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Motivating Management to Reveal Inside Information

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ABSTRACT

This paper develops incentive schemes which motivate a manager to release private information that he has concerning the probabilities of occurrence of the various output levels of his firm. It is shown that, in the context of a pure-exchange economy, a complete prohibition on the manager's trading in his firm's stock is sufficient to motivate him to truthfully release his private information. When the setting is extended to that of a production-exchange economy, the manager must also be allowed to choose the production plan that he most prefers in order for him to be motivated to release his information truthfully. In fact, no incentive scheme in a general production-exchange economy can be guaranteed to motivate the manager to release his information truthfully if he is not allowed to choose the production plan freely. However, when more structure is placed on the economy, such an incentive scheme can be developed as described in the latter part of this paper.

THERE HAS BEEN MUCH research recently into incentive-signalling problems involving firm management. (See Haugen and Senbet [2], Leland and Pyle [3], and Ross [7, 8]). In this research, the manager of a firm is assumed to know, while its stockholders do not, the value of some important characteristic of the firm, such as the firm's true value, the value of one of its investment projects, or the form of its efficient production set. The problem is then to motivate the manager to reveal his information truthfully. Another important characteristic about which informational asymmetry may exist is the probability distribution of output of the firm. If management has more accurate information about these probabilities than do the other stockholders, then information asymmetries will exist even if all agree on the form of the firm's production function and on the firm's value. This study explores the resulting equilibrium and describes incentive schemes which will eliminate incentives for management to misrepresent or hold back inside information, thereby leading to the truthful revelation of this inside information.[1]

Except for a study by Diamond [1], no research has specifically addressed this issue. Further, Diamond's setting is very specialized; there is only one probability, known solely by a risk neutral manager, that stockholders want to obtain. The production technology is such that there is no choice over the pattern of output

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[1] As will be described later, the elimination of incentives for management to misrepresent or hold back inside information is tantamount to motivating management to reveal its inside information truthfully.

attainable; the returns are always either zero or an amount "a." The technological choice is only over the probability with which "a" will occur. Since the stockholders know the manager's utility function they can infer, from the manager's actions, what his private information must be. In the study here, by contrast, stockholders would like an entire probability distribution to be revealed; at the same time, they do not know the manager's utility function so that they cannot infer from the manager's actions the nature of the probability distribution known by him. In such a situation, if stockholders want to learn the distribution, the manager must be motivated to release it truthfully.

Motivating management to release this private information is important to the Securities and Exchange Commission (SEC), among other groups. The SEC has proposed that managerial forecasts of future profitability be required to be revealed if released to at least one outsider [9]. Without a motivational scheme, even if the SEC's proposal were adopted, there would be no guarantee that the managerial forecasts would be truthfully revealed.

The truthful revelation of this inside information has important positive economic implications, as shown in Trueman [10]. Only when it is revealed can the economic equilibrium be guaranteed to be efficient with respect to the information (both public and private) existing in the economy. This is so because only then can all agents make the most informed exchange and production decisions.

It is shown that, in the context of a pure-exchange economy, where inside information has no effect on production decisions, a complete prohibition on the manager's trading in his firm's stock will eliminate all incentives that could cause him not to release his private information truthfully. This is an extension of the SEC's current restriction on insider trading which eliminates the profit potential from buy-sell transactions in the firm's stock made six or fewer months apart.[2] When the economic setting is extended to that of a production-exchange economy, which allows for the possibility that the information release will affect production decisions, a complete prohibition on managerial trading is no longer sufficient to motivate the truthful revelation of information. The manager must also be given the freedom to choose the production plan that he most desires (not necessarily coinciding with that which the stockholders prefer.)[3,4]

[2] Section 16b of the Securities Exchange Act of 1934.

[3] This is in contrast to the result in Ross [8] where a constraint on the manager's shareholdings is sufficient, along with an appropriate compensation scheme, to motivate the manager to reveal the production plan he has chosen and have it be the one preferred by stockholders. To get his result, Ross assumes that the manager and the stockholders both value production plans in the same way. (Haugen and Senbet also implicitly make the same assumption in order to get their results.) This, however, is not the case, in general, even in a complete market, when the manager is effectively constrained in his shareholdings. Acknowledging this difference, it can be seen that in this setting unless the manager is allowed to choose the production plan he most desires he would still have an incentive to release false information. He would do so in order to trick the stockholders into approving a plan more in line with his preferences. See below.

[4] In Leland and Pyle, there is no mention of the requirement that the manager be allowed to choose the production plan as he desires. This is because they are essentially in an exchange economy; the production plan is fixed. The additional effect of information on the production decision then does not arise in their model. Further, in their exchange economy they are able to develop an equilibrium in which information is signalled truthfully, without the manager's shareholdings being

It is not entirely satisfying to have, as the price of information revelation, production decisions made contrary to stockholder preferences. However, as is shown, in a general production-exchange economy it is not possible to find a scheme which is guaranteed to remove all incentives for the manager not to release his information truthfully at the same time as he is required to choose the production plan most favored by stockholders. The economy must be further specified and constrained before a scheme which satisfies both objectives can be developed. Such a set of economic conditions and the resulting incentive scheme are described in the latter part of this paper.

The plan of this work is as follows. In Section I the economy is described. The manager's decision problem, including his determination of whether or not to release truthfully any private information, is discussed in Section II. This is followed in Section III by the development of plans to gain the release of the inside information in both a pure exchange and a production-exchange economy. In Section IV the practical implementation of the plans developed is discussed. A summary in Section V concludes the paper.

I. Economic Setting

There are I individuals and F firms operating in a two-date environment with the date 0 state certain and the date 1 state unknown. There is only one good in the economy. The firms take as input, at date 0, quantities of the good and transform them into output of the good at date 1. There is one manager for each firm. Individuals trade securities, consisting of claims to initial consumption and shares in the various firms. There is perfect competition in that individuals and firms consider themselves to be price-takers.

