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Transmission and Production of Information in Imperfectly Competitive Financial Markets

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This paper studies the problem of information sharing among insiders in a financial market with traders who are not price takers, but act strategically. The different types of associations are ranked from the viewpoint of insiders' profits. As a byproduct, I also consider the decision problem faced by a monopolistic producer of information who is able to control the quality of the information he sells.

I. Introduction

This paper studies the problems of information transmission and information acquisition in financial markets. I will follow in my analysis the paradigm pioneered by Kyle (1985) and Glosten and Milgrom (1985). These authors depart from previous models with perfect competition by assuming that each trader in the market has a nonnegligible effect on prices, and takes this effect into account when choosing his optimal demand for risky assets.

Monopolistic markets for information have been studied by Admati and Pfleiderer (1986) and Allen (1990) for perfectly competitive financial markets in the tradition of Grossman and Stiglitz (1980) and Hellwig (1980). Admati and Pfleiderer (1988b) consider a financial market with strategic agents in which the precision of the information sold is given. In contrast, I will make the quality of private information endogenous in Section III. This means that I will analyze the performance of a monopolistic information market in which a single insider is able to control the precision of the information he sells. It is shown that the induced change in the incentives to produce private information when additional public information is released depends on the average cost of producing such private information. Only when it is sufficiently cheap to produce information does the insider have incentives to produce more private information to keep his informational advantage with respect to the market maker.

The previous results are readily applicable to the problem of information transmission. The issue of information sharing has been analyzed in the context of oligopolistic competition by Gal-Or (1985) and Shapiro (1986), among others. The

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basic question posed by these authors is whether or not competitors are better off if they share their private information. I translate this question to an imperfectly competitive financial market.

Two kinds of associations of investors are considered: associations in which the members precommit ex ante to share their private information, and associations which submit collective demands on behalf of their members (mutual funds). I will show that the latter type of syndicate is the best arrangement possible for the insiders since they can extract the monopolist's expected profits there. In contrast, the former type is even worse than pure competition without information sharing because the correlation among strategies, induced by the common information, reduces the comparative advantage of insiders with respect to market makers.

The paper is organized as follows. Section II presents the model and derives some of its properties. The results of Section II are used to analyze a monopolistic market for information (Section III), and the comparison of associations of investors (Section IV). Section V concludes the paper.

II. The Model

Let us consider a financial market with a single asset whose random payoff $\tilde{v}$ is normally distributed with mean $\bar{v}$ and precision (the inverse of the variance) equal to $\tau_v > 0$.

I assume that there is a random demand $\tilde{z}$ of risky asset which is normally distributed with variance $\sigma_z^2 > 0$ and, without loss of generality, with zero mean. This random demand can be interpreted as the total net demand for shares by noise traders. These traders either buy or sell quantities of risky asset motivated by liquidity constraints which are not related to the payoff of the financial asset.

There are basically two kinds of active traders in the market: informed traders and market makers. All agents are assumed to be risk neutral. The N informed traders, indexed by n, trade on the basis of their information about the future payoff of the risky asset. They know the parameters of the distribution of the random demand $\tilde{z}$ for shares, but they ignore the exact realization of that random variable. Each informed trader owns a piece of private information which takes the form of a signal $\tilde{s}_n$ where $\tilde{s}_n = \tilde{v} + \tilde{\epsilon}_n$. The noise $\tilde{\epsilon}_n$ of the signal is also normally distributed with zero mean and finite precision $\tau_\epsilon > 0$ for all n.

I will consider two polar cases. In one case, private information will be diverse, and this will mean that the random variables $\tilde{\epsilon}_1, \tilde{\epsilon}_2, \ldots,$ and $\tilde{\epsilon}_N$ are mutually independent. In the other polar case, private information is common, and this means that $\tilde{\epsilon}_1, \tilde{\epsilon}_2, \ldots,$ and $\tilde{\epsilon}_N$ are perfectly correlated or, equivalently, that $\tilde{s}_n = \tilde{s} = \tilde{v} + \tilde{\epsilon}$ for all n, where $\epsilon \sim N(0, 1/\tau_\epsilon)$. The random variables $\tilde{v}$, $\tilde{z}$, $\tilde{\epsilon}_1, \ldots, \tilde{\epsilon}_N$ are mutually independent for the diverse information case. When private information is common, the random variables $\tilde{v}$, $\tilde{z}$, and $\tilde{\epsilon}$ are mutually independent. The optimal demand of the informed trader n is denoted as $\tilde{x}_n = x_n(\tilde{s}_n)$ where $x_n(\cdot)$ is assumed to be a measurable function of $\tilde{s}_n$.

