CONTRACTS TO SELL INFORMATION

by

Franklin Allen

12-85

RODNEY L. WHITE CENTER FOR FINANCIAL RESEARCH
The Wharton School
University of Pennsylvania
Philadelphia, PA 19104

CONTRACTS TO SELL INFORMATION

Franklin Allen*
University of Pennsylvania

Abstract

There is often a moral hazard when information is sold since anyone can claim to have superior information. This paper considers feasible and optimal strategies which allow this problem to be overcome, in the context of a standard one-period, two-asset model. It is shown that it is always better for informed people to sell their information rather than to just use it for speculation. However, because of the moral hazard problem the seller cannot obtain the full returns to his information. This provides an incentive for intermediation since an intermediary may be able to capture some of the remaining returns.

Address: Finance Department
The Wharton School
University of Pennsylvania
Philadelphia, PA 19104
U.S.A.

---

*I am grateful to S. Bhattacharya for many helpful discussions, and to the Fishman-Davidson Center for financial support.

1. Introduction

Hirshleifer (1971) suggested three ways in which individuals can use private information about the future returns to securities: consumptive adaptation, speculation and the sale of information. He considered the first two in detail but did not pursue the third, pointing out that there is a significant moral hazard problem when information is sold (p. 565): ". . . it may not be easy for an informed individual to authenticate possession of valuable foreknowledge for resale purposes. After all, anyone could claim to have such knowledge." Despite this problem it would seem that information about future returns to securities is often sold. This takes the form either of a direct sale of advice on which securities to invest in, or of an indirect sale where portfolio managers use their superior information to manage other people's assets.

The purpose of this paper is to consider feasible and optimal strategies for the direct sale of information in the context of a standard one-period, two-asset model. Since consumption only occurs at the end of the period, there is no scope for consumptive adaptation: an informed person can either use his information to speculate or he can sell it. The model involves exponential utility functions and normally distributed returns to the risky asset. The other important assumptions are that a person's degree of risk aversion is unobservable and the transmission of information from a seller to a buyer takes a finite time.

Information about the return to the risky asset is sold in the following way. Before the informed person observes his information, he announces to prospective buyers a set of schedules where the payment to the seller depends on the realization of the return to the risky asset. It can be shown that this is equivalent to his announcing his degree of risk aversion and the variance of his estimate of the return to the risky asset. The seller identifies himself as informed by constraining each schedule in such a way that nobody who was uninformed would accept it, no matter what their degree of absolute risk aversion: they would always be better off just investing in the two assets. The optimal set of schedules that satisfy this constraint involve payments which are a quadratic function of the return to the risky asset. Next the buyers decide whether or not the information is worth purchasing. Finally, the seller observes his information and chooses a particular payment schedule from the previously announced set. This is equivalent to his announcing his expected return to the risky asset.

The seller is unable to obtain the full value of his information because of the restriction on the payment schedules necessary to overcome the moral hazard problem: nevertheless he is always better off selling his information rather than just using it to speculate. If sufficient time remains, before asset markets meet, for a buyer to resell his information then he will also be better off doing this than just speculating. The model thus provides a motive for intermediation: although the original seller is unable to obtain the full returns to his information, an intermediary may be able to capture some of the remaining returns. The only people who will use the information to speculate are those who receive it too late to resell it.

In a related paper, Bhattacharya and Pfleiderer (1984) have considered the question of how portfolio owners can ensure that only portfolio managers with access to precise estimates of future returns are hired. A principal-agent framework, in which the owners are the principal and the manager the agent, is used. The main difference in assumptions is that the utility function of the manager is assumed to be known by the owners. Also, the owners are able to ensure the manager only receives the utility corresponding to his exogenously given alternative opportunity, if he does not manage the portfolio. Bhattacharya and Pfleiderer derive the approximately optimal contract in the case where the portfolio owners are effectively risk-neutral and show it also involves a reward schedule which is a quadratic function of the payoff to the risky asset.