Each individual i chooses his initial consumption and shareholdings in order to maximize his utility, U_i. Formally, his problem is to

$$\underset{c_0^i,\{t_{ik}\}}{\text{maximize}} \quad U_i = U_i(c_0^i, c_1^i, \ldots, c_S^i) \tag{1}$$

$$\text{subject to:} \quad c_0^i + \textstyle\sum_k t_{ik} v_k = \bar{c}_0^i + \sum_k \bar{t}_{ik}(v_k - q_{0k}) \tag{2}$$

$$c_s^i = \textstyle\sum_k t_{ik} q_{sk} \ \forall s \tag{3}$$

where

c_0^i is individual i's consumption at date 0;
$\bar{c}_0^i$ is individual i's endowment of date 0 consumption;
c_s^i is individual i's consumption at date 1, state s;
t_{ik} is individual i's fractional shareholding in firm k;
$\bar{t}_{ik}$ is individual i's fractional shareholding endowment in firm k;
v_k is the value of firm k at date 0;
q_{0k} is the initial input of firm k at date 0;
q_{sk} is the output of firm k at date 1 in state s.

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constrained, because they have only one parameter being signalled and because the manager's utility function is known. Such a result is not possible when the goal is the revelation of an entire probability distribution and where the manager's utility function is not known, as is the case here.

U_i is assumed to be strictly quasiconcave with $\frac{\partial U_i}{\partial c_0^i} \rightarrow \infty$ as $c_0^i \rightarrow 0$ and, for each s, $\frac{\partial U_i}{\partial c_s^i} \rightarrow \infty$ as $c_s^i \rightarrow 0$. It is also assumed that each agent attaches a positive probability to the occurrence of each state of nature.

The first assumption formalizes the individual's desire to consume in all states with a positive probability of occurrence, in order to survive. Along with the second assumption, it also rules out the possibility of bankruptcy by forcing every c_s^i to be greater than zero.

The formulation of the budget constraint (2) implicitly assumes that the inputs, q_{0k}, are financed solely by equity, so that $(v_k - q_{0k})$ is the net market value of firm k to its initial shareholders. The constraint (3) specifies that the individual's consumption at date 1, state s must equal the sum of each of his shares of the output in that state of each firm.

If the market for date 1 consumption is not complete, the firm's objective function is not necessarily well-defined (see Mossin [5]). To keep the analysis as general as possible, and to avoid an unnecessary (for the purposes of this study) discussion of an appropriate firm objective function, none will be specified for the incomplete market setting. It will be assumed that the manager and stockholders of each firm decide, in some manner, on the firm's production plan in such a situation. However, in the context of a complete market or when there is spanning and perfect competition in an incomplete market, all investors agree that the firm's goal should be that of net market value maximization. Formally, the manager of each firm k would then solve the problem:

$$\underset{q_{0k},\{q_{sk}\}}{\text{maximize}} \quad v_k - q_{0k} \tag{4}$$

$$\text{subject to:} \quad f_k(q_{1k}, \ldots, q_{Sk}) - q_{0k} = 0 \tag{5}$$

where (5) represents the firm's production function.

II. The Manager's Problem—The Information Revelation Decision

Assume that the manager of firm j has private information, which is not possessed by all other agents, and that some group of agents (such as the SEC) has mandated that this information be released. The information concerns the probabilities of the various states of nature and it is considered by the manager and other agents to be firm-specific so that, if released, it would affect the value and production plan only of firm j. In addition to choosing his optimal consumption plan and executing the production plan for firm j, the manager must decide whether to release his private information truthfully at date 0, before trading and production decisions have been made, or whether to try to deceive investors as to its true nature. His decision is assumed to be based on his objective of maximizing his utility. The information he releases affects his attainable utility through its effect on the equilibrium prices at which he can trade and with which production decisions will be made (see Ng [6]).

III. Incentive Schemes for the Truthful Release of Inside Information

A. Introduction

In order to guarantee that the manager will release his information truthfully, the incentive scheme must be such that the manager's utility will be maximized by truthfully revealing his information. All three incentive schemes to be presented have this property. The first two eliminate entirely any effect that information revelation can have on the manager's utility through changing shareholding and production decisions and changing equilibrium prices. This, by itself, causes the manager to be indifferent among all possible information disclosures. However, this, combined with the fact that the SEC imposes penalties if the manager is caught releasing anything other than truthful information is sufficient to motivate the manager to reveal his information truthfully.[5,6]

Suppose that the manager has released publicly an estimate of the probabilities of occurrence of the future states of nature, denoted by $\{\pi_1(\lambda), \pi_2(\lambda), \ldots, \pi_S(\lambda)\}$, at date 0. The probabilities are parametrized by λ for ease of analysis. A change in λ then represents a change in the information released by the manager. With the announcement of λ all agents decide the extent to which they will revise their prior beliefs. Given the equilibrium prices established in the economy after this release, the manager will maximize his utility, U_m, by choosing shareholding levels to satisfy the following first-order conditions arising from Equations (1)–(3):

$$v_k = \sum_s \frac{U_{ms}}{U_{m0}} q_{sk} \qquad \forall k \tag{6}$$

[5] Explicit costs could arise either in the presence or in the absence of a formal routine auditing of the probabilities provided by the manager. Under a routine audit of the probabilities an auditor would require the manager to substantiate his probabilities with underlying data and analyses. If the auditor would become suspicious (based on his prior beliefs as to the probabilities and the additional supporting data provided by the manager) that the manager has not released his information truthfully, a further investigation could be required. This would divert the manager's time from the operation of the firm, lowering the firm's value and the value of the manager's holdings in the firm. Aside from this explicit cost to the manager, there are the costs of fines to be paid as a result of lawsuits brought by the shareholders of the firm if it is felt that the manager was deliberately misleading in his information. (Rule 10b-5 of the Securities Act of 1934 prohibits the firm from engaging "in any act, practice, or course of business which operates or would operate as a fraud or deceit").