Trading is conducted in two periods. In period 1, each trader submits a market order to the risk neutral market making sector. Market makers establish a price p for the risky asset after observing the total net quantity demanded by the traders. It is important to note that market makers observe only the aggregate demand. Thus, they cannot know if an order comes from an informed trader or from the random demand. Neither market makers nor informed agents have short-selling constraints. The parameters of the distributions of the random variables $\tilde{v}$, $\tilde{z}$, and $\tilde{\epsilon}_n$ are common knowledge for all agents.

I assume competition among market makers. This competition among price setters forces them to select a price such that they earn zero expected profits, as in the Bertrand model of oligopolistic competition. Thus, the market making sector must sell $\tilde{w}$ shares, where $\tilde{w}$ is the net total order flow:

$$\tilde{w} = \sum_{n=1}^{N} x_n(\tilde{s}_n) + \tilde{z}. \tag{1}$$

The zero profit condition implies that the selected price equals the expected payoff conditional on all information available to market makers. Thus, the price $\tilde{p} = p(\tilde{w})$ is a random variable which is measurable with respect to order flows, and satisfies

$$p(\tilde{w}) = E(\tilde{v} \mid \tilde{w}). \tag{2}$$

In period 2, the realization of $\tilde{v}$ is observed, and each agent receives his payoff.

The objective of an informed trader is to maximize expected profits conditional on his information. The optimal demand for risky asset of an informed agent n is

$$x_n(s_n) = \underset{x \in \mathbb{R}}{\operatorname{argmax}} E[(\tilde{v} - p(\tilde{w}))x \mid s_n]$$

Definition. The equilibrium of the economy described above is a set of N strategies $x_n(\tilde{s}_n)$, $n = 1, \ldots, N$, which maximize the expected profits for each informed trader given the observed signal, and a price function $p(\tilde{w})$ which makes the expected profits of market makers equal to zero for each realization of the order flow.

For tractability, I restrict attention to symmetric and linear equilibria, i.e., equilibria in which $x(\tilde{s}_n) = x_n(\tilde{s}_n)$ for all n, and both $x(\tilde{s}_n)$ and $p(\tilde{w})$ are linear functions. The equilibrium with diverse private information is given in Proposition 2.1, whereas the case of common information is covered in Proposition 2.2.

Proposition 2.1. There exists a unique symmetric, linear equilibrium with diverse private information which is given by

$$\tilde{x}_n = x(\tilde{s}_n) = \beta(\tilde{s}_n - \bar{v}), \qquad n = 1, \ldots, N,$$

$$\tilde{p} = p(\tilde{w}) = \bar{v} + \lambda \tilde{w}$$

where

$$\beta = \left(\frac{\sigma_z^2}{N\left(\frac{1}{\tau_v} + \frac{1}{\tau_\epsilon}\right)} \right)^{1/2} \quad \text{and} \quad \lambda = \frac{1}{2\left(\frac{\tau_v}{\tau_\epsilon}\right) + N + 1} \left(\frac{N\left(\frac{1}{\tau_v} + \frac{1}{\tau_\epsilon}\right)}{\sigma_z^2} \right)^{1/2}.$$

PROOF. The computation of the equilibrium follows the same steps as the proofs of Lemmas 1 and 3 in Admati and Pfleiderer (1988a). However, we must replace $\sigma_v^2 = 1$ by $1/\tau_v$ in their proof. The complete derivation can be found in Caballé (1989). □

Proposition 2.2. There exists a unique symmetric, linear equilibrium with common private information which is given by

$$\tilde{x}_n = x(\tilde{s}) = \beta^*(\tilde{s} - \bar{v}), \qquad n = 1, \ldots, N,$$

$$\tilde{p} = p(\tilde{w}) = \bar{v} + \lambda^* \tilde{w}$$

where

$$\beta^* = \left(\frac{\sigma_z^2}{N\left(\frac{1}{\tau_v} + \frac{1}{\tau_\epsilon}\right)} \right)^{1/2} \quad \text{and} \quad \lambda^* = \frac{1}{(N+1)\tau_v} \left(\frac{N}{\sigma_z^2\left(\frac{1}{\tau_v} + \frac{1}{\tau_\epsilon}\right)} \right)^{1/2}.$$

