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Profit-Sharing Arrangements in a Team and the Cost of Information

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This paper considers the effects of the production technology of a team, the environmental risk, and the characteristics of principal and agent on profit-sharing arrangements. The costs of information in a principal-agent relationship are identified in principle. In particular, an explicit expression of information costs will be derived. Thereby, production and utility functions will be specified (LEN model), however, the principal is not restricted to risk neutrality.

1. Introduction

Neoclassical theory of the firm has never completely satisfied in so far as internal processes of organizations are not adequately reflected. In a recent essay on transaction costs and property rights, L. De Alessi (1983) recalled the contributions made by Herbert Simon, Oliver Williamson, Armen Alchian and others who focused on the process of decision making *within* the firm. Key notions of these approaches include satisficing, multiple goals, organizational slack, resistance to change, that is, behavior that today is subsumed under the term of *shirking*.

From this perspective, business enterprises have to solve the shirking-information problem of team production. Alternative organizational designs are intended to handle efficiently with divergent motivations of team **(p. 42)** members and discretion. Organizational designs range from enforcing contracts to profit-sharing arrangements. In these and similar types of arrangements the reward of cooperating members depends on the team output, which is supposed to be observable, rather than on individual input, which is hard to monitor. Though economic theory has mostly dealt with cooperation across markets, the design of efficient contracts for partners cooperating within an organization is of no less importance.

Payment schemes which include result sharing can be analysed within the framework of *agency theory*, the analysis of economic cooperation under risk and conditions of incomplete information. Indeed: If risk ac-companies decision making, it might be difficult to observe the actions by partners.

In real situations, imperfect information will be mutual: each individual is confronted with some limits in observing all the relevant aspects of other team members behavior. For analytical purposes, however, in agency theory cooperation is considered to occur between two individuals only: One of them, the principal, cannot observe behavior, actions,

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decision, or characteristics of the other, called agent. Notable work on this relation between principal and agent includes S.A. Ross (1973), B. Holmstrom (1979), S. Shavell (1979), K.J. Arrow (1986). In addition, some authors discussed the implications of agency on the theory of finance, see M.C. Jensen and W.H. Meckling (1976), E.F. Fama (1980), A. Barnea et al. (1985). For a recent collection of contributions see G. Bamberg and K. Spremann (1987).

Although several papers, such as S.J. Grossman and O.D. Hart (1983), R. Rees (1985), present fairly general models, several problems of agency theory still deserve attention. One of these questions concerns the way in which efficient profit-sharing arrangements depend on model parameters such as the production technology of the team, the environmental risk, and the characteristics of principal and agent. So the related task would be to formulate a model of the principal-agent relationship that is simple enough to permit to arrive at solutions in explicit and analytic form. An-other question concerns the concept of agency costs. Agency costs were introduced by M.C. Jensen and W.H. Meckling (1976) who suggested to rank and compare alternative arrangementsjust according to their respective agency costs. The definition, however turned out to be ambiguous, and consequently the use of agency costs has fonnd severe criticism.

The present paper is intended to give answers to these two questions. Thereby, we focus on the situation where the agent's decision might best be interpreted as effort. At first, in Section 2, a conceptual distinction has to be made between the cases of hidden effort, ignorance, screening, and more complex situations. The situation ofhiddell effort is then formulated in Section 3 while Section 4 presents the specific model. This model will

be termed LEN (Linear-Exponential-Normal) since

. the production of the team and feasible arrangements are supposed

to be linear functions,

. utility functions of principal and agent are exponential, i.e., both

team members have constant but presumably different risk aversion,

. states of nature are normally distributed.

In Section 5 the LEN-Model is solved and resuJts are discussed. Sec-tion 6 presents a rigorous definition of agency costs, determines these costs in dependence of the model parameters, and shows its meaning as a value of perfeet information. Section 7 suggests some modifications and extensions.

2. Hidden Effort, Ignorance, Hidden Characteristics

Agency theory is the analysis of economic cooperation under risk and con-ditions of imperfect information. The cooperation is seen to be asymmet-rie and to occur, either within organizations or across markets, between two individuals or groups of individuals called principal and agent. The agent chooses an action that affects not only her own welfare but also that of the principal. These external elfects are negative: Modifications of the agent 's actions which increase the welfare of the principal yield disutilities to the agent. The principal is therefore ready to reward the agent but, unfortunately, he cannot observe which action the agent has chosen and is actually undertaking.