Ramakrishnan and Thakor (1984) have considered the role of intermediaries in assuring information reliability. Their model involves firms which issue new securities, hiring information producers to certify the value of these. In contrast to here, they assume that the utility functions of the information producers are publicly known and that there is a stochastic ex-post indicator of the effort expended in acquiring the information. These assumptions enable information reliability to be ensured, by conditioning the information producers' payment on the signal of effort. In this context they are able to demonstrate a different rationale for intermediation: provided information producers can monitor each other directly, it is better for them to form an intermediary rather than operate individually, since this permits diversification of the risk associated with the effort indicator.

The paper proceeds as follows. Section 2 describes the model in detail. Section 3 considers the market for information. Finally, Section 4 contains concluding remarks.

2. The Model

A standard one-period, two-asset model is used. The i^{th} trader is assumed to be endowed with stocks of the two types of security: each originally has $\overline{M}_i$ of the riskless asset and $\overline{X}_i$ of the risky asset. When trade occurs each person buys M_i and X_i of the two assets respectively. The price of the safe asset is normalized at unity and the price of the risky asset is P. The i^{th} person's budget constraint is therefore

$$W_{0i} = \overline{M}_i + P\overline{X}_i = M_i + PX_i \ . \tag{1}$$

The safe asset yields R and and the risky asset u. At the end of the period, when the asset returns are received, the i^{th} trader's wealth is

$$W_{1i} = RM_i + uX_i = RW_{0i} + (u - RP)X_i \ . \tag{2}$$

Each person has an exponential utility function which depends on wealth at the end of the period:

$$V(W_{1i}) = - \exp(-a_i W_{1i}) \ . \tag{3}$$

Everybody is risk averse. The distribution of a_i is unbounded above and has positive density for all $a_i > 0$.

The return on the risky asset u is normally distributed with a distribution function denoted F(u). It is the sum of two independent variables, θ and ε, which are $N(E\theta, \sigma_\theta^2)$ and $N(0, \sigma_\varepsilon^2)$ respectively

$$u = \theta + \varepsilon \ . \tag{4}$$

Hence u is $N(E\theta, \sigma_u^2)$ where

$$\sigma_u^2 = \sigma_\theta^2 + \sigma_\varepsilon^2 \ . \tag{5}$$

There is a person, denoted I for informed, who can observe θ. For simplicity, his cost of doing this is taken to be zero. (The only difference if there was a positive cost would be that the person would have to decide whether it was worthwhile becoming informed, and choose the optimal value of σ_θ^2 if a range was possible at different costs. Apart from this, the analysis below would be unchanged.) The distribution function of his prior on u having observed θ, is $F(u|\theta)$. Nobody else observes θ directly or any other variable correlated with θ, except u. There is also no direct indicator of whether the person has observed θ. The assets and trades of the informed person are observable, but his degree of absolute risk aversion, a_I, is not.

There is a continuum of traders so that the actions of any single trader or finite group of traders have no effect on prices. This implies all transactors are price-takers and prices convey no information about θ provided only a finite number of traders become informed through the information market.

The model assumes rational expectations: the structure of the economy is known to all the participants. In particular, they know u is $N(E\theta, \sigma_u^2)$, they are aware that everybody has an exponential utility function and they know the distribution of a_i. However they do not know a_I or σ_θ^2.

There is a finite amount of time taken for the transmission of information between seller and buyer. Initially it is assumed there is only sufficient time between the informed person's receipt of his information and the meeting of the asset markets for information to be sold once. Hence any buyers of information can only use it to speculate with: they cannot resell it.

3. The Market for Information

The sequence of events when information is sold is the following:

(i) The seller announces a set of optimal payment schedules with one schedule for each possible value of θ. It is shown below this is equivalent to his announcing a_I and σ_θ^2(or σ_ε^2). Each schedule specifies the total payment from the buyers to the seller as a function of the payoff u to the risky asset. The seller makes each of the n buyers bear an equal proportionate share, 1/n, of the payment.

(ii) Each buyer decides whether or not to purchase the information.