PROOF. The proof mimics the one of the previous proposition. The only difference is that we have to replace $E\left(\sum_{j \neq n} \tilde{s}_j \mid \tilde{s}_n\right)$ in that proof by $(N-1)\tilde{s}$. The details are also left to the reader. □

The following corollary will be useful in order to conduct the profits comparison analysis in the next sections:

Corollary 2.3. (a) For the case with diverse private information, expected profits for informed traders are

$$E(\pi^n) = \frac{1}{2\left(\frac{\tau_v}{\tau_\epsilon}\right) + N + 1} \left(\frac{\sigma_z^2\left(\frac{1}{\tau_v} + \frac{1}{\tau_\epsilon}\right)}{N} \right)^{1/2}. \tag{3}$$

(b) For the case with common private information, expected profits for informed traders are

$$E(\tilde{\pi}^{s}) = \frac{1}{(N+1)\tau_{v}}\left[\frac{\sigma_z^2}{N\left(\dfrac{1}{\tau_v}+\dfrac{1}{\tau_\epsilon}\right)}\right]^{1/2}. \tag{4}$$

PROOF. (a) Compute $E(\pi^n) = E[(\tilde{v} - p(\tilde{w}))x(\tilde{s})]$, where $\tilde{w}$ is defined in (1), and the functions $p(\tilde{w})$ and $x(\tilde{s})$ are given in Proposition 2.1.

(b) As in part (a), but using the equilibrium derived in Proposition 2.2. □

It is straightforward to see that expected profits of insiders are always decreasing in the level of public information τ_v. When more precise public information becomes available, the informative advantage of insiders with respect to market makers is dissipated. Moreover, the financial market becomes more liquid (both λ and λ^* are decreasing in τ_v), which in turn decreases the cost of trading for liquidity-constrained traders.

III. A Monopolistic Market for Information

The corollaries of the previous section have immediate implications referred to the performance of a monopolistic market for information in the spirit of Admati and Pfleiderer (1986, 1988b). Let us assume that there is a risk neutral monopolist who is able to produce information about the payoff of the risky asset. This monopolist has to select the number of traders to whom he is going to sell the information, the precision of this information, and finally, its price. In order to simplify the analysis, I assume that information garbling is not allowed, and that the information owned by the informed agent is verifiable by the potential buyers. Thus, I abstract from the reliability problems analyzed, for instance, in Allen (1990).

I proceed to describe the technology of information product. The monopolist may produce signals of the asset payoff $\tilde{v}$ at unitary cost $\hat{c} > 0$. Each signal s_j takes the form $\tilde{s}_j = \tilde{v} + \tilde{\epsilon}_j$ where $\tilde{\epsilon}_j$ are i.i.d. normal with zero mean and variable $1/\tau$ for all j, and independent of both $\tilde{v}$ and $\tilde{z}$. Therefore, if the monopolist produces J signals, then the unbiased and most efficient estimate about $\tilde{v}$ is

$$\tilde{s} = \frac{\sum_{j=1}^{J} \tilde{s}_j}{J} = \tilde{v} + \frac{\sum_{j=1}^{J} \tilde{\epsilon}_j}{J}.$$

Define $\tilde{\epsilon} = \sum_{j=1}^{J} \tilde{\epsilon}_j / J$, and it follows that the precision τ_ϵ of $\tilde{\epsilon}$ is equal to $J\tau$. Finally, it is clear that the cost of producing a signal with noise precision τ_ϵ is $c\tau_\epsilon$, where $c = \hat{c}/\tau$. Therefore, we see that the problem of selecting a level of precision for the estimate of $\tilde{v}$ is equivalent to one of selecting the number J of observations.

The price at which the monopolist sells his information can be determined in a straightforward way. Given this monopolistic setup, I can assume that the monopolist extracts all the surplus from the buyers. This means that the price $p^*(N, \tau_\epsilon)$ of a signal with noise precision τ_ϵ sold to N buyers is equal to the certainty equivalent of the profits per capita when there are N informed agents who trade in the financial market using the same signal with noise precision equal to τ_ϵ. From risk neutrality and from (4), we can conclude that

$$p^*(N, \tau_\epsilon) = \frac{1}{(N+1)\tau_v}\left[\frac{\sigma_z^2}{N\left(\dfrac{1}{\tau_v}+\dfrac{1}{\tau_\epsilon}\right)}\right]^{1/2}. \tag{5}$$

Therefore, the maximization problem faced by the monopolist is to select τ_ϵ and N in order to maximize $E(\pi(N, \tau_\epsilon)) = Np^*(N, \tau_\epsilon) - c\tau_\epsilon$, subject to $N \leq \bar{N}$, where $\bar{N}$ is the number of potential buyers, and $\bar{N} \geq 1$.