It does not make sense if principal and agent were bargaining in order to agree upbn a certain action in exchange for a certain amount of money in the case there is no unlimited reliability of the agent's behaviour and there is no sufficient confidence between principal and agent. Rather than bargaining on pairs of effort and wage, the principal is in search of a more sophisticated reward scheme which alters the agent's welfare in such a way that the agent, selfishly, decides for an action which the principal prefers. In other words, the principal wants to induce the agent to make her decisions in a particular way.

In many situations the agent's action can best be referred to as elfort. While more effort is preferred by the principal, it is a disutility to the agent herself. Although it is sometimes easier to speak of the effort level, one should note that in most cases effort will be a multi-dimensional decision variable. Hidden effort usually becomes and issue when cooperation takes place within organizations, more precisely, at the point in time when two individuals already agreed to form a team. Examples are an employce working for an employer or managers running a firm on behalf of its shareholders. These examples explain why the result of the principal's limited ability to monitor the agent has been called managerial discce-tioIl.

The limits to observe the agent's eifort mainly result from some kind of uneertainty. Note that the principal is neither ignoring the way in whieh his welfare depends on the possible levels nor the types of eifort the agent ean choose, but his welfare also depends on same exogenous risk. Think of the owner of a trust fund or portfolio which is administered by an investment advisor. Although the principal might know the eorresponding functional dependencies and although he will have no doubts on his actual level of welfare, he is unable to separate the twc' factors: to which extent is his realized welfare a consequenee of the agent's eifort, and to which extent is his welfare resulting from a more or less lucky state of nature?

In situations of hidden eifort the principal is supposed to know the agent's characteristics. Among the relevant characteristics are the agent's disutility of effort and her degree of risk-aversion. The principal is thus in the position to ealculate the way in which the agent will respond to a certain reward scheme. Prediction, however, must be distinguished from actual observation. The principal can predict the agent's decision on effort, but he cannot verify his calculations through observation. What that essentially means is: Not any pair of a payment made to the agent and an eifort level ean be a result of an agreement. Rather than that, the eifort level must be induced by the payment scheme. The unobservability of the agent's effort gives thus cause for an additional constraint. This eonstraint usually prohibits "first-best agreement" between the members of the team.

When this situation is modelIed, its formal structure is applicable to an even wider class of problems, where no formal delegation relationship is involved. A person (agent), taking out theft or health insurance, for example, will decide on some activities which could reduce the risk of the event insured against and this will aifect the pr<>bable income of the insurer (principal). A firm handling dangerous chemieals (agent) will take decisions which affect the likelihood and extent of damage which could be caused to others (principal) by an accidentj see R. Rees (1985). llidden eifort and monitoring are thus closely related to problems of incentive eifects, risk sharing, and moral hazard; see B. Holmström (1979).

Although this paper exclusively deals with hiddcn effort, one should distinguish hidden effort from other situations. We conclude this section with remarks on the cases of (i) ignorance, (ii) hidden characteristics, (iii) overlapping problems.

(i) Ignorance. The principal, so far, knows the imp!ications of each action (eifort) the agent can ehoose on his wea.lth. In other words, the principal knows the functional relationship between eifort and his own wel-fare. The principle could say which one of the agent's actions he prefers. The only problem with the hidden-eifort case is that the principal cannot observe the agent's decision. In a few situations, however, the principal

may not even know the way in which his welf are depends on the agent's action. We refer to these cases as ignorance. Ifunder ignorance the princi-pal could observe the agent's ac-tion this had no value to hirn just because he does not know which action he prefers.

(ii) Hidden Characteristics. In other situations the principal does not know the agent's action in time. Consider a principal contacting, one after the other, many individuals who could cooperate and serve as agents. The team is not yet formed. At the moment when the princi-pal has to make an offer to one of these individuals he may not know the characteristics of a particular individuals such as her skill, her productivity, her degree of risk-aversion, her disutility of effort. Uncertainty here prevails with respect to the type of individual.