(iii) The seller observes θ. He chooses the actual payment schedule, from the previously announced set, to be used and transmits it to the buyers. This is equivalent to announcing θ.

(iv) Asset markets meet.

(v) The payoff to the risky asset is realized and this determines the buyers' payments to the seller.

The analysis proceeds as follows. First, the question of how payment schedules can be designed to ensure that the seller is informed is considered and the optimal schedules are then derived. Second, it is shown that announcing the set of optimal schedules in stage (i) of the procedure is equivalent to announcing a_I and σ_θ^2. Also, choosing a particular schedule in stage (iii) from this set is equivalent to announcing θ. The third stage of the analysis is to demonstrate buyers will be willing to purchase the information, provided their proportionate share of the payment schedule is sufficiently low. Fourth, it is shown that the informed person is always better off selling his information than using it to just speculate. Fifth, the implication of this for the role of intermediaries is considered. Finally, the assumptions and results obtained are compared with those of related papers.

The main problem in selling information is the moral hazard pointed out by Hirshleifer. To overcome this, the contract for selling the information must be such that it demonstrates the seller does indeed have superior knowledge. Nobody apart from the informed person observes θ and it is not correlated with any observable variables except u. Hence the seller's compensation should depend on u and appropriate restrictions should be imposed which ensure no uninformed person would be willing to accept this reward schedule.

Since the informed person's assets and trades are observable, it is possible for the contract to be written in terms of his total receipts, including the returns from his own assets. For ease of notation and without loss of generality, it is simplest to work with a payment schedule $\Pi(u)$ which consists of his total receipts over and above RW_{0I}. Hence the informed person's wealth at the end of the period will be

$$W_{1I} = RW_{0I} + \Pi(u) \quad . \tag{6}$$

In order to ensure the information seller is informed, the payment schedule must be such that no uninformed person would be prepared to accept it. Now if an uninformed person just invests in the two assets, it can be shown in the usual way using (2), (3) and the moment generating function for the normal distribution that his expected utility is given by:

$$EV_{Ui} = -\exp\left(-a_i\left[RW_{0i} + (E\theta - RP)X_{Ui} - \frac{1}{2}a_i\sigma_u^2 X_{Ui}^2\right]\right) \quad . \tag{7}$$

This gives the standard result that his optimal demand for the risky asset is

$$X_{Ui} = \frac{E\theta - RP}{a_i\sigma_u^2} \quad . \tag{8}$$

Hence substituting back into (7)

$$EV_{Ui} = -\exp\left(-a_i RW_{0i} - \frac{\zeta^2}{2\sigma_u^2}\right) \tag{9}$$

where

$$\zeta = E\theta - RP \quad . \tag{10}$$

It follows that a necessary and sufficient condition for $\Pi(u)$ to ensure the seller is informed is (cancelling the constant $\exp(-a_i RW_{0i})$)

$$-\int \exp\left[-a_i\Pi(u)\right]dF(u) < -\exp\left(-\frac{\zeta^2}{2\sigma_u^2}\right) \qquad \text{for all } a_i > 0 \quad . \tag{11}$$

(It is assumed in the usual way that, when indifferent, the seller acts in the buyers' interests.) Clearly (11) is sufficient to ensure that the seller is informed. It is also necessary since, if it were not satisfied an uninformed person would be better off to offer $\Pi(u)$ than to undertake his best alternative, which is just to invest in the two assets.

Let

$$\eta(a) = - \int \exp\left[- a\Pi(u)\right] dF(u) \; . \tag{12}$$

Since η is a concave function of a, its maximum value is attained at a* where

$$\eta'(a^*) = \int \Pi(u)\exp\left[-a^*\Pi(u)\right] dF(u) = 0 \; . \tag{13}$$

Hence (11) is equivalent to (13) taken together with the requirement

$$- \int \exp\left[-a^*\Pi(u)\right] dF(u) < - \exp\left(- \frac{\zeta^2}{2\sigma_u^2}\right) \; . \tag{14}$$

The sellers' optimal payment schedule, $\Pi^*(u, a_I, \sigma_\theta^2, \theta)$, is the solution to (ignoring the constant $\exp(- a_I RW_{0I})$)

$$\text{Max} \; - \int \exp\left[- a_I \Pi(u)\right] dF(u|\theta) \tag{15}$$

subject to (13) and (14).