These same costs arise, although with a lesser likelihood, without the establishment of a routine auditing structure for probability information. A worker in the firm might report to the SEC that he has evidence of the manager falsely reporting the probabilities. Or, in the course of a normal audit of the firm's financial statements, an auditor might come across some information that leads him to become suspicious of the probabilities released by the manager. (According to Section 550 of the AICPA Code of Professional Ethics, auditors are required to take note of any information, accompanying audited financial statements, which appears to be misleading, even if that information is not to be audited.) In either case, this could prompt an investigation that could lead to the same explicit costs as delineated above.

[6] As will become clearer below, it is not necessary to explicitly model these costs for the purposes of this study. It only need be assumed that they are such that the manager believes that they will be minimized if he truthfully reveals his information, a very reasonable assumption.

where

$$U_{m0} = \frac{\partial U_m}{\partial c_0^m} \quad \text{and} \quad U_{ms} = \frac{\partial U_m}{\partial c_s^m} \qquad \forall s$$

Denote the manager's resulting utility level by $U_m^*(\lambda)$.

Similarly, for given λ, the first-order conditions of every other agent i are

$$v_k = \sum_s \frac{U_{is}}{U_{i0}} q_{sk} \qquad \forall k \tag{7}$$

Also, given λ, each firm k decides on its production plan. For a complete market, or an incomplete market with spanning and perfect competition, it follows from (4)–(5) that the production plan will satisfy

$$\frac{\partial v_k}{\partial q_{sk}} = \frac{\partial f_k}{\partial q_{sk}} \qquad \forall s \tag{8}$$

The effect on the manager's maximum utility level of a small change in the information released is given by:[7]

$$\frac{\partial U_m^*(\lambda)}{\partial \lambda} = U_{m0}\Bigg[(\bar{t}_{mj} - t_{mj}^*)\frac{\partial v_j^*}{\partial \lambda} + \bar{t}_{mj}\sum_s\left(\frac{\partial v_j^*}{\partial q_{sj}^*} - \frac{\partial f_j}{\partial q_{sj}^*}\right)\frac{dq_{sj}^*}{d\lambda} + t_{mj}^*\sum_s\left(\frac{U_{ms}}{U_{m0}} - \frac{\partial v_j^*}{\partial q_{sj}^*}\right)\frac{dq_{sj}^*}{d\lambda}\Bigg] \tag{9}$$

where the starred variables represent optimal levels at the given λ. (See the Appendix for the derivation of (9)).

B. An Incentive Scheme for a Pure-Exchange Economy

In a pure-exchange economy production plans are fixed. In such a case (9) reduces to:

$$\frac{\partial U_m^*(\lambda)}{\partial \lambda} = U_{m0}(\bar{t}_{mj} - t_{mj}^*)\frac{\partial v_j^*}{\partial \lambda} \tag{10}$$

The manager's utility, $U_m^*(\lambda)$, is affected by the manner in which the change in information causes the value of the firm to change $\left(\frac{\partial v_j^*}{\partial \lambda}\right)$ and by whether the manager is a net buyer or a net seller of shares in his firm (the sign of $(\bar{t}_{mj} - t_{mj}^*)$). Considering this effect, the manager may not maximize his utility by releasing his information truthfully. This possibility is eliminated by the following: *Incentive Scheme—Pure-Exchange Economy*: Restrict the manager's holdings in his firm's shares to equal exactly his endowment of the firm's shares.

The manager would be told that he is not permitted to trade in his firm's shares during his tenure as manager, that is, that he must hold $\bar{t}_{mj}$ shares. The

[7] "Small" is defined as causing an infinitesimal change in the value of firm j and in the production plan of firm j.

derivatives (9) and (10) remain of the same form except that $\bar{t}_{mj}$ replaces t^*_{mj}.[8] The effect of changing prices has been negated. Leaving the costs of deception as the only remaining effect of information revelation on the manager's utility, it becomes optimal for him to release his information truthfully.

This incentive scheme corresponds to the SEC's restriction on insider trading. Not only does this restriction satisfy the SEC's goal of preventing insiders from profiting from their inside information, it also eliminates any incentive for the manager not to release his information truthfully.

C. An Incentive Scheme for a Production-Exchange Economy

Consider again the derivative (9). If the manager is restricted in his holdings of his firm's shares, as in the pure-exchange economy, then (9) reduces to:

$$\left(\frac{\partial U^*_m(\lambda)}{\partial \lambda}\right) = U_{m0}\left[\bar{t}_{mj} \sum_s \left(\frac{\partial v^*_j}{\partial q^*_{sj}} - \frac{\partial f_j}{\partial q^*_{sj}}\right)\frac{dq^*_{sj}}{d\lambda} + \bar{t}_{mj} \sum_s \left(\frac{U_{ms}}{U_{m0}} - \frac{\partial v^*_j}{\partial q^*_{sj}}\right)\frac{dq^*_{sj}}{d\lambda}\right] \quad (11)$$

This derivative represents the effect, on the manager's maximum utility level, of changes in the firm's production plan as a result of different information becoming available to the stockholders. This derivative is, in general, nonzero for two reasons: first, because the market is incomplete, without unanimity over production decisions, and second, because the manager is constrained from holding his optimal number of shares in the firm. It can easily be shown that with these two conditions removed the derivative (11) vanishes.[9]

When either or both of the two conditions mentioned above exists, the production plan chosen will not, in general, be that most preferred by the manager. In an incomplete market this is so because agents do not, in general, agree on the valuation of incremental outputs resulting from an increment to the input level. What one agent sees as an optimal production plan is suboptimal to

[8] The constraint on shareholdings in firm j does not introduce any terms involving $\frac{dt^*_{mk}}{d\lambda}$, $k \neq j$, into the derivative (9). Although the manager is now forced to keep $\bar{t}_{mj} v_j$ of his initial wealth invested in firm j, he is allowed, for each λ, to choose his optimal shareholdings in all other firms. By the Implicit Function Theorem terms involving $\frac{dt^*_{mk}}{d\lambda}$, for each $k \neq j$, are then equal to zero.