Instead of hidden effort, these situations are referred to as hidden characteristics. Instead of monitoring the effort of one agent, screening or sorting the characteristics of many indi-viduals is required. Important examples are related to issues of labor market and job as-signment. One might think of sorting devices such as tests and questionnaires to iden-tify a person's characteristics. In addition, signaling is likely to occur. On the other hand, an im-portant dass of screening devices consists of self-selection schemes. An example is the screening of consumers through sdf-selection: they are offered a choice among different qualities of a prod-ud. K.J. Arrow (1986) analysed a public utility (principle) that wants to differentiate consumers but is unable to observe the customers' (agent's) willingness to pay.

(iii) Overlapping Problems. The situations of either monitoring ef-fort or of screening char-acteristics can be analyzed in formal models if, as assumed, the asymmetry of information is one-directional only. In more complex situations, however, asymmetric information may be two-directional or might prevail with respect to both effort and characteris-tics. Consider the relationship between physician and patient. At least four overlapping principal-agent relations can be identificd. Firstly, the patient has to screen the skill of physicians berore he or slle chooses the one to visit. Secondly, each physician screens the patients and can send some of the patients to other doctors dedaring them, perhaps, to be more competent for the disease under discussion. Thirdly, the patient is con-

fron ted with monitoring the physician's effort. Fourth, the doctor has to monitor the pa-tient's willingness to obey the cu re prescribed. These för principal-agent relations are all interrelated. The general process of

screening physicians by patients, for example, helps to control each doc-tor's effort. E.F. Fama (1980) focuRed on how competition on the labor market for top managers, essentially a screening device, helps the stock-holders to monitor the effort of their execlltives.

3. Induced Effort

A common situation of monitoring is one in which the principal seeks cooperation because the team output depend8 on inputs, services, and effort the agent can provide. Team output, however, is not only affected by the agent 's effort x. Another factor is some kind of exoge-nous randomness Ö the probability distribution of which neither principal nor agent can contro!. The values of Ö can be viewed as states of nature. Team output, denoted by the random variable fi, is thus a function 1 of both effort x and the environmental risk Ö,

fj = I(x, Ö)

(1)

The only input that can vary is the agent's effort x, which may have more than one dimensions. All other inputs are fixed before-hand. Instead of output, we will also speak of result or profit.

Risk has two major implications. Uncertainty helps to explain the asymmetry of information and raises the issue of risk-sharing.

Assumption 1. The principal is not ignorant, he is supposed to know the function 1 BS well BS the distribution ofÖ. Later, the principal will also observe the realization y of result y. But he will neither learn whieh is the realization 8 of Ö nor whieh effort x has aetually been undertaken by the agent. (Note, however, that the principal knows the agent's eharaeteristies and ean thus prediet the agent's effort BS a response to tbe Fee sehedule).

Nevertheless, the principal cannot infer the agent's effort x from the knowledge of 1 and y. Consequently, the agent could explain poor re-sults simply by bad luck, though pretending a high effort level. On the other hand, ifit was good luck which brought success, the agent will claim her effort to be the only reason for the good news. Under circumst&.nces of no accountability, it does not make too much sense to bargain on the level and kind of effort. This leads to the requirement: Anyarrangement to be considered must make the agent's rewa::d depend on such variables the values of which can be observed and audited by both parties.

Assumption 2. The proß! y ean be eorreetly observed by both principal and agent.

The payment made to the agent can thus be a function of profit: p(Y). Note that the payment is not a function of the state of nature 0 which, by Assumption 1, cannot be observed by the principal. At the point in time when y is not yet realized and when the agent decides upon eff::>rt x, her reward is still uncertain,

p = p(fj) = p(f(x, Ö))

(2)

Since the agent willlater on be assumed to be risk averse, the principal does not only have to pay a compensation for the agent's disutility of effort. In addition, the agent will require a risk premium for bearing some of the risk in the profit y.

In the process of decision making relevant to the team profit there are three parties involved. The principal selects a payment scheme P(.)

from a set P of feasible schemes. The agent decides upon her effort XiX where x denotes a set of feasible effortR. Nature realizes the state, and the team profit y be comes knovi".1 to both principal and agent. The agent receives the payment p(y) and the principal gets the residuum y - p(y).

Who of the members of a team plays the role of the principal? Who is the agent? Principal is that member of a team who is unable to observe the effort (action) of the other team member! Agent is the team member whose action cannot be observed by the principal! We stress that not necessarily the principal is the owner of resources (land, capital) utilized by the agent who contributes labor or management services. We also stress that not necessarily it must be the principal who claims the team profit and pays areward to the agent. In models of share cropping, it is usually the farmer who pays a rent to the landlord, see J.E. Stiglitz (1974). Only for convenience of notation we said that the principal will give areward p(y) to the agent and keep the residuum y - p(y). Important is only that the team profit depends on the agent's action which is unobservable by the principal and that both team members come to an agreement how to share the team profit y.