It is then possible to show:

<u>Proposition 1</u>

The optimal set of schedules involves

$$\Pi^*(u, a_I, \sigma_\theta^2, \theta) = \alpha u^2 - 2\beta u + \gamma \tag{16}$$

where

$$\alpha = \frac{\sigma_\theta^2}{2(a^* - a_I)\sigma_\varepsilon^2\sigma_u^2} \tag{17}$$

$$\beta = \frac{1}{2(a^* - a_I)}\left(\frac{\theta}{\sigma_\varepsilon^2} - \frac{E\theta}{\sigma_u^2}\right) \tag{18}$$

$$\gamma = \frac{a_I(\theta - E\theta)^2}{2(a^* - a_I)(a^*\sigma_u^2 - a_I\sigma_\varepsilon^2)} + \frac{\zeta^2}{2a^*\sigma_u^2} + \frac{1}{2a^*}\log\left[\frac{\sigma_\varepsilon^2(a^* - a_I)}{a^*\sigma_u^2 - a_I\sigma_\varepsilon^2}\right] + \frac{1}{2(a^* - a_I)}\left[\frac{\theta^2}{\sigma_\varepsilon^2} - \frac{(E\theta)^2}{\sigma_u^2}\right] \tag{19}$$

and a* is given uniquely by

$$\xi_1(a^*) = (a^*\sigma_u^2 - a_I\sigma_\varepsilon^2)\left(\frac{\zeta^2}{\sigma_u^2} + \log\left[\frac{\sigma_\varepsilon^2(a^* - a_I)}{a^*\sigma_u^2 - a_I\sigma_\varepsilon^2}\right]\right) + a^*\sigma_\theta^2 - \frac{a^{*2}\sigma_u^2(\theta - E\theta)^2}{a^*\sigma_u^2 - a_I\sigma_\varepsilon^2} = 0\ . \tag{20}$$

together with the requirement

$$a^*\sigma_u^2 - a_I\sigma_\varepsilon^2 < 0\ . \tag{21}$$

Proof

The maximization problem (15) can be solved straightforwardly to give (16) - (19). Then substituting in (13) gives (20). However, (20) alone does not necessarily uniquely define a*. For example, in the case where $\sigma_u^2 = 2$, $\sigma_\varepsilon^2 = \sigma_\theta^2 = 1$, $a_I = 1$, $\zeta = 1$ and $\theta = E\theta = 1$, it can readily be seen $a^* = 0.37$ and $a^* = 1.76$ are both solutions to (20). Nevertheless, combining (20) with (21) does give a unique optimal value of a*. This is shown in two steps: first, there does exist a unique value satisfying (20) and (21), and second, this value yields a strictly higher expected utility than any value of a* not satisfying (21).

A value of a* satisfying (20) and (21) exists since ξ_1 is continuous in this range, $\xi_1(0) < 0$ and $\lim_{a^* \to a_I\sigma_\varepsilon^2/\sigma_u^2} \xi_1(a^*) > 0$. The value is unique because given (21), it can be shown that whenever $\xi_1(a^*) = 0$, $\xi_1'(a^*) > 0$.