[9] If the manager can freely choose his shareholdings in firm j, then equation (6) will be satisfied:

$$v_j = \sum_s \frac{U_{ms}}{U_{mo}} q_{sj} \quad (6)$$

With unanimity, the manager, as well as the other investors will prefer net market value maximization, yielding first order conditions (8):

$$\frac{\partial v_j}{\partial q_{sj}} = \frac{\partial f_j}{\partial q_{sj}} \ \forall s \quad (8)$$

Given the competitivity assumption, this can be written as:

$$\frac{\partial v_j}{\partial q_{sj}} = \frac{U_{ms}}{U_{mo}} \ \forall s \quad (\text{F.1})$$

Using (8) and (F.1) in (11) the derivative (11) equals zero.

another. The final production plan will then not be the most preferred plan to all investors. Even if the market is complete, because the manager is constrained from holding his optimal number of shares in the firm, he will again, in general, prefer a production plan different from that agreed upon. To see this, note that since the manager cannot adjust his portfolio optimally, in general it will be true that his first-order condition for purchases of shares in firm j will not be fulfilled. Formally:

$$v_j \neq \sum_s \frac{U_{ms}}{U_{m0}} q_{sj} \tag{12}$$

That is, the manager's valuation of the firms outputs, $\sum_s \frac{U_{ms}}{U_{m0}} q_{sj}$, will be different from the market value of the firm, the value that all other investors place on the firm's outputs. The production plan agreed upon by the other shareholders, maximizing net market value, then need not be optimal for the manager.

In such a situation, the significance of the manager's changing the information that is released and used by stockholders is that it can change the production plan agreed upon, moving it either closer to what the manager prefers, increasing his utility, or further from what he wants, decreasing his utility. This effect could cause the manager to release other than truthful information.

The following incentive scheme eliminates this effect and thus motivates the manager to truthfully release his information:

Incentive Scheme—Production-Exchange Economy: In addition to constraining the manager to hold exactly $\bar{t}_{mj}$ shares, he must be allowed to choose, as the firm's production plan, the plan that he most prefers.

It can easily be shown that the production plan most preferred by the manager, maximizing his utility subject to the requirement that $\bar{t}_{mj}$ shares be held, must satisfy the following first-order conditions:

$$\frac{U_{ms}}{U_{m0}} = \frac{\partial f_j}{\partial q_{sj}} \qquad \forall s \tag{13}$$

With these first-order conditions fulfilled, and with t^*_{mj} set equal to $\bar{t}_{mj}$, the derivative (9) vanishes. With the manager allowed to set the production plan as he desires and with him being constrained in his shareholdings, there is no longer any incentive, for trade or for production reasons, for the manager to deceive stockholders as to the nature of his information.

With this incentive scheme, there is a tradeoff between stockholders receiving truthful information from the manager and their controlling the production decision. It should be clear, from the discussion above, that there is no incentive scheme which can be guaranteed to satisfy both objectives in a general production-exchange economy.[10] In order to eliminate the managers' incentive to

[10] There is a trivial solution that will satisfy both objectives: hire as managers only those agents who have no endowment in the firm. The derivative (11) then drops out to zero. However, this would mean choosing a manager on the basis of a criterion other than his ability or his commitment to the firm (as represented by his shareholdings), not a very pleasant alternative.

manipulate the information released so as to gain from changing prices, it is necessary to either constrain the manager's shareholdings (as was done above) or require him to forfeit any gain from the changing prices. In either case, this ensures that the manager will disagree with stockholders as to the optimal production plan, in either a complete or an incomplete market setting.[11] Unless the manager is also given the freedom to choose the production plan that he most desires, he will then continue to have an incentive to manipulate the information released, now in order to influence the stockholders' choice of production plan, to bring it closer to the plan that he prefers. In order to assure that the manager truthfully releases his information in a general production-exchange economy, then, the manager must be given control over the production decision.

However, there are certain more specified production-exchange settings in which an incentive scheme for the truthful revelation of information can be developed while the manager is also required to set the production plan according to the desires of the stockholders. Such an economy is described in the next section.

D. Development of an Incentive Scheme for a More Specific Production-Exchange Setting

In addition to the assumptions embodied in Sections I–II, add the following:

a. Utility Function

For each agent i, his utility function takes the form

$$U_i = w_i(c_0^i) + \textstyle\sum_s \pi_s^i y_i(c_s^i) \tag{14}$$

where π_s^i is individual i's subjective probability for the occurrence of state s.

The utility function is now of the expected utility form and is time separable.

b. Production Function and Production Decision

The production function for firm k takes the form

$$q_{sk} = n_k(s) f_k(q_{0k}) \ \forall s \tag{15}$$

where $n_k(s) > 0$, $f_k(q_{0k})$ is concave, $f_k(0) = 0$ and $f_k^1(0) > 0$.

The stockholders of each firm have complete knowledge of its production function and require the manager to choose the plan they most prefer, maximizing the firm's net market value.[12]

c. Information Possessed by Agents

All agents, except for the manager of firm j, have homogeneous probability assessments for the date 1 states, donated by π_s for each state s. The manager of firm j, in addition to the information possessed by other agents about the state probabilities, has, at date 0, further information which causes him to form a

[11] Although this was shown above only for the case where the manager is constrained in his shareholdings, it can also easily be demonstrated to hold for the case where the manager is forced to give up the gain, $(\bar{t}_{mj} - t_{mj}^*) \dfrac{\partial v_j^*}{\partial \lambda}$, from changing prices.

[12] It can be shown that to maximize net market value the production plan for firm k must satisfy the condition that $\sum_s \dfrac{U_{is}}{U_{io}} \dfrac{dq_{sk}^*}{dq_{ok}^*} = 1$ for every agent i.

probability belief, π_s^m, for the occurrence of state s, different, in general, from that formed by the other agents.

