A list of Working Papers on the last pages

No. 208, 1988

INCENTIVE CONTRACTS FOR MANAGERS WHO DISCOVER AND MANAGE INVESTMENT PROJECTS

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Paper prepared for the IUI Conference on
Markets for Innovation, Ownership and Control,
June 12–16, 1988, at Grand Hotel, Saltsjöbaden

May, 1989

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WHO DISCOVER AND MANAGE INVESTMENT PROJECTS

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REVISED AUGUST 1988

Prepared for conference on Markets for Innovation, Ownership and Control, Stockholm, June 1988.

I. INTRODUCTION

A crucial part of the process of innovation is the discovery of new investment projects which appear, ex ante, to have attractive returns. In most real investment projects, information about the investment's future profitability must be generated or discovered by those who will manage that project. As a result, the managers who discover the project will often be better informed about that project than will investors who provide the necessary capital. While managers may be better informed about projects than will investors, both types of market participants will generally be imperfectly informed about the ability of individual managers. We can expect that managers will make decisions about whether to use investors' capital to undertake risky investments on the basis of how those decisions will affect their own personal returns, including the return on their human capital. The problem facing investors is to devise ways to provide the proper incentives for innovation---where innovation involves the discovery of new investments and decision-making about whether to undertake those investments.

In this paper we are concerned with these incentive problems pertaining to innovation. We will focus on organizations where there is imperfect information about both the characteristics of investment projects and the ability of managers. We will assume that managers in these organization are hired to discover projects which appear to be profitable, ex ante as well as to manage those projects in order to produce profits. We assume that managers who have superior ability will be more proficient

at both of these tasks, but we also assume that both managers as well as all other market participants do not know, with certainty, the ability of individual managers. As a result, managers, as well as employers, learn by observing performance, where performance means both the selection of projects and the actual returns those projects eventually generate. This paper is devoted to exploring how principals may select contracts to induce managers to make optimal investment decisions, when managers privately observe information which is informative both about their own ability and about the value of projects which they may choose to undertake.

Our paper is most closely related to recent papers by Holmstrom and Ricart i Costa [1986] and Christensen [1981] [1982]. Holmstrom and Ricart i Costa consider a model where managers are employed by principals in a firm which lasts for an arbitrary number of periods (at least two). At the end of the initial period, managers observe a signal about the value of a new investment which might be undertaken by the firm and the managers have responsibility for deciding whether the project should be undertaken. In general, managers' incentives to undertake the project will differ from those of the principal because the project can produce information about the ability of managers which is valuable to managers but not to principals. The investment project undertaken by the firm is in part an experiment which generates information about managerial ability. Since managers will make the firm's investment decision on the basis of the value of the project to principals as well as the value of the information generated by this experiment, it is

apparent that the manager's decision criterion can diverge from that of the principal.

Throughout their analysis, Holmstrom and Ricart i Costa assume that the ability of the manager influences the actual returns generated by an investment project but not the quality of the signal observed by the manager. They characterize this as an assumption that the manager has no forecasting ability. This implies that the actual decision as to whether a project should be undertaken communicates no information to the market about ability. However, observed returns do communicate this information. Since the market cannot learn anything about managers from the go or no go announcement itself, the announcement cannot affect the manager's compensation. Holmstrom and Ricart i Costa's approach allows them to focus on the role of the project as an experiment which produces information about managerial ability.

In this paper we are interested in exploring the incentive problems surrounding managers who are responsible both for discovering projects and managing them and we postulate that managerial ability is relevant for both tasks. Hence, we need to imbue the managers with what Holmstrom and Ricart i Costa called forecasting ability. However, unlike Holmstrom and Ricart i Costa, we will completely ignore the role of investments as experiments which produce information about managerial ability. The assumption that ability influences both the discovery as well as the management phases of investment activities implies that managers will learn more about their own ability than will

outsiders or principals. By observing a signal about the value of an investment, a manager acquires information about his own ability. Assuming that the market and the manager have common priors about ability and the returns from the discovery process, then the manager's announcement of the decision to undertake or forego an investment will communicate information about ability. However, the manager will know the precise value of that signal while the principal will be forced to draw an inference about ability from the dichotomous decision about the project. The asymmetry created provides a natural setting for adverse selection problems to develop.