The second result follows from the expression for the expected utility of the information seller which can be shown to be:

$$- \int \exp\left[- a_I\left(RW_{0I} + \Pi^*(u)\right)\right] dF(u|\theta) = - \exp\left[- \frac{a_I}{2}\left(2RW_{0I} - \frac{(\theta - E\theta)^2}{a^*\sigma_u^2 - a_I\sigma_\varepsilon^2}\right.\right.$$

$$\left.\left. + \frac{\zeta^2}{a^*\sigma_u^2} + \frac{1}{a^*}\log(1 - a^*\nu) - \frac{1}{a_I}\log(1 - a_I\nu)\right)\right] \tag{22}$$

where

$$\nu = \frac{\sigma_\theta^2}{a^*\sigma_u^2 - a_I\sigma_\varepsilon^2} . \tag{23}$$

In order for the expected utility integral to exist either $a^* < a_I\sigma_\varepsilon^2/\sigma_u^2 (< a_I)$ or $a^* > a_I (> a_I\sigma_\varepsilon^2/\sigma_u^2)$. Let

$$\ell(a) = \frac{1}{a^*}\log(1 - a^*\nu) - \frac{1}{a}\log(1 - a\nu) . \tag{24}$$

It can be seen $\ell(a^*) = 0$. For $\nu = 0$, it can be shown $\partial\ell/\partial a = 0$. For $\nu < 0$, $\partial^2\ell/\partial a\partial\nu < 0$ and so for $a^* < a_I\sigma_\varepsilon^2/\sigma_u^2$, $\partial\ell/\partial a > 0$ and $\ell(a_I) > 0$. For $\nu > 0$, $\partial^2\ell/\partial a\partial\nu > 0$ and so for $a^* > a_I$, $\partial\ell/\partial a > 0$ but now $\ell(a_I) < 0$. The remaining terms in (22) are clearly greater when $a^* < a_I\sigma_\varepsilon^2/\sigma_u^2$ than when $a^* > a_I$. Hence any solution with a^* satisfying (21) is strictly better than any other feasible solution not satisfying (21) and the proposition is demonstrated.

The use of the set of schedules $\Pi^*(u, a_I, \sigma_\theta^2, \theta)$ identifies the seller as informed since no uninformed person would want to choose any of these. It is next shown how the buyer can relate the schedules to the seller's information.

Proposition 2

Announcing a set of schedules $\Pi^*(u, a_I, \sigma_\theta^2, \theta)$ at stage (i) is equivalent to announcing a_I and σ_θ^2. Subsequently, announcing at stage (iii) which of these is to be used, is equivalent to announcing θ.

Proof

To demonstrate the first part of the proposition, it is necessary to show that there is a one-to-one correspondence between a_I and σ_θ^2 and the set of schedules. It follows directly from Proposition 1 that for each a_I and σ_θ^2 there is a unique set. It then remains to show that for each set the values of a_I and σ_θ^2 can be uniquely identified.

To see this, first consider what can be deduced, given a single schedule (i.e., a particular α, β and γ) and the equations (17) - (21). Rewriting (17) gives

$$\frac{(a^* - a_I)\sigma_\varepsilon^2}{\sigma_\theta^2} = \frac{1}{2\alpha\sigma_u^2} = Z \tag{25}$$

where Z (< 0 from (21)) is a constant which is observable to the buyer. Using (25) together with (18) allows (20) to be written in the form

$$\xi_2(a^*) = (a^* + Z)\left[\frac{\zeta^2}{\sigma_u^2} + \log\left(\frac{Z}{a^* + Z}\right)\right] + a^* - a^{*2}\,\frac{(\beta/\alpha - E\theta)^2}{\sigma_u^2(a^* + Z)} = 0 \;. \tag{26}$$

Since $\xi_2(0) < 0$, $\lim_{a^* \to -Z} \xi_2(a^*) > 0$ and $\xi_2'(a^*) > 0$, this equation enables the unique value of a^* satisfying (21) to be found. However, it is not then possible to use the remaining equations to solve for θ, σ_θ^2 and a_I. This is because substituting into (19) using (17), (18) and (25) gives

$$\gamma = \frac{(\beta/\alpha - E\theta)^2 a^*}{2\sigma_u^2(a^* + Z)Z} + \frac{\zeta^2}{2a^*\sigma_u^2} + \frac{1}{2a^*}\log\left(\frac{Z}{a^* + Z}\right) - \frac{(E\theta)^2}{2Z\sigma_u^2} + \frac{\beta E\theta}{\alpha Z\sigma_u^2} \tag{27}$$

which is independent of a_I, σ_θ^2 and θ.