Some authors stress that, in addition to not being able to observe the agent's effort, the principal-agent relationship implies that the principal is the person who designs the fee schedule and has the right to claim the residues (output net of payment to the agent). Accordingly, the relation-ship does imply so me sort of hierarchical relation.

A second remark makes the above statement that "not necessarily it must be the principal who claims the team profit and pays areward to the agent" questionable: That the landlord may get a fixed rent from the tenant does not mean that the principal does not claim the team profit. It is because the differences in their respective risk attitude that the landlord (principal) can extract the profit beforehand in the form of a fixed payment (from the tenant). The tenant (agent) only enjoys his reservation utility.

Denote by c(x) the money equivalent ofthe agent's disutility ofeifort.

Her final wealth, payment net of disutility, is thus w = p(Y) - c(x). The agent will choose her effort x E X such that the expected utility E[u(w)] of wealth will be maximized. Instead of expected utility Eu, we base the analysis on the certainty equivalent u-l Eu. For a payment scheme p(.) offered, the agent will thus maximize the certainty equivalent of her

wealth

Ca(p,x):= u-l(E[u(p(y) - C(X»])

{3)

with respect to effort x EX. Let x. (p) be such a response to the payment scheme p, that is Ca(p, x.(p» ~ Ca(p,x) for all x E X.

As stated, the principal can choose any payment scheme p(.) from a set P. His criterion is the expected utility or the certainty equivalent of the residual wealth y - p(jj). Hence the principal wants to maximize his welf are

Cß(p,x):= v-l(E[v(jj- p(jj»)])

(4)

The principal is not necessarily risk neutral, and v denotes his Neumann-Morgenstern utility function.

So far, the criteria (3), (4) would determine agame where the agent chooses effort x E X and the principal chooses payment scheme p(.) E P. One of the stronger assumptions of the hidden-effort situation is th~t the principal can predict the agent's response x.(p) to a payment scheme.

Assumption 3. The principal knows the agent's characteristics such as utility function u(.), disutility of effort c(.), and set X offeasible decisions on effort.

The principal can thus predict the agent's response x.(p) E X to each feasible payment scheme p(.) E P, he knows the effort response x' : P -+ X. Thus, Assumption 3 reduces the principal's task to maximize Cß(p, x.(p» with respect to feasible payment schemes pEP.

One might suspect that this formulation assigns considerable power to the principal. He knows the response his agent will give and could exploit her. That, however, is not the intention of Assumption 3. In fact, the agent could refuse to work with the team. The agent will refuse a payment scheme p(.) if her welfare attained with optimal effort Ga(p, x.(p» where below some reservation level m.

Assumption 4. The reservation level m (in terms of a money equivalent of the agent's welf are) either results from another engagement or is the result of negotiations with the principal.

So it could be the case that, due to bargaining power of the agent, the principal must take into account a certain level ofthe agent's utility. Then it is the principal, not the agent, who seems to be in a weak position. Market power is not the issue and no hierarchical relation between agent and principal is supposed. Rather than tbat, agency tbeory focuses on efficient profit sharing as a means to deal with tbe lacking observability of effort. Consequently, we suppose that the reservation level m belongs to the exogenous data.

To sum up, the situation of hidden effort requires the principal to solve two problems. First, the principal has to determine the agent's response x. : P -t X using the knowledge of her characteristics (Assump-tion 3). Secondly, the principal addresses to

Maximize Cp(p, x.(p»

subject to Ca(p, x.(p» ~ m

with respect to pEP

(5)

Let p' E P denote a solution of (5). The agent's effort can be predicted to and will be x.(p') EX. Questions of existence and uniqueness left aside (see S.J. Grossman and O.D. Hart, 1983, for some of the problems involved), the optimal payment scheme p' E PasweIl as the agent's effort response x.(p') will depend on the exogenous data: technology I, distribution of states of nature 8, degrees ofrisk aversion -U" I u' (agent) and -v" Iv' (principal), reservation level m.

