \sigma_v^2 \left[(\rho_1 + \rho_2)(1-r^2)\sigma_v^2 + \lambda^{MO} + \rho_1(\lambda^{MO})^2 \sigma_z^2 \right]}{\sigma_z^2 \left[\rho_1(1-r^2)\sigma_v^2 + \lambda^{MO} + \rho_1(\lambda^{MO})^2 \sigma_z^2 \right]^2} - \rho_2 \sigma_v^2 - \frac{r^2 \sigma_v^2}{\sigma_z^2} \\
&\quad \frac{\left[(\rho_1 + \rho_2)(1-r^2)\sigma_v^2 + \lambda^{MO} + \rho_1(\lambda^{MO})^2 \sigma_z^2 \right]}{\left[\rho_1(1-r^2)\sigma_v^2 + \lambda^{MO} + \rho_1(\lambda^{MO})^2 \sigma_z^2 \right]^2} - \frac{r^2 \sigma_v^2}{\sigma_z^2} \frac{\lambda^{MO}}{\left[\rho_1(1-r^2)\sigma_v^2 + \lambda^{MO} + \rho_1(\lambda^{MO})^2 \sigma_z^2 \right]^2} = \\
&= \rho_1(\lambda^{MO})^2 \sigma_z^2 + \rho_2 \sigma_v^2 + \frac{r^2 \sigma_v^2 \left[(\rho_1 + \rho_2)(1-r^2)\sigma_v^2 + \rho_1(\lambda^{MO})^2 \sigma_z^2 \right]}{\sigma_z^2 \left[\rho_1(1-r^2)\sigma_v^2 + 2\lambda^{MO} + \rho_1(\lambda^{MO})^2 \sigma_z^2 \right]^2} > 0.
\end{aligned}$$

(iii) The variance of \tilde{v} conditional on the price can be written as (whatever the type of order used by the insider) $Var(\tilde{v}|p) = \sigma_v^2 \frac{[\alpha^2(1-r^2)\sigma_v^2 + r^2\sigma_\varepsilon^2]}{\alpha^2\sigma_v^2 + r^2\sigma_\varepsilon^2}$, so that, given r^2 ,

$$\frac{\partial var(\tilde{v}|p)}{\partial \alpha^2} = \frac{-\sigma_v^2\sigma_v^2r^2\sigma_\varepsilon^2r^2}{[\alpha^2\sigma_v^2 + r^2\sigma_\varepsilon^2]} < 0. \text{ Now, from this result and } \alpha^{LO} > \alpha^{MO}, \text{ we get } \tau^{LO} > \tau^{MO}.$$

(iv) By definition, $q^{LO} = \frac{Var(\tilde{v}|p^{LO})}{Var(\tilde{v}|\theta)}$ and $q^{MO} = \frac{Var(\tilde{v}|p^{MO})}{Var(\tilde{v}-p^{MO}|\theta)}$. Then

$q^{LO}/q^{MO} = (\tau^{MO}/\tau^{LO})[1 + \lambda^2\sigma_\varepsilon^2/Var(\tilde{v}|\theta)]$. If r^2 tends to 1, then $var[\tilde{v}|\tilde{\theta}]$ tends to zero ($q^{LO} \rightarrow \infty$) and q^{MO} is finite. On the other hand, if r^2 tends to 0, then $\tau^{LO} - \tau^{MO}$ tends to τ_v and $q^{LO}/q^{MO} = 1 + \lambda^2\sigma_\varepsilon^2/\sigma_v^2 > 1$.

(v) From propositions 4.1 and 4.2, if $\rho_1=0$, it is obvious that $\Lambda^{LO} = 2/\lambda^{LO}$ and $\Lambda^{MO} = 1/\lambda^{MO}$. If $\rho_1=0$, λ^{LO} is a fixed point of $f(\lambda) = \rho_2\sigma_v^2 + \frac{r^2\sigma_v^2}{\lambda^2\sigma_\varepsilon^2}[\rho_2(1-r^2)\sigma_v^2 + \lambda]$.

Since $f(\lambda)$ is strictly decreasing, we know that $\lambda' - f(\lambda') > (<=)0 \Leftrightarrow \lambda' > (<=)\lambda^{LO}$.

Using the implicit definition of λ^{MO} , $\lambda^{MO} = \rho_2\sigma_v^2 + \frac{r^2\sigma_v^2}{4(\lambda^{MO})^2\sigma_\varepsilon^2}[\rho_2(1-r^2)\sigma_v^2 + \lambda^{MO}]$, we

directly obtain that $2\lambda^{MO} \geq f(2\lambda^{MO})$ and, as a consequence, $2\lambda^{MO} \geq \lambda^{LO}$. Moreover, we have previously proved that $\lambda^{LO} > \lambda^{MO}$, so that $1 \leq (\lambda^{LO}/\lambda^{MO}) \leq 2$. From this result and the equilibrium conditions $\Lambda^{LO} = 2/\lambda^{LO}$ and $\Lambda^{MO} = 1/\lambda^{MO}$, it is clear that $1 \leq (\Lambda^{LO}/\Lambda^{MO}) \leq 2$.

####

Proof of proposition 5.2.: We have shown [see the proof of the proposition 5.1.] that $\alpha^{LO} > \alpha^{MO} \Rightarrow \lambda^{LO} < 2\lambda^{MO} + \rho_1(\lambda^{MO})^2\sigma_\varepsilon^2$. Multiplying by 2 and adding $2\rho_1(1-r^2)\sigma_v^2$ lead to

$$m^{LO} \leq 2\left[2\lambda^{MO} + \rho_1(\lambda^{MO})^2\sigma_\varepsilon^2\right] + 2\rho_1(1-r^2)\sigma_v^2 = 2m^{MO}. \quad (*)$$

From the equilibrium condition which implicitly defines λ^{LO} , it is obvious that λ^{LO} is strictly increasing in ρ_2 . Moreover, from that condition it follows that $(\lambda^{LO})^2 \geq \frac{r^2\sigma_v^2}{\sigma_\varepsilon^2}$ if $\rho_2 =$

0, where the inequality holds if and only if $\rho_1 = 0$ or $r^2 = 1$. If $\rho_2 > 0$, then

$$(\lambda^{LO})^2 \geq \left(\lambda_{(\rho_2=0)}^{LO}\right)^2 \geq \frac{r^2\sigma_\varepsilon^2}{\sigma_\varepsilon^2} \text{ (since } \lambda^{LO} \text{ is strictly increasing in } \rho_2\text{) or equivalently}$$

$(\lambda^{LO})^2\sigma_\varepsilon^2/(r^2\sigma_v^2) \geq 1$, which directly implies that

$$\left[1 + (\lambda^{LO})^2\sigma_\varepsilon^2/(r^2\sigma_v^2)\right] > 2. \quad (**)$$

It is obvious that $E[U_i^{LO}] > E[U_i^{MO}] \Leftrightarrow \left[\frac{r^2 \sigma_v^2 + (\lambda^{LO})^2 \sigma_z^2}{r^2 \sigma_v^2} \right] \left[\frac{m^{MO}}{m^{LO}} \right] > 1$. From (*) and

(**) it is clear that $\left[\frac{r^2 \sigma_v^2 + (\lambda^{LO})^2 \sigma_z^2}{r^2 \sigma_v^2} \right] \left[\frac{m^{MO}}{m^{LO}} \right] > 2 \left[\frac{m^{MO}}{m^{LO}} \right] \geq 2 \frac{1}{2} = 1 \Rightarrow E(U_i^{LO}) > E(U_i^{MO})$

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