However, it follows from (20) that $da^*/d(\theta - E\theta)^2 < 0$. Hence, given any two schedules (denoted by the subscripts 1 and 2) from a set, it is possible to use (26) to find the values of a_1^* and a_2^*. Then using the corresponding coefficients α_1 and α_2 together with (17) gives two simultaneous equations which can be solved uniquely to give

$$a_I = \frac{\alpha_2 a_2^* - \alpha_1 a_1^*}{\alpha_2 - \alpha_1} \tag{28}$$

$$\sigma_\theta^2 = \frac{2\alpha_1(a_1^* - a_I)\sigma_u^4}{1 + 2\alpha_1(a_1^* - a_I)\sigma_u^2}\,. \tag{29}$$

Hence the first part of the proposition is proved.

For the second part of the proposition, it can again be seen from Proposition 1 that for each θ there is a unique schedule. To deduce θ from a particular schedule, (17) can be divided by (18) and rearranged to give

$$\theta - E\theta = \left(\frac{\beta}{\alpha} - E\theta\right)\frac{\sigma_\theta^2}{\sigma_u^2}\,. \tag{30}$$

The value of σ_θ^2 obtained in stage (i) of the procedure can be used in this to uniquely deduce θ and the proposition is proved.

It has now been shown how information can be sold: it remains to demonstrate that buyers will be prepared to purchase the information at stage (ii) of the procedure.

Proposition 3

Provided a buyer's proportionate share of the payment is sufficiently small (i.e., n is sufficiently large), it will always be worthwhile for him to purchase information. Hence information can always be sold.

Proof

When the informed person sells to a finite number of people, his actions will have no effect on the price of the risky asset since there is a continuum of traders. This means the uninformed will not be able to deduce anything about θ from this price. In deciding whether to purchase the information, they therefore compare their average expected utility given θ, n and Π^* to their expected utility when uninformed.

The final wealth of an information buyer (denoted by the subscript B) is

$$W_{1B} = RW_{0B} + (u - RP)X_B - \frac{\Pi^*(u)}{n} . \tag{31}$$

Using this in (5) and evaluating expected utility by taking expectations over ε, it can be shown

$$\begin{aligned} EV_B = - \exp\Big[-a_B\Big(RW_{0B} &+ \frac{(\theta - RP)^2}{2a_B\sigma_\varepsilon^2}\left[1 - \frac{a_B}{n(a^* - a_I)}\frac{\sigma_\theta^2}{\sigma_u^2}\right] \\ &+ \frac{1}{2a_B}\log\left[1 - \frac{a_B}{n(a^* - a_I)}\frac{\sigma_\theta^2}{\sigma_u^2}\right] - \frac{1}{2(a^* - a_I)n}\Big[\frac{a_I(\theta - E\theta)^2}{a^*\sigma_u^2 - a_I\sigma_\varepsilon^2} - \frac{(\theta - E\theta)^2}{\sigma_u^2} \\ &+ \frac{2(\theta - E\theta)(\theta - RP)}{\sigma_u^2}\Big] - \frac{1}{2na^*}\Big(\frac{\zeta^2}{\sigma_u^2} + \log\Big[\frac{\sigma_\varepsilon^2(a^* - a_I)}{a^*\sigma_u^2 - a_I\sigma_\varepsilon^2}\Big]\Big)\Big)\Big] . \end{aligned} \tag{32}$$

It can be seen immediately that

$$\lim_{n\to\infty} EV_B = - \exp\left[-a_B\left(RW_{0B} + \frac{(\theta - RP)^2}{2a_B\sigma_\varepsilon^2}\right)\right] . \tag{33}$$

which (similarly to (9)) is the expected utility of somebody informed at zero cost. Since it can be easily shown that it is strictly better to be informed at zero cost than not to be, it follows that a sufficiently large n can always be found such that the buyer is strictly better off purchasing the information at stage (ii). Thus the proposition is demonstrated.