In deciding on the nature of the information to release, the manager is constrained either to revealing his information fully, by releasing π_s^m $\forall s$, revealing none of his information, by releasing π_s $\forall s$, or revealing part of his information, by releasing $\pi_s(\lambda)$ $\forall s$ $0 \leq \lambda \leq 1$, according to the following formula:

$$\pi_s(\lambda) = \pi_s + \lambda(\pi_s^m - \pi_s) \; \forall s \; 0 \leq \lambda \leq 1 \tag{16}$$

That is, the manager can release a convex combination, $\pi_s(\lambda)$ $\forall s$, of the distribution he holds, π_s^m $\forall s$, and the initial distribution held by the other agents, π_s $\forall s$. $\lambda = 1$ represents the full release of information, with $\pi_s(1) = \pi_s^m$ $\forall s$ while $\lambda = 0$ represents no release of information with $\pi_s(0) = \pi_s$ $\forall s$.

This limitation on the manager's actions can be thought of as equivalent to allowing him only to hold back information. That is, he need not give out all of his information (the case where $\lambda = 1$) but is not allowed to misrepresent it (thereby requiring that $0 \leq \lambda \leq 1$).[13] One way of justifying this restriction is to assume the existence of an auditor of these forecasts. If there is an auditor whose job it is to verify that the manager is releasing his probability distribution, π_s^m $\forall s$, the auditor would request supporting evidence for the probabilities released. At the manager's disposal are his data which led him to his probability distribution. Also on hand presumably are the data with which the other stockholders estimated the probability distribution as π_s $\forall s$. The auditor could best be convinced that the released distribution, $\pi_s(\lambda)$ $\forall s$, represents the manager's information if it is some weighted average of the two sets of data available to the manager, that is, if $0 \leq \lambda \leq 1$.

Because of the manager's superior information, all other agents will revise their beliefs to π_s^m $\forall s$ if the manager fully releases his information and if the agents knew that he is doing so. However, even if the information is only partially revealed, according to (16), it is in the agents' interests to use the released distribution (see Trueman [10]).[14] Therefore, in what follows it will be assumed that, if information is revealed, the agents will revise their beliefs to whatever is the released distribution.

In this context, a successful incentive scheme is one that motivates the manager to choose $\lambda = 1$, giving him his highest utility level at that value of λ. A shareholding constraint with the following provisions will provide such motivation:

a. If the manager releases a λ which results in $v_j^*(\lambda) - v_j^*(0) > 0$ (that is, in the equilibrium value of firm j with λ released being greater than that when no information is released), then the manager is required to be holding no more than $\bar{t}_{mj}$ shares at equilibrium.

b. If the manager releases a λ which results in $v_j^*(\lambda) - v_j^*(0) \leq 0$, then the manager is required to be holding at least $\bar{t}_{mj}$ shares at equilibrium.

[13] This restriction on the manager's actions in the context of information revelation is also found elsewhere. (See Milgrom [4].)

[14] Also they know that if they do so the manager will fully release his information upon implementation of the incentive scheme developed below.

c. If the manager does not release any information ($\lambda = 0$) then he is required to be holding exactly $\bar{t}_{mj}$ shares at equilibrium.

Conditions (a) and (b) give the consequences of the manager's releasing partial information, and (c) states the consequences of his not releasing any information.

Given these three conditions, the manager is faced with the following revised maximization problem (P):

$$\max_{c_0^m, \{t_{mk}\}, \lambda} \quad U_m = w_m(c_0^m) + \textstyle\sum_s \pi_s^m y_m(c_s^m) \tag{17}$$

subject to

$$c_0^m + \textstyle\sum_k t_{mk} v_k = \bar{c}_0^m + \sum_k \bar{t}_{mk}(v_k - q_{0k}) \tag{18}$$

$$c_s^m = \textstyle\sum_k t_{mk} q_{sk} \tag{19}$$

$$\bar{t}_{mj} \geq t_{mj} \quad \text{if} \quad v_j - v_j(0) > 0,\ \lambda > 0 \tag{20}$$

$$\bar{t}_{mj} \leq t_{mj} \quad \text{if} \quad v_j - v_j(0) \leq 0,\ \lambda > 0 \tag{21}$$

$$\bar{t}_{mj} = t_{mj} \quad \text{if} \quad \lambda = 0 \tag{22}$$

$$0 \leq \lambda \leq 1 \tag{23}$$

As shown in the appendix, the following proposition holds for problem P:

Proposition: The manager of firm j, when faced with problem P, will choose $\lambda = 1$.

The shareholding constraint for $\lambda > 0$ works to motivate the manager to fully release his information because it serves two positive functions. To see this, consider the derivative $\dfrac{\partial U_m^*(\lambda)}{\partial \lambda}$:

$$\frac{\partial U_m^*(\lambda)}{\partial \lambda} = U_{m0}\left[(\bar{t}_{mj} - \hat{t}_{mj}^*)\,\frac{\partial v_j^*}{\partial \lambda} + \hat{t}_{mj}^*\left(\textstyle\sum_s \dfrac{U_{ms}}{U_{m0}}\dfrac{dq_{sj}^*}{d\lambda} - \dfrac{dq_{0j}^*}{d\lambda}\right)\right] \tag{24}$$

where $\hat{t}_{mj}^*$ is the manager's optimal firm j shareholding level given that he is constrained in his actions according to problem P. (The derivation of (24) follows along the same lines as the derivation of (9).) The shareholding constraint first eliminates the possibility that a higher level of information release would cause unfavorable price changes, from the manager's viewpoint, (see the first term of (24)) by requiring $(\bar{t}_{mj} - \hat{t}_{mj}^*)$ and $\dfrac{\partial v_j^*}{\partial \lambda}$ (which is of the same sign as $v_j^*(\lambda) - v_j^*(0)$; see the proof of the proposition) to be of the same sign. Whenever an increase in λ would raise the value of the firm, the manager is required to be a net seller in the firm's shares. Whenever it would lower the value of the firm, he is required to be a net buyer. Second, the constraint gives the manager an incentive to increase λ in order to have the firm's production plan more closely aligned to his own preferred plan (the second term of (24)). To see this, consider the case where $v_j^*(\lambda) - v_j^*(0)$ and $\dfrac{\partial v_j^*}{\partial \lambda}$ are positive at a given λ, with the manager therefore being required to hold no more than $\bar{t}_{mj}$ shares. If this constraint is not binding, then the second term of (24) drops out. But if it is binding, then the manager is holding fewer shares than he desires and, as demonstrated in lemma 1, in equilibrium:

$$\Sigma_s \frac{U_{ms}}{U_{m0}} \frac{dq_{sj}^*}{dq_{0j}^*} > 1 \tag{25}$$

or

$$\Sigma_s \frac{U_{ms}}{U_{m0}} \frac{dq_{sj}^*}{d\lambda} > \frac{dq_{0j}^*}{d\lambda} \tag{26}$$

The second term of (24) is then nonzero. The manager's implicit valuation of a change in output caused by an infinitesimal change in input is greater than the input change. The manager therefore prefers a higher production level than do the other shareholders. Since $\frac{\partial v_j^*}{\partial \lambda}$ and $\frac{dq_{0j}^*}{d\lambda}$ have the same sign (see the proof of lemma 2), when $\frac{\partial v_j^*}{\partial \lambda}$ is positive, $\frac{dq_{0j}^*}{d\lambda}$ is positive; in order for stockholders to approve a higher production level, as the manager desires, then, the manager must increase λ. Similarly when $v_j^*(\lambda) - v_j^*(0)$, $\frac{\partial v_j^*}{\partial \lambda}$ and $\frac{dq_{0j}^*}{d\lambda}$ are negative, and the constraint of holding at least $\bar{t}_{mj}$ shares is binding, the manager prefers a lower production level than do the other stockholders and must against increase λ, this time in order to have them approve a lowering of the production level. Finally, when $\frac{\partial v_j^*}{\partial \lambda}$ and $\frac{dq_{0j}^*}{d\lambda}$ equal zero, the second term of (24) drops out to zero. In sum, in all cases, the second term of (24) is nonnegative. The manager never loses utility by raising the level of λ.[15]

The form of the constraint for the case of $\lambda = 0$ must be different from that for $\lambda > 0$. The manager must be required to hold exactly $\bar{t}_{mj}$ shares in firm j. This is because, when $\lambda = 0$, no information is released and stockholders are unable to know the sign of $\frac{\partial v_j^*}{\partial \lambda}$. They then cannot determine which of the constraints to impose on the manager's shareholdings in the firm in order to make (24) nonnegative. The imposition, effectively, of both constraints when $\lambda = 0$, however, lowers the manager's utility at $\lambda = 0$ so that he prefers to release a positive λ.

It is seen, that in this setting, to motivate the manager to release his information truthfully, while at the same time choosing the production plan most desired by stockholders, maximizing net market value, a shareholding constraint representing a modified insider trading restriction is employed. The manager is not completely restricted from trading in shares of his firm, the restrictions varying, depending on the sign of $v_j^*(\lambda) - v_j^*(0)$.

IV. Comments on the Implementation of the Incentive Schemes

From the point of view of the implementation of the two schemes developed for the production-exchange economy, it is clear that the first of the two is the easier

[15] The importance of the constraint (16) is now clear. It allows the manager to increase λ only to the point where $\lambda = 1$, where the information is truthfully revealed.

to implement. The manager would simply be told that he must hold exactly his initial endowment of shares in his firm during his tenure as manager. The implementation of the second plan is more difficult, not only because the manager must be monitored in order to insure that he chooses the production plan most preferred by the stockholders, but also because the type of shareholding constraint to be imposed on the manager during any given period must be determined. To do so, the sign of $v_j^*(\lambda) - v_j^*(0)$, the effect that the information has on the firm's value, must be found. This is not an easy task because there are many factors influencing the movement of any firm's value. The smaller the interval between the time that the information is released and the time that the value of the firm is observed, however, the greater the chance that the movement found is due solely to the announcement.

V. Summary and Conclusions

If the SEC or other body is concerned with the revelation of the type of inside information which will not have any impact on the firm's production decisions, then it is clear that a complete restriction on managerial trading in the firm's shares is the appropriate incentive. However, if production decisions are affected by the relevation, the choice of implementation plan is not clearcut. The complete restriction on insider trading can be imposed, but the manager must then be allowed to select the production plan that he most desires. Alternatively, a modified insider trading rule as described in Section III.D can be used, with the manager then required to produce so as to maximize net market value. If the assumptions underlying the latter scheme are realistic and its implementation does not pose difficulties, then it is reasonable that the SEC would opt for its use. It places less stringent restrictions on the manager's shareholdings while giving stockholders their preferred production plan.

APPENDIX

A. Derivation of (9)

Using the definition of c_0^m, $U_m^*(\lambda)$ can be expressed as

$$U_m^*(\lambda) = U_m(\bar{c}_0^m + \textstyle\sum_k \bar{t}_{mk}(v_k^* - q_{0k}^*) - \sum_k t_{mk}^* v_k^*, \sum_k t_{mk}^* q_{1k}^*, \ldots, \sum_k t_{mk}^* q_{Sk}^*) \tag{A.1}$$

Differentiating with respect to λ gives

$$\frac{\partial U_m^*(\lambda)}{\partial \lambda} = U_{m0}\left[\bar{t}_{mj}\left(\frac{dv_j^*}{d\lambda} - \frac{dq_{0j}^*}{d\lambda}\right) - \sum_k \frac{dt_{mk}^*}{d\lambda} v_k^* - t_{mj}^* \frac{dv_j^*}{d\lambda}\right] + \sum_s U_{ms}\left(\sum_k \frac{dt_{mk}^*}{d\lambda} q_{sk}^* + t_{mj}^* \frac{dq_{sj}^*}{d\lambda}\right) \tag{A.2}$$

Using (6) and (A.10) (see the proof of lemma 2) and noting from (5) that:

$$\sum_s \frac{\partial f_j}{\partial q_{sj}} \frac{dq_{sj}}{d\lambda} = \frac{dq_{0j}}{d\lambda},$$

gives (9).