Lemma 3.1. The optimal values $(N^*, \tau_\epsilon^*, p^*)$ for the monopolist's maximization problem satisfy

$$N^* = 1,$$

$$c = \frac{1}{4}\left(\frac{\sigma_z}{\tau_v}\right)\frac{1}{\left[\dfrac{(\tau_\epsilon^*)^{4/3}}{\tau_v} + (\tau_\epsilon^*)^{1/3}\right]^{3/2}}, \tag{6}$$

$$p^* = \frac{1}{2\tau_v}\left[\frac{\sigma_z^2}{\dfrac{1}{\tau_v}+\dfrac{1}{\tau_\epsilon^*}}\right]^{1/2}. \tag{7}$$

PROOF. After differentiating $E(\pi(n, \tau_\epsilon))$ with respect to N and simplifying, we obtain

$$\frac{\partial E(\pi(N, \tau_\epsilon))}{\partial N} = \frac{1}{2N^{1/2}}\left(\frac{1-N}{(N+1)^2}\right)\left(\frac{\sigma_z}{\dfrac{1}{\tau_v}+\dfrac{1}{\tau_\epsilon}}\right)^{1/2}.$$

Therefore, for any value of τ_ϵ, $N^* = 1$ is the value of N that maximizes $E(\pi\ (N, t_\epsilon))$.

Differentiate, now, $E(\pi(N, \tau_\epsilon))$ with respect to τ_ϵ, and make $N = 1$ to obtain (6). To see that the optimal precision τ_ϵ^*, defined implicitly in (6), is unique and belongs to the open interval $(0, \infty)$, note that the right-hand side of (6) is a continuous and strictly decreasing function of τ_ϵ which we denote as $F(\tau_\epsilon)$. It can be checked that $\lim_{\tau_\epsilon \to \infty} F(\tau_\epsilon) = 0$ and $\lim_{\tau_\epsilon \to 0} F(\tau_\epsilon) = \infty$. Then, continuity of $F(\cdot)$, and the fact that $c > 0$, proves the existence of $\tau_\epsilon^* \in (0, \infty)$. Uniqueness follows from the strict monotonicity of $F(\cdot)$.

To obtain the optimal value of p^* in (7), replace in (5) N and τ_ϵ by their optimal values. □

Lemma 3.1 tells us that if the monopolist chooses to sell information, then he wants to sell it to a single buyer. This buyer will be able to extract the maximum surplus from the financial market since he will compete with the market maker only without facing competition from other informed traders. This result resembles the one in the theory of oligopolistic competition, which says that the sum of profits obtained by oligopolistic firms operating in a market is lower than the profits obtained by a monopolistic firm operating in the same market. Obviously, the risk neutral monopolist is indifferent about whether he sells his information to a single agent and extracts all the surplus, or uses the information by himself and trades actively in the market for the risky asset.

An obvious comparative statics result which we get from (6), after implicitly differentiating, is that the equilibrium private precision τ_ϵ^* is decreasing in the unitary cost c of producing it.

I can now analyze the effects of public information on the incentives to produce private information. Basically, we want to know how τ_ϵ^* responds to changes in τ_v. Note that changes in τ_v can be induced through disclosure laws which force firms to publicly inform about their activities.

Proposition 3.2. There exists a $c^* > 0$ such that the optimal value of τ_ϵ^* in the monopolist problem is strictly increasing (decreasing) in τ_v if and only if the unitary cost of producing private information is smaller (greater) than c^*.

