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Agent and Principal

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Summary:

In most general terms, agency theory focuses on co-operation in the presence of external effects as well as asymmetric information. To have a look on external effects first, consider two individuals. One of them, the agent, is decision making. He is thus affecting his own welfare and, in addition, that of the other individual called principal. These external effects of the agent's decisions or actions are negative: modifications of the agent's action which are preferred by the principal yield disutilities to the agent. A common example is a situation where the principal is assisted by the agent and the agent is deciding on level and kind of his effort. The principal is thus ready to pay some kind of