B. Proof of Proposition

In order to prove the proposition, the following two lemmas are first needed:

Lemma 1: The term $\sum_s \frac{U_{ms}}{U_{m0}} \frac{dq^*_{sj}}{d\lambda} - \frac{dq^*_{0j}}{d\lambda}$ is of the same sign as (opposite sign to) that of $\frac{\partial v^*_j}{\partial \lambda}$ whenever the manager is required to hold no more than (at least) $\bar{t}_{mj}$ shares and the constraint is binding.

Proof: The proof will be shown for the case where the manager is required to hold at least $\bar{t}_{mj}$ shares. The case where he must hold no more than $\bar{t}_{mj}$ shares is similarly proven. If the minimum limit on shareholdings is binding, then the manager prefers to hold fewer shares than he is required to hold. At the constrained equilibrium the manager therefore values the firm less highly than do the other stockholders. That is:

$$\sum_s \frac{U_{ms}}{U_{m0}} q^*_{sj} < \sum_s \frac{U_{is}}{U_{i0}} q^*_{sj} \tag{A.3}$$

Because of the form of the production function, (A.3) implies that:

$$\sum_s \frac{U_{ms}}{U_{m0}} dq^*_{sj} < \sum_s \frac{U_{is}}{U_{i0}} dq^*_{sj} \tag{A.4}$$

and therefore

$$\sum_s \frac{U_{ms}}{U_{m0}} \frac{dq^*_{sj}}{dq^*_{0j}} < \sum_s \frac{U_{is}}{U_{i0}} \frac{dq^*_{sj}}{dq^*_{0j}} \tag{A.5}$$

$$= 1 \tag{A.6}$$

To use this, note that the term $\sum_s \frac{U_{ms}}{U_{m0}} \frac{dq^*_{sj}}{d\lambda} - \frac{dq^*_{0j}}{d\lambda}$ can be rewritten as

$$\frac{dq^*_{0j}}{d\lambda}\left(\sum_s \frac{U_{ms}}{U_{m0}} \frac{dq^*_{sj}}{dq^*_{0j}} - 1\right) \tag{A.7}$$

Then, from (A.6), it has the opposite sign to $\frac{dq^*_{0j}}{d\lambda}$.

To complete the proof, it is necessary to show that $\frac{dq^*_{0j}}{d\lambda}$ and $\frac{\partial v^*_j}{\partial \lambda}$ have the same sign. Totally differentiating the first-order condition (8) (which can be written as $\frac{\partial v_j}{\partial q_{0j}} = 1$ in this setting) with respect to λ and q_{0j} and rearranging gives

$$\frac{dq^*_{0j}}{d\lambda} = \frac{-\left[\partial\left(\frac{\partial v^*_j}{\partial \lambda}\right)\right] \Big| \partial q^*_{0j}}{\partial^2 v^*_j / \partial q^{*2}_{0j}} \tag{A.8}$$

The denominator is negative because of the concavity of the production function. Because of the form of the production function, the numerator is a positive proportion of $\frac{\partial v_j^*}{\partial \lambda}$. This completes the proof. Q.E.D.

Lemma 2: (a) $\frac{dv_j^*}{d\lambda}$ and $\frac{\partial v_j^*}{\partial \lambda}$ are nondecreasing with λ; (b) if $\frac{dv_j^*}{d\lambda}\left(\frac{\partial v_j^*}{\partial \lambda}\right) = 0$ for some λ, then $\frac{dv_j^*}{d\lambda}\left(\frac{\partial v_j^*}{\partial \lambda}\right)$ remains constant as λ increases above that value; (c) $\frac{dv_j^*}{d\lambda}$ and $\frac{\partial v_j^*}{\partial \lambda}$ have the same sign.

Proof: Differentiate v_j^* totally with respect to λ:

$$\frac{dv_j^*}{d\lambda} = \frac{\partial v_j^*}{\partial \lambda} + \frac{\partial v_j^*}{\partial q_{0j}^*}\frac{dq_{0j}^*}{d\lambda} + \sum_l \sum_i \frac{\partial v_j^*}{\partial t_{il}^*}\frac{dt_{il}^*}{d\lambda} \tag{A.9}$$

This can be simplified to

$$\frac{dv_j^*}{d\lambda} = \frac{\partial v_j^*}{\partial \lambda} + \frac{dq_{0j}^*}{d\lambda} \tag{A.10}$$

because

$$\frac{\partial v_j^*}{\partial q_{0j}^*} = 1; \frac{\partial v_j^*}{\partial t_{il}^*} = 0 \quad \forall i, l \tag{A.11}$$

holds at equilibrium.

Rewrite (A.10) as

$$\frac{dv_j^*}{d\lambda} = \sum_s (\pi_s^m - \pi_s)\frac{y_{is}}{w_{i0}} q_{sj}^* + \sum_s \pi_s(\lambda)\frac{y_{is}}{w_{i0}}\frac{dq_{sj}^*}{d\lambda} \text{ for any } i \neq m \tag{A.12}$$

where

$y_{is} = \frac{dy_i(c_s^i)}{dc_s^i}$, $w_{i0} = \frac{dw_i(c_0^i)}{dc_0^i}$, and making use of the fact that the first-order condition (8) can also be written as $\sum_s \pi_s(\lambda)\frac{y_{is}}{w_{i0}}\frac{dq_{sj}}{dq_{0j}} = 1$. Then

$$\frac{\partial\left(\frac{dv_j^*}{d\lambda}\right)}{\partial \lambda} = \sum_s (\pi_s^m - \pi_s)\frac{y_{is}}{w_{i0}}\frac{dq_{sj}^*}{d\lambda} \text{ for any } i \neq m \tag{A.13}$$

It is shown in Trueman [10] that

$$\frac{dq_{0j}^*}{d\lambda} \geq 0 \text{ iff } \sum_s (\pi_s^m - \pi_s)\frac{y_{is}}{w_{i0}}\frac{dq_{sj}^*}{dq_{0j}^*} \geq 0 \text{ for any } i \neq m \tag{A.14}$$

(The notation has been changed to be compatible with this setup.)