We will demonstrate that if there were no adverse selection problem, then principals would be able to structure a compensation package, based solely on the observed level of returns actually generated by investment, that would induce the manager to follow a first-best decision rule. However, while such a compensation structure exists, it will never survive the pressures of competitive managerial labor markets when the adverse selection problem is taken into account. Once a compensation function which generates a first-best decision rule for the manager is chosen, the degree of contingency is fixed. Then, a competing firm can always offer managers a compensation package which has a larger portion of total compensation in contingent form. Managers who are undervalued by their firms, based on the signal they alone have observed, will find the competing compensation more attractive. As a result, the firm which initially employs the manager will be compelled to utilize the more contingent contract in order to remain competitive with

other firms who will attempt to bid away its more capable managers. But there is no limit on the degree of contingency. The underlying problem here is that the degree of contingency is indeterminant, yet contingency is the mechanism used to compete for undervalued managers.

We will show that there is a solution to this adverse selection problem which entails contracts that compel managers to reveal their private information. One way to interpret such contracts is that they involve a prior commitment by the manager to a level of future performance. That is, the contract includes contingent compensation based on deviations of performance from a predetermined target level chosen by the manager. Under one possible contract, the principal will commit ahead of time to a schedule which rewards higher target levels with higher shares of the deviations from the target for the manager. In selecting the target, the manager will understand that the higher the target, the higher the share, but also the lower the expected compensation, for any given share. For any specific function for assigning shares to a target chosen by the manager, the principal can infer the manager's private information from his choice of a target. However, the principal must choose that function so that the compensation received by the manager is equal to his fair market valuation, given the inside information he has revealed. We will demonstrate that as long as managers are risk neutral, then there will exist contracts which provide for truthful revelation. Once there is truthful revelation, then the first-best investment decision is achievable.

We will demonstrate that one solution to the problem which we have structured is virtually the same as the solution to the problem posed by Christensen [1981] and [1982]. Christensen considers a model of a moral hazard problem where agents choose an unobservable level of effort which affects the returns on a risky investment. Christensen assumes that the manager can also privately observe a signal which is informative about the level of returns on this project. He then studies the property of a contract between the principal and agent which is dependent both on the observed outcome of the investment and a message or report from the manager to the principal. In his second paper Christensen interprets such a message or reporting in light of accounting procedures as a performance standard where the agent is compensated according the deviation between actual performance and some standard. In Christensen's model the principal will choose a contract which elicits truthful revelation from the agent. He can never be worse off with such a contract and in at least some instances he will be better off. In our model truthful revelation of the agent's inside information is important because it resolves an adverse selection rather than a moral hazard problem. Christensen encounters no adverse selection problem since managerial ability is not an important part of his model and since managers are not allowed to recontract after they have observed their private information. In our model, since managers will be allowed to recontract when their private information is observed, competing firms will attempt to bid away managers whose ability is undervalued. This competition from alternative firms will induce principals to

offer contracts which result in full revelation of private information.

II. THE MODEL

Assumptions

We consider a three-date, two-period model of managerial choice, with time indexed as t = 0,1,2. A manager is endowed with ability level a which is unknown to all market participants. At time zero, the market and the manager share a prior normal distribution on managerial ability with mean a_0 and precision h_0. Time period 1 is a discovery period during which the manager applies himself to the firm, receives a private signal at t = 1, and learns about his ability as well as the returns that he would generate from taking on a risky project. At time one, the manager uses his newly acquired information to make a dichotomous investment choice between a risky project and a risk free default project with a period-two return equal to R. That is , the decision to proceed (not proceed) with the risky project means rejection (acceptance) of the risk free project. Let the period-two return generated by the risky investment project, designated X, be the sum of the true ability of the manager who manages that project and a random term, e:

$$X = a + e. \qquad (1)$$

The private signal observed by the manager at time one is given by

$$z = a + u,$$

where u is a normally distributed random variable with zero mean and precision h_u. The signal z determines the expected value of e through a function $\bar{e}(z)$:

$$E_1[e] = \bar{e}(z), \tag{2}$$

where we assume that $\bar{e}(0) = 0$, $\bar{e}' > 0$, and $\bar{e}'' < 0$. Because both the prior distribution on ability and the distribution on u are assumed to be normal, we can express the mean of the manager's posterior distribution on ability at time 1, a_1, for a given z as

$$a_1 = [h_0/(h_u + h_0)]a_0 + [h_0/(h_u + h_0)]z. \tag{3}$$

To simplify notation, where convenient we will express this as:

$$a_1 = a_1(z) = c + bz. \tag{4}$$

In each period, the manager is compensated for the service he provides---either discovery or management. In addition, it is assumed that the manager always has available alternative employment in a spot labor market which involves management of existing projects where he will be paid a lump-sum payment equal to his perceived ability. As a result, compensation provided to managers must be competitive compared to that available in spot labor markets.

For simplicity we will restrict our analysis to compensation functions for managing a risky project which are a linear function of X. However, it should become apparent that our analysis can easily be extended to more general compensation functions.

Compensation in the first period will always be simply a lump sum payment. Compensation in the second period will depend upon whether the manager chooses to proceed with the risky investment after the discovery phase. If the manager chooses to proceed with the risky project he will receive a share in the returns of that project. If he chooses not to proceed and takes on the risk free project he will receive the lump-sum payment R. Below, R will be taken to be equal to the expected compensation for a risky project which is marginally profitable. Then the compensation in period t will take the form:

$$\text{Period 1} \qquad C_1 = a_0,$$

$$\text{Period 2} \qquad C_2 = \begin{cases} w_P + sX & \text{if he proceeds with the risky project} \\ R & \text{if he does not proceed with the risky project} \end{cases}$$

where w represents the fixed wage and s the share of returns awarded to the manager.

The Investment Decision

At time zero, the principal must decide whether to retain managers in a discovery phase. At time one, managers must decide whether to invest in the risky project or the risk free project. In this section, we will assume that sufficient conditions for the retention of managers are met and we will develop the first-best decision rule for the manager at time one.

At time one, the risky project is expected to be more or less profitable than the risk free project as

$$a_1(z) + \bar{e}(z) \begin{matrix} > \\ = \\ < \end{matrix} R.$$

The critical z such that these expected returns are equal is given, from (4), by the z* solving

$$c + bz^* + e(z^*) = R.$$

Normalizing, we can set R such that $z^* = 0$. Given $\bar{e}(0) = 0$, we have that

$$R = a_1(0) = c. \tag{5}$$

The first-best decision rule at time 1 is then

proceed with the risky project if	$z > 0$,
do not proceed with the risky project if	$z < 0$,

(6)

At time zero, the principal must decide whether it is profitable to retain managers to undertake the discovery phase. If G(z) represents the period zero distribution function associated with the signal z, the retention of managers in the discovery phase is guaranteed by

$$a_1(0)G(0) + [(1 - G(0))E(X|z > 0)] \geq 2a_0. \tag{7}$$

In the next section we will analyze the principal's choice of the parameters of the manager's compensation function.

III. THE DESIGN OF A COMPENSATION STRUCTURE

Contracts Based on Performance

The principal can affect the agent's time one decision by choosing a compensation function which attempts to induce the agent to obey the first-best decision rule. In addition, the principal will be able to retain all the surplus in investment projects if the compensation provided to managers is just equal

to the competitive level of compensation, on average, or if the principal expects he is paying no excess compensation to the manager. In order to define this requirement of no excess compensation, let $f_o(a)$ and $F_o(a)$ denote the normal density and distribution functions on the market's prior distribution on managerial ability. The average ability of managers who observe $z > 0$ is defined by

$$a_p = \int_c^{+\infty} f_o(a)a\, da/[1 - F_o(c)].$$

A principal who employs a manager who does not proceed with a project at time 1 pays the lump-sum payment $C_2 = R$ to managers who have made that choice. Similarly, a principal who employs a manager who does proceed with a risky project, should set the expected compensation of such managers equal to the expected ability of those who have made that choice. The latter restriction is written as

$$w_p + s(a_p + \bar{e}(z_p)) = a_p, \tag{8}$$

where z_p is defined as $\bar{e}^{-1}\{E[\bar{e}(z)\,|\,z>0]\}$.

Given that $C_2 = R$ for those who take the risk free investment, a first-best compensation function will consist of a pair, $\{w_p, s\}$ such that (8) is met and

$$w_p + s(c + bz + \bar{e}(z)) \begin{matrix} > \\ = \\ < \end{matrix} c \text{ as } z \begin{matrix} > \\ = \\ < \end{matrix} 0, \text{ for all } z. \tag{9}$$

Equation (8) and the equality version of (9) determine the first-best $\{w_p, s\}$ as

$$s' = (a_p - c)/(a_p + \bar{e}(z_p) - c)$$
$$w_p' = c(1 - s'), \tag{10}$$

where $0 < s' < 1$.

We summarize this result in the following proposition:

Proposition 1: There exists a unique first-best contract defined by the pair $\{w_p', s'\}$ which induces the manager to make the first-best investment decision at time 1 and which involves no expected excess compensation for managers.

Adverse Selection

While there exists a unique contract which induces the manager to follow a first-best decision rule, this contract is subject to adverse selection problems. The difficulty is that managers who choose to proceed (not proceed) with a project are all valued the same by the market. As a result, a competing firm has an incentive to utilize an alternative type of contract to attempt to induce managers who are undervalued by the market to leave their firm. As long as managers have knowledge of the specific value of z observed during the discovery process, then there will be potential for adverse selection.

The specific way in which adverse selection manifests itself in this context is that the principal announces the first-best compensation function $\{w_p', s'\}$ which will be used to compensate a manager who chooses to proceed with a risky project in period 2. Then the compensation expected by the manager who has observed z during the discovery conducted during period 1 is

$$E[w_P' + s'X|z] = w_P' + s'(c + bz + \bar{e}(z)).$$

Now suppose a competing firm offers an alternative compensation function $\{w_P'',s''\}$ which has the same value to the average manager who proceeds with a risky investment but with $w_P'' < w_P'$ and $s'' > s'$. If both contracts have the same value for the average manager then this requires

$$E[w_P' + s'X|z_P] = E[w_P'' + s''X|z_P].$$

A manager who is undervalued will observe $z = \hat{z} > z_P$. An undervalued manager who compares the two contracts will find that the second contract with more contingent compensation will have a higher expected value. We can see this by solving for the relative magnitudes of compensation under the two contracts:

$$E[w_P' + s'X|\hat{z}] \;?\; E[w_P'' + s''X|\hat{z}].$$

Substituting from above yields

$$w_P' + s'(c+b\hat{z}+\bar{e}(\hat{z})) \;?\; w_P'' + s''(c+b\hat{z}+\bar{e}(\hat{z})).$$

Subtracting

$$E[w_P' + s'X|z_P] = E[w_P'' + s''X|z_P]$$

from both sides yields

$$s'[b(\hat{z}-z_P)+\bar{e}(\hat{z})-\bar{e}(z_P)] \;?\; s''[(b(\hat{z}-z_P)+\bar{e}(\hat{z})-\bar{e}(z_P)].$$

Since $\hat{z}-z_P > 0$, the contract with greater contingent compensation has greater expected value.

Any competing firm which observes a specific incentive contract in place will know that it can attract undervalued managers who are compensated with that contract by offering them

one which has even slightly more contingent compensation. Of course, when principals are designing these contracts in the first place, they should understand their vulnerability to adverse selection and should respond by increasing the degree of contingency. However, when principals and agents are risk neutral, there is no limit to the degree of contingency which might be included, especially if any functional form for the contract is allowed. Hence, any contract which is announced will be unstable since it can always be improved upon by increasing the degree of contingency. We state this result in Proposition 2 as:

Proposition 2 Any contract based solely on observed return will be unstable in competitive spot labor markets.

The Role of Contracts With Target Performance

The problem with contracts which are based solely on the observed return in an investment is that they incorporate no device which allows a manager to reveal inside information to the principal. The asymmetry in information that results makes these contracts vulnerable to adverse selection. However, there is least one type of contract which can be used to facilitate revelation of information acquired in the discovery process. This contract includes a target performance level chosen by the manager at time 1. As we will see, his choice of the target performance level will reveal his private information. The problem facing the principal is to select a compensation function which relates contingent compensation to the announced target level in such a way that the manager is always compensated at the

market level, based on his private information. We will show that it is feasible and optimal for principals to select such a compensation function.

We will assume that when a manager undertakes a project he commits to a target performance level, X_T. Prior to the agent's choosing X_T, the principal will announce a function which relates compensation to the announced X_T. For simplicity we will restrict our attention to the class of linear incentive compensation contracts with the following characteristics:

$$\text{(i) } C_2 = w_P + s(X_T)(X - X_T) \text{ and (ii) } ds(X_T)/dX_T > 0, \qquad (11)$$

where w_P is a fixed wage and $s(X_T)$ is the share of the manager's income over his target performance standard, X_T. The expected compensation for managers who proceed with projects will now be:

$$E(C_2) = w_P + s(X_T)[E(X) - X_T]. \qquad (12)$$

At time 1 the manager who has chosen to proceed with a project will choose X_T in order to maximize expected compensation, given the principal's announced function for determining s as a function of X_T. Hence the manager will solve:

$$\underset{\{X_T\}}{\text{Max}}\ L = E[w_P + s(X_T)(X-X_T)\,|\,z].$$

The first-order necessary condition is

$$dL/dX_T = -s + ds/dX_T\ (E[X|z] - X_T) = 0. \qquad (13)$$

The first-order condition implies that, for any given function $s(X_T)$, we can express X_T as a function of z,

$$X_T^* = X_T^*(z).$$

While there will be such an implicit function corresponding to any increasing function $s(X_T)$, the resulting compensation

function may not be competitive for any z. In order to resolve the adverse selection problem, there must exist a function $s(X_T)$ which provides competitive compensation for any manager who proceeds with a project. That is, $s(X_T)$ must be chosen so that the compensation expected by the manager is always equal to his perceived ability at time 1, given his observed z:

$$E(C_2) = E[w_P + s(X_T^*(z))(X-X_T^*(z))|z] = a_1(z), \text{ or}$$

$$w_P + s(X_T^*(z))(E[X|z]-X_T^*(z)) = a_1(z) \text{ for } z > 0 \qquad (14)$$

and,

$$E(C_2) = R \quad \text{for } z < 0. \qquad (15)$$

$s(X_T)$ can be solved simultaneously from the first-order condition (13) and the competitive compensation conditions (14) and (15). Differentiating (14) with respect to z and using (13),

$$s(X_T^*(z)) = a_1'(z)/q'(z) \quad \text{for } z > 0, \qquad (16)$$

where $a_1'(z) = da_1(z)/dz$ and $q'(z) = dE[X|z]/dz$. Substituting for $a_1(z) = c + bz$ and $E[X|z] = c + bz + \bar{e}(z)$ in (16), we have

$$s(X_T^*(z)) = b/[b + \bar{e}'(z)]. \qquad (17)$$

Differentiating (17) again with respect to z,

$$(ds/dX_T)(dX_T^*/dz) = -b\bar{e}''(z)/[b+\bar{e}'(z)]^2 > 0. \qquad (18)$$

Since $ds/dX_T > 0$ for the linear incentive compensation contracts, $dX_T^*/dz > 0$ in equilibrium. That is, we have shown that in the signaling equilibrium the contract $\{w_P, s(X_T)\}$ induces first-best investment decisions and truthful revelation of the manager's private information, z, by imposing higher performance standard X_T^* for managers who claim to have high ability. We state this as Proposition 3.

Proposition 3 It is feasible for principals to choose a linear incentive compensation contract $\{w_P, s(X_T)\}$, which will cause all

managers who proceed with a project to be compensated at a level equal to that which they could obtain in spot labor markets. Furthermore, in equilibrium, a more able manager will reveal his ability by imposing on himself a higher performance standard.

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