PROOF. Applying the Implicit Function Theorem to (6), it can be shown that

$$\frac{\partial \tau_\epsilon^*(\tau_v, c)}{\partial \tau_v} = -\frac{2\hat{a}^{1/3} - \hat{a}^{4/3}}{4\hat{a}^{1/3} + \hat{a}^{2/3}} \quad \text{where} \quad \hat{a} = \frac{\tau_\epsilon^*}{\tau_v}. \tag{8}$$

It follows that $\partial \tau_\epsilon^*/\partial \tau_v > (<)\ 0$ iff $\hat{a} > (<)\ 2$. Notice that for a given level of τ_v, the optimal private precision $\tau_\epsilon^*(\tau_v, c)$ is strictly decreasing in c and tends to zero (infinite) when c tends to infinity (zero). Therefore, define implicitly the threshold c^* as $\tau_\epsilon^*(\tau_v, c^*) = 2\tau_v$, and the result follows. □

This proposition tells us that, when the production of information is very costly, the direct negative effect of increasing public information, which reduces the insider's informative advantage, is never overcome by means of producing more private information. However, when c is low enough, the insider wants to produce still more private information so as to keep his relative advantage with respect to the market maker. Figure 1 illustrates the previous discussion. In this figure, the information costs c_i satisfy $c_1 < c_2 < c_3$. When c_i is lower, the optimal demand for information τ_ϵ^* is more likely to be increasing in τ_v.

This result contrasts with the one in Verrecchia (1982b) for perfectly competitive economies with risk averse agents. There, additional public disclosures motivate agents to cut back the production of information. However, when the strategic relationship between the informed agent and the market maker is taken into account, the effect on the production of private information depends on the cost to produce it.

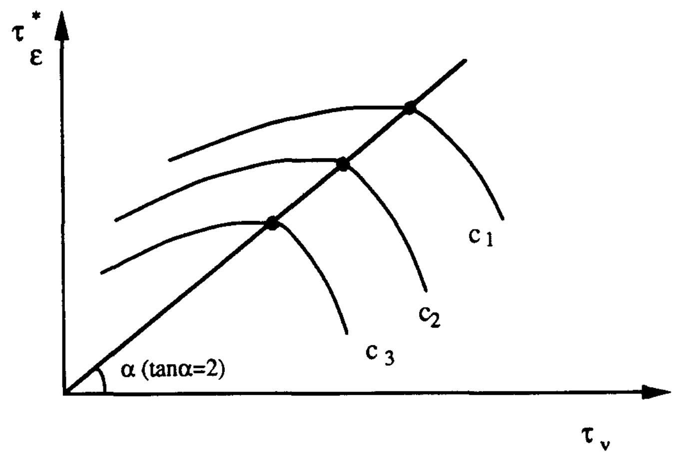

Figure 1. Production of private information.

Another natural question to ask is: how does public disclosure effect the total level of informedness of the trader? The overall level $\hat{\tau}$ of a trader's informedness can be defined as the sum of precisions of prior and private information, i.e., $\hat{\tau} = \tau_v + \tau_\epsilon$.

The following corollary gives the comparative statics result:

Corollary 3.3. The overall level of the trader's informedness is increasing in τ_v.

PROOF. Compute the derivative of $\hat{\tau}$ with respect to τ_v:

$$\frac{\partial \hat{\tau}}{\partial \tau_v} = 1 + \frac{\partial \tau_\epsilon^*(\tau_v)}{\partial \tau_v} = 1 - \frac{2\hat{a}^{1/3} - \hat{a}^{4/3}}{4\hat{a}^{1/3} + \hat{a}^{2/3}} = \frac{\hat{a}^{4/3} + \hat{a}^{2/3} + 2\hat{a}^{1/3}}{4\hat{a}^{1/3} + \hat{a}^{2/3}} > 0. \quad \square$$

Thus, public information increases the trader's informedness despite the fact that it may reduce the amount of private information produced. This result is similar to the one in Verrecchia (1982b).

IV. Associations of Investors

The analysis of Section III gives us an immediate corollary about the desirability of associations or syndicates of investors from the point of view of informed traders. Two types of associations are considered: 1) associations in which the members precommit to share their information before receiving their private signals, and they compete afterwards in the financial market using a more precise common information, and 2) mutual funds in which informed traders not only share their information, but the association submits a collective demand to the market maker based upon all the information collected by its members. Profits will be distributed equally among members of the association.

Let us assume that each agent owns a private signal s_n $(n = 1, \ldots, N)$ about $\tilde{v}$ with independent noises (diverse information case). Denote $E(\pi^j(N, \tau_\epsilon))$, $j = n$, s, as the expected profits of informed agents when there are N informed agents, each of them receiving a signal with precision τ_ϵ. The superindex j can take the values n or s, depending on whether the private information is diverse or common, respectively. $E(\pi^n(N, \tau_\epsilon))$ is given in (3) and $E(\pi^s(N, \tau_\epsilon))$ is given in (4).