Then $\sum_s (\pi_s^m - \pi_s) \dfrac{y_{is}}{w_{i0}} \dfrac{dq_{sj}^*}{d\lambda} \geq 0$ and therefore $\dfrac{\partial\left[\dfrac{dv_j^*}{d\lambda}\right]}{\partial\lambda \geq 0.}$ This is also equal to $\dfrac{d\left(\dfrac{\partial v_j^*}{\partial\lambda}\right)}{d\lambda}$. $\dfrac{\partial v_j^*}{\partial\lambda}$ is then nondecreasing with λ.

Then, when $\dfrac{dq_{oj}^*}{d\lambda} = 0$ and $\sum_s (\pi_s^m - \pi_s) \dfrac{y_{is}}{w_{io}} \dfrac{dq_{sj}^*}{dq_{oj}^*} = 0$, $\dfrac{\partial v_j^*}{\partial\lambda} = 0$ (see the proof of Lemma 1) and $\dfrac{\partial\left[\dfrac{dv_j^*}{d\lambda}\right]}{\partial\lambda} = 0$. Therefore, if $\dfrac{\partial v_j^*}{\partial\lambda} = 0$ for some λ, then $\dfrac{\partial v_j^*}{\partial\lambda}$ remains constant as λ increases above that value.

Finally, from Equation (A.12), since $\dfrac{dq_{oj}^*}{d\lambda}$ and $\dfrac{\partial v_j^*}{\partial\lambda}$ have the same sign, (see the proof of Lemma 1), $\dfrac{\partial v_j^*}{\partial\lambda}$ and $\dfrac{dv_j^*}{d\lambda}$ have the same sign. Q.E.D.

Proof of Proposition: The proposition will be proved by showing that $U_m^*(\lambda)$ is a nondecreasing function of λ. To do so, the derivative $\dfrac{\partial U_m^*(\lambda)}{\partial\lambda}$ will be evaluated. This presents a problem, however, at $\lambda = 0$. To see why, notice first that the manager is subject to either constraint (20) for all $\lambda > 0$ or to constraint (21) for all $\lambda > 0$. This is so because, from Lemma 2, $\dfrac{\partial v_j^*}{\partial\lambda}$ and $v_j^*(\lambda) - v_j^*(0)$ are either positive for all λ or nonpositive for all λ. The manager therefore faces the same constraint set for all $\lambda > 0$. But at $\lambda = 0$ the constraint set changes. $U_m^*(\lambda)$ may then be discontinuous at $\lambda = 0$. Because of this problem another method must be used below to show that $U_m^*(\lambda)$ is also nondecreasing at $\lambda = 0$.

For $\lambda > 0$:

$$\frac{\partial U_m^*(\lambda)}{\partial\lambda} = U_{m0}\left[\left(\bar{t}_{mj} - \hat{t}_{mj}^*\right)\frac{\partial v_j^*}{\partial\lambda} + \hat{t}_{mj}^*\left(\sum_s \frac{U_{ms}}{U_{m0}}\frac{dq_{sj}^*}{d\lambda} - \frac{dq_{0j}^*}{d\lambda}\right)\right] \tag{A.15}$$

where $\hat{t}_{mj}^*$ is the manager's optimal firm j shareholding level given that he is constrained in his actions according to problem P. (The derivation of (A.15) follows along the same lines as that for (9).)

Given (20), (21), and Lemma 2, the first term of (A.15) is nonnegative. The second term is also nonnegative as is easily shown. If $v_j^*(\lambda) - v_j^*(0) > 0$ and therefore $\dfrac{\partial v_j^*}{\partial\lambda} > 0$, then the manager is constrained to hold no more than $\bar{t}_{mj}$ shares. If the constraint is binding, then, from Lemma 1 $\sum_s \dfrac{U_{ms}}{U_{m0}}\dfrac{dq_{sj}^*}{d\lambda} - \dfrac{dq_{0j}^*}{d\lambda} > 0$. If the constraint is not binding, then the term drops out to zero. A similar argument shows that the term is also nonnegative when $\dfrac{\partial v_j^*}{\partial\lambda} \leq 0$. Therefore

$\dfrac{\partial U_m^*(\lambda)}{\partial \lambda}$ is uniformly nonnegative for all λ: $0 \leq \lambda < 1$.

To show that $U_m^*(\lambda)$ is also nondecreasing at $\lambda = 0$, assume, for the moment, that constraint (22) read instead as follows:

$$\bar{t}_{mj} - t_{mj} \geq 0 \quad \text{if} \quad \frac{\partial v_j}{\partial \lambda} > 0,\ \lambda = 0 \tag{A.16}$$

$$\bar{t}_{mj} - t_{mj} \leq 0 \quad \text{if} \quad \frac{\partial v_j}{\partial \lambda} \leq 0,\ \lambda = 0 \tag{A.17}$$

If this were the constraint, then, from the reasoning above, $\dfrac{\partial U_m^*(\lambda)}{\partial \lambda}$ would exist at $\lambda = 0$ and would be nonnegative. $U_m^*(\lambda)$ would be nondecreasing at $\lambda = 0$. The actual constraint (22), however, is more constricting than are constraints (A.16) and (A.17); the manager would not be able to attain a higher utility with it in effect than with (A.16) and (A.17) in effect. Therefore $U_m^*(\lambda)$, using constraint (22) at $\lambda = 0$, must be nondecreasing at $\lambda = 0$. Q.E.D.

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