The assumption of a continuum of traders means that the seller can ignore the effect of his actions on the price of the risky asset. If the model involved a finite number of traders, the price of the risky asset would convey information about θ to the uninformed. In this case the buyers' appropriate comparison of the average expected utility from buying the information would be with the average expected utility, given the information about θ deduced from the price. Provided there is sufficient noise in the supply or demand for the risky asset, a similar result to that above should hold. However, in the extreme case where there is no noise, the risky asset's price would perfectly reveal θ and it would not be possible to sell information. (See e.g., Grossman and Stiglitz (1980), Hellwig (1980) and Diamond and Verrechia (1981).)

Although it has now been shown that information can be sold, the constraints (13) and (14) mean that it is not necessarily optimal for the informed person to do this. He could simply use his information to speculate in which case he will not be constrained by (13) and (14). In fact it is possible to show:

<u>Proposition 4</u>

It is always better for the informed person to sell his information than to use it to just speculate.

Proof

If the informed person sells his information, his expected utility, denoted EV_{IS}, is given by (22). If he just uses his information to invest in the two assets, his expected utility, EV_{IRA}, is as in (33). Dividing (22) by (33) gives

$$\frac{EV_{IS}}{EV_{IRA}} = \exp\Big[-\frac{a_I}{2}\Big(\frac{\zeta^2}{a^*\sigma_u^2} - \frac{(\theta - E\theta)^2}{a^*\sigma_u^2 - a_I\sigma_\varepsilon^2} - \frac{(\theta - RP)^2}{a_I\sigma_\varepsilon^2}$$

$$+ \frac{1}{a^*}\log(1 - a^*\nu) - \frac{1}{a_I}\log(1 - a_I\nu)\Big)\Big] \;. \tag{34}$$

Using (10)

$$\frac{\zeta^2}{a^*\sigma_u^2} - \frac{(\theta - E\theta)^2}{a^*\sigma_u^2 - a_I\sigma_\varepsilon^2} - \frac{(\theta - RP)^2}{a_I\sigma_\varepsilon^2} = \frac{[(\theta - E\theta)a^*\sigma_u^2 - \zeta(a_I\sigma_\varepsilon^2 - a^*\sigma_u^2)]^2}{(a_I\sigma_\varepsilon^2 - a^*\sigma_u^2)a^*\sigma_u^2 a_I\sigma_\varepsilon^2} > 0 \tag{35}$$

where the inequality follows from (21). In addition, it was shown in the proof of Proposition 1 that for $a^* < a_I\sigma_\varepsilon^2/\sigma_u^2$, $\ell(a_I) > 0$.
Thus $EV_{IS}/EV_{IRA} < 1$ or equivalently $EV_{IS} > EV_{IRA}$ (since utility is negative) and the proposition is demonstrated.

The moral hazard problem associated with selling information means that the original seller is unable to obtain the full benefits of his information: these benefits are unbounded since there is a continuum of traders, but because of the moral hazard constraint (11) the seller can only obtain the expected utility EV_{IS}. So far it has been assumed that the buyers obtain the information too late to resell it. If the model is extended to the case where sufficient time remains to allow buyers to resell the information, then they can become intermediaries and obtain some of the private benefits of the information that the original seller is unable to extract.

If the payment schedules the original seller announces at stages (i) and (iii) cannot be observed at any point by the second-stage buyers, then the intermediary must again use payment schedules of the type described above to verify that he is informed. Proposition 4 will still hold and the buyer will always be better off acting as an intermediary rather than using the information to speculate. If the payment schedules the original seller announces are observable to second-stage buyers, possibly ex-post, then the intermediary can use this to verify the information he sells. In this case there is no need to make the payment for the information depend on the payoff to the risky asset: it would, for example, be possible to use a fixed fee.

This discussion is summarized by the following:

Proposition 5

If a buyer of information has sufficient time before asset markets meet to act as an intermediary and resell the information, it will always be worthwhile for him to do this.