4. The LEN - Model

The hidden-effort model cannot explicitly be solved in its general form. In order to study how the profit-sharing arrangement and the agent's effort response depend on the exogenous data, the model has to be spec-ified further. The set of specifications suggested here is termed Linear-Exponential-Normal-Model, since

(L) team output fJ is a linear function of risk 8, and feasible payment

schemes p(.) E P are linear functions of team output,

(E) utility functions of agent and of principal are exponential,

(N) risk (J is normally distributed.

Specifications (N), (L) imply that both the agent's wealth and the principal's residuum are normally distributed. That, in conjunction with (E), implies that the certainty equivalents (3), (4) can be expressed as expected value minus half the variance times risk aversion, see also G. Bamberg and K. Spremann (1981). A simple version of the LEN-Model IS:

fJ = I(x, 0) = x + 0

= [0,1/2], x E X,

0 normal, E[O] = 0, Var[O] = 0-2

pEP iff: p(y) = r + sy,

u(w) = -exp(-aw),

v(w) = -exp(-ßw),

c(x) = x2

The agent's effort' is a one-dimensional decision variable and team profit fj

is the sum of effort x and the one-dimensional environmental risk B. Both agent and principal have constant risk aversion denoted by a = -u" / u' i. 0 (agent) and ß = -v"/v' 2 0 (principal). In order to describe increasing marginal disutility of effort, the function c is supposed to be quadratic.

Two parameters r, s determine feasible payment schemes: r will be called fee and s will be called share. So far there are no restrictions on r, sEI R although the share may be viewed as constrained to 0 :S s :S 1. In the case s = 0 the principal pays a fixed fee r for the services provided by the agent, independent of team profit. In the case s = 1 it is the agent who bears all the risk, while the principal's wealth will be risk free under such an agreement. The fee r can be negative, too, which could be indicated in particular if the agent receives a positive share s > 0 of the result. One could then refer to r as a rent paid to the principal.

This version of the LEN-Model is given by four exogenous par~meters: the agent's risk aversion a > 0, her reservation level m, the variance (J"2 > 0 of the risk, and the principal's risk aversion ß 2 O. There are three endogenous variables: effort x, fee/rent r, share s. The purpose is to study how the effort chosen by the agent and how the arrangement (r,s) chosen by the principal depend on the exogenous data.

5. Solution

The principal can determine an optimal payment scheme in three steps which answer three questions.

Question 1. In which way will the agent choose x*(r, s) aB a response to an arrangemen t (r, s) ?

The agent's wealth, payment net disutility of effort, is

w = r + (x + 8)8 - x2

(6)

and her certainty equivalent thereof is

Ca(r, s; x) = E[w] - :: Var[w]

2

a

= r + sx - x2 - -s2(J"2

2

(7)

Maximization of (7) with respect to effort x yields the response s

x*(r,s) = 2

(8)

(and 0 :S s :S 1 implies x* EX). This proves:

Theorem 1. Neither the fee r nor (the result of negotiations on) the reservation level m have an impact on the agent's effort. In particular, a fixed-fee arrangement, s = 0, induces the agent to the lowest feasible effort, x*(r,O) = 0, however large the fee may be.

Question 2. Which arrangements (r, s) will not be rejected by the agent in view of the reservation constraint Ca ~ m?

Eq. (7), (8) imply

2

Ca(r, s; x*) = r + s4 (1 - 20'(7"2)

(9)

and consequently, the reservation constraint is satisfied if the fee has the size

82

r = m - -(1 - 20'(7"2)

4

(10)

at least.

A common hypothesis is that the fee can be reduced in an arrange-ment is the share s is increased. As (10) indicates, however, that is cor-reet only if both the agent's risk aversion 0' and the variance (7"2 are small enough, i.e., if 20'(7"2 < 1. To see the reason, recognize the difference be-tween expected value and certainty equivalent of the agent's wealth (6) as a risk premium. The risk premium is equal to (0'/2)82(7"2. Thus a rising share s has three effects. (i) A higher bonus simply increases the expected income. (ii) A higher share induces the agent to more effort. Thus, she is participating in a better result. (iii) The agent is demanding a higher risk premium because she is going to bear more of the risk as the share is increased. If the third effect outweighs the first and the second effect, the overall result is that the fee r has to be increased instead of decreased as a high er share is envisaged.

Theorem 2. If the agent 's risk aversion 0' and/or the variance 0'2 of the en vironmen tal risk are large (in the sense of 1 < 20'(7"2), an increase of the share 8 requires an increase of the fee r.