The desirability of associations of type 1 depends on the expected profits $E(\pi^1) = E(\pi^s(N, N\tau_\epsilon))$ when the N informed agents share their information and use the same estimate with precision $N\tau_\epsilon$. On the other hand, to analyze the desirability of mutual funds in which the demand is submitted collectively (type 2), we have to compute the profits "per capita" $E(\pi^2) = (1/N)E(\pi(1, N\tau_\epsilon))$ obtained through the association. When $N = 1$, the superindex is obviously redundant.

From Lemma 3.1, it immediately follows that $E(\pi^1) < E(\pi^2)$ for $N > 1$. This confirms the intuition that collusive behavior delivers higher profits per capita then competition. The following proposition compares those two magnitudes with $E(\pi^n) = E(\pi^n(N, \tau_\epsilon))$, which are the expected profits obtained without any kind of collusive arrangement.

Proposition 4.1. For $N > 1$, $E(\pi^1) < E(\pi^n) < E(\pi^2)$.

PROOF. Compute the following ratios, and simplify to obtain

$$R_1(a) \equiv \frac{E(\pi^1)}{E(\pi^n)} = \frac{N^{1/2}}{N+1}\left(\frac{4 + (N+1)^2 a^2 + 4(N+1)a}{1 + Na^2 + (N+1)a}\right)^{1/2},$$

$$R_2(a) \equiv \frac{E(\pi^2)}{E(\pi^n)} = \frac{1 + \left(\frac{N+1}{2}\right)a}{(1 + (N+1)a + Na^2)^{1/2}}$$

where a is the private–public information ratio, $a \equiv \tau_\epsilon/\tau_v$. It can be easily proved that the derivative of $R_i(\cdot)$ with respect to a is strictly positive whenever $N > 1$, for $i = 1, 2$. It can also be proved that $\lim_{a\to\infty} R_1(a) = 1$, $\lim_{a\to 0} R_1(a) = (2N^{1/2}/N + 1) < 1$, $\lim_{a\to\infty} R_2(a) = (N + 1/2N^{1/2}) > 1$, and $\lim_{a\to 0} R_2(a) = 1$, for $N > 1$. The result follows. □

To interpret Proposition 4.1, note that the configuration associated with $E(\pi^2)$ is a monopolistic one in which the association is not facing competition and also possesses more information than any individual trader. Therefore, $E(\pi^2) > E(\pi^n)$ is the logical result.

A little bit more surprising is that $E(\pi^n) > E(\pi^1)$, i.e., that information pooling and competing delivers lower expected profits than competing without information sharing. The reason is that, when the informed traders share their diverse information, the local monopolies enjoyed by each investor disappear. Note that when all agents make trades based on the same information, the order flow is more informationally pure in the sense of having less noise due to the existence of diverse signals, possibly in opposite directions. The existence of this diverse information makes it more difficult for the market maker to predict $\Sigma_{Sn=1}^{N} s_n/N$, the sufficient estimate for all private information available in the economy.

V. Conclusion

The expected profits of different informational arrangements among insiders are ranked in this paper. With respect to the incentives to produce private information when more public information becomes available, it has been shown that the results are ambiguous, depending on the unitary cost of producing such private information. Thus, legislation forcing firms to publicly disclose part of their information might even stimulate the production of further private information.

The model has obvious limitations and, therefore, it has room for extensions. One shortcoming of the approach is that I have assumed that participants in the market are risk neutral. However, given the difficulty of explicitly modeling risk aversion in this imperfectly competitive setup (at least with the same distributional assumptions), there is a more promising line of research which involves a more general analysis of the information acquisition problem. The obvious extension should be to allow for several endogenously informed agents. In that model, we should specify a two-stage game. In the first stage, the insiders would select the amount of information they will produce, and in the second stage, they will compete using that information. Initial computations make clear that it is impossible to get explicit solutions under Gaussian assumptions, and therefore a binary approach seems more appropriate. At this point, I should mention that Verrecchia (1982a, 1982b) has studied this problem for the competitive case, and Matthews (1984) has some related results for auctions with prices as strategic variables and a finite number of agents.

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