Bhattacharya and Pfleiderer (1984) consider a related single-period, two-asset model. Their concern is to construct screening contracts which assure that owners of portfolios are able to identify portfolio managers capable of precise (i.e., low variance) estimates of the expected return to the risky asset.

They also use exponential utility functions and normally distributed returns. However, their model differs in a number of other ways. First, they assume the utility function of the portfolio manager (who corresponds to the information seller above) is observable, whereas here it is taken to be unobservable. Second, the portfolio owners (here the information buyers) are able to ensure that the manager's utility does not exceed that from an exogenously specified alternative earnings opportunity. This means the portfolio owners obtain all the surplus that arises from the manager's superior information. In contrast, here the seller is able to obtain a surplus from his information. If n is sufficiently large or intermediation is feasible, the buyers may also obtain a surplus.

Bhattacharya and Pfleiderer are able to show that the approximately optimal contract in the case where the portfolio owners are effectively risk neutral, also involves a reward schedule which is a quadratic function of the payoff to the risky asset. However, because of the nature of the differences in assumptions, the schedules differ in ways which are difficult to interpret.

Ramakrishnan and Thakor (1984) are concerned with deriving a theory of intermediation based exclusively on informational asymmetries and the related issue of information reliability, rather than on transaction cost advantages. They consider a model where firms issuing new securities hire information producers to certify the value of these securities. The moral hazard problem is to ensure that the information producers do the necessary research. The main differences between their model and the one above is that they assume the existence of a noisy ex-post indicator of effort, and that utility functions are observable. It is therefore possible to overcome the moral hazard problem directly by conditioning the payment to the information producer on this ex-post indicator. However, because the indicator is stochastic, the information producers must bear the associated risk. Ramakrishnan and Thakor are able to show that if the information producers can costlessly monitor each other, they can diversify away this risk by joining together and forming an intermediary.

The analysis above presents another theory of intermediation based solely on informational asymmetries and information reliability. In contrast to

Ramakrishnan and Thakor, the incentive to form an intermediary arises because the solution to the moral hazard problem limits the returns the original seller can obtain. Intermediation is profitable because the intermediary is able to obtain some of the uncaptured benefits of the original seller's information.

4. Concluding Remarks

This paper has been concerned with deriving feasible and optimal strategies for selling information. To make the analysis tractable exponential utility functions and normally distributed returns were assumed. These allow restrictions on payment schedules, which are both necessary and sufficient to ensure the seller is informed, to be derived. In more general models, simple sufficient conditions can be fairly easily found. For example, it can be shown that requiring the expected value of the payment schedule, in terms of the uninformed distribution, to be zero, is sufficient to identify the seller as informed. However, finding conditions which are also necessary is much more complex in such situations.

An important feature of the model is that the time horizon is only one period. In any multiperiod model, reputation considerations seem likely to be of importance in eliminating the moral hazard associated with information sales. In any finite horizon situation, the above analysis should be directly applicable to the last period and information sales in the previous periods should then be dependent on this. However, for infinite horizon models the analysis above may not be directly applicable.

References

Bhattacharya, S. and P. Pfleiderer (1984). "Delegated Portfolio Management," Journal of Economic Theory, (forthcoming).

Diamond, D. W. and R. E. Verrecchia (1981). "Information Aggregation in a Noisy Rational Expectations Economy," Journal of Financial Economics, 9, 221-235.

Grossman, S. J. and J. E. Stiglitz (1980). "On the Impossibility of Informationally Efficient Markets," American Economic Review, 70, 393-408.

Hellwig, M. F. (1980). "On the Aggregation of Information in Competitive Markets," Journal of Economic Theory, 22, 477-498.

Hirshleifer, J. (1971). "The Private and Social Value of Information and the Reward to Inventive Activity," American Economic Review, 61, 393-408.

Ramakrishnan, R. T. S. and A. V. Thakor (1984). "Information Reliability and a Theory of Financial Intermediation," Review of Economic Studies, 51, 415-432.