The rationale of this result is that the agent will not only share in "profits" ii > ° but in "losses" ii < 0, too.

Question 3. Which arrangement (r, 8) maximizes the principal 's welJ::lre given the agent.'s response (8) and subject to the reservation constraint (1O)?

The principal's residual wealth, using (8) and (10), is

2

ii - (r + 8ii) = (1- 8)(i + 0) - m + : (1- 20'(7"2)

(11)

and his certainty equivalent thereof is

)

8 82 2 ß 2 2

Cß = (1 - s - - m + -(1 - 20:er) - -(1 - s) er

2 4 2

(12)

Taken as a function of share s, (12) assumes a maximum value Cß for

* 1 + 2ßer2

s -

- 1 + 2(0: + ß)er2

and the maximum of the principal's welfare is

C* = 1 + 2ßer2(1 - 20:er2) - 'In

ß 4(1 + 2(0: + ß)er2

Remember that the agent's welf are is C; = m. the optimal fee r* is now determined by (10), (13), and the agent's effort response x*(r*,~*) is given by (8), (13).

One implication of (14) is that the principal's welf are is inversely related to 0::

Theorem 3. If the principal could choose between two agents who differ only with respect to risk aversion, he prefers the agent with the lower risk averSIOn.

(13)

(14)

To comment on (13), the principal finds it best to reduce the agent's share s* as her risk aversion 0: and/or the variance er2 increase. This is because the agent will then ask for a higher risk premium. however, the agent will never get a fixed-fee salary.

Theorem 4. No fixed-fee agreement (r,O) will be made, however large the agent's risk aversion iso

A particular case is where the principal is risk neutral. ß = ° implies

s* = 1/(1 + 20:er2), (15)

x* = 1/(2(1 + 20:er2)),

Cß = 1/(4(1 + 20:er2) - m

The agent's share s*, her effort x*, expected team profit EW*] and the

principal's welfare Cß are inversely related to o:er2.

On the other hand the principal prefers to keep a residuum almost free ofrisk, s* ~ 1, ifthe agent's risk aversion or the variance er2 are small. In such situation it is cheap to motivate through profit sharing since the risk premium required by the agent is smalI. An extreme situation is that of a risk neutral agent 0: = 0. A risk neutral agent bears all the risk, s* = 1. Further, as will be shown in the next section, cf, (19), the effort x* = 1/2 applied can be seen as a "social optimum". Finally the welf are of the principal assumes the largest value ever possible, Cß = 1/4 - m. One can therefore conclude:

Theorem 5. It is the connection ofunobservabüity (ofthe agent's effort) and of risk aversion (of the agent) that excludes first-best arrangements.

6. Agency Costs

In the seminal paper by M.C. Jensen and W.H. Meckling (1976) agency costs were proposed to be a key tool in evaluating alternative designs of a principal-agent relation. the authors defined agency costs as the sum of (i) the monitoring expenditure by the principal (no such expenditures are modelIed here) , (ii) the bonding expenditures by the agent, and (iii) the residualloss, i.e. the monetary equivalent of the reduction in welfare experienced by the principal due to the divergence between the agent's decisions and "those decisions which would maximize the welfare of the principal" (1976, p. 308). The latter formulation, however, is not dear and ambiguous if taken literally.

The rationale of the principal-agent relationship is that the agent's effort cannot be observed by the principal. A rigorous approach has thus to define agency cost as a value of information: how much money wil1 the principal offer, at most, iE he could observe the agent 's effort?

Ir the principal has perfect information on the true effort of the agent, both team members can bargain and agree upon anyeffort in exchange for any payment. No longer has effort to be induced by a payment scheme. Under perfect information the principal would thus address to

Maximize Cp(p,:r:) subject to Ccr(p,:r:) ~ m

with respect to pEP and :r: E X

instead of (5), and no longer has effort to be the agent's response x.(p). Here we assumed that both individuals agreed upon the same reservation level m. In order to be able to compare the first-best and second-best sit-uations it is further necessary to assurne that the parties' utility functions are invariant in the two different information structures.

Ir the principal had to pay, in addition to the agent's reward p, the amount of money AC in order to get perfect information, he would max-imize the certainty equivalent of his residual wealth Cp(p + AC, x), team output net of agent's reward plus information cost. Agency costs are therefore the maximum of all AC > 0 Buch that

max{Cp(p + AC,:r:)ICcr(p, x) ~ m, pEP, x E X} ~ max{Cp(p,x.(p))lCcr(p,:r:) ~ m, pE P}

(17)

This is the definition of agency costs for the most general case. It can be simplified if the principal has constant risk aversion, because then his

certainty equivalent Qß is additive in risk-free amounts, cf. Bamberg and Spremann (1982). Ir -v"/v' == ß, condition (17) simplifies to

Agency Costs = Cß(po, .x°) - Cß(p*, .x*(p*))

(18)

where pO,.x° denote a solution to problem (16).

In the case the principal has exponential utility, agency costs are equal to the difference in the principal's welf are (expressed in terms of a monetary equivalent) with respect to two situations. One of these is the given situation of limited observability. The other situation is that where the principal could observe the agent's true effort.

For the LEN-Model presented and analysed in Sections 4,5 it is easy to see that

.x° = 1/2

(19)

This is the "socially-optimal" effort in the sense that principal and .agent would agree upon .x° if effort was observable. The payment they will agree upon is given by the share

sO = ß/(a + ß)

(20)

and the fee rO = m - s°.x° - (.x°)2 + (a/2)(sO)2 u2. These results together with (13), (10), (8) lead to agency costs AC

AC = (1 - sO)xo - rO - ~(1 - sO)2 u2

2

- (1 - s")x" - r" - ~(1 - s")u2

2

(21)

In the case the principal is risk neutral, eq. (21) simplifies to

au2

AC = 4au2 + 2

(22)

Both (21), (22) are increasing functions of au2 which means:

Theorem 6. The unobservability of the agent's eifort becomes as more a drawback the agent's risk aversion and the larger the variance of the environmental z:isk are.

7. Some Extensions

To conclude the analysis we propose modifications and extensions. Four groups ofsuch generalizations will be discussed. These conc~rn (i) the type

ofpayment scheme, (ii) the technology, (iii) the introduction ofmonitoring signals, and (iv) diversification of the risk of team output.

(i) Payment. Quite often arrangements can be found where the agent's reward is not a linear function of team output. Sometimes, the agent participates in gains but not in losses,

p(y) = r + 8' max{O, y}

(23)

such that the risk premium demanded will be reduced. Denote the set of payment schemes (23) by P+. Not only is the question wh ich are the parameters r,8 chosen in the situation where P+ is the set of feasible arrangements. Another issue is whether 01' not the best schemes in P+ are superior to linear profit-sharing arrangements in P. In other words:

which arrangements would be chosen in the set PUP+? Another common arrangement is a"bonus-fine scheme: a fuced fee r is applied as long as the profit is not below a certain criticallevel YL, combined with a fine t ~ 0 for too pOOl' results: p(y) = r if Y ~ YL and p(y) = r - t if Y < YL.

(ii) Technology. The analysis of Section 4, 5 was based on a pro-duction function where effort determined the expected output, E[Y] = x, whereas the variance Var[Y] = x, whereas the variance Var[Y] = q2 and

hence the risk to be shared have been constant. One modification is a

technology where effort controls the risk Var[Y], while the expected profit could be constant. An example is a firm (agent) borrowing from a bank (principal) and selecting among a set of investment projects that differ with respect to riskinessL see J .E. Stiglitz and A. Weiss(1981). A simple formulation is ii = a + xB such that E[Y] == a and Var[Y] = X2q2.

(iii) Monitoring-Signals. The model presented can also be extended by introducing monitoring signals. Such aM-signal s is viewed as a ran-dom variable that is related to the agent's effortj for instance

s=x+l

(24)

where l is a random observation error. Extend Assumption 2 such that both the profit and the realization S of the M-signal can be obscrvcd by principal and agent. Then, arrangements that make the agent's payment depending on Y and s become feasible, see M. Blickle (1987), K. Spre-mann(1987).

(iv) Diversification. The drawback due to the imperfect information becomes smaller if the environmental risk can be reduced, cf. (22). The principal will thus be inclined to diversify within the team even if such a diversification is more expensive than other forms of risk bearing. The theory offinance indicates that diversification within firms is not necessary since risk can best be diversified across capital markets. This result,

however, holds no longer if shareholders (principals) have only imperfect information on the decision making of firms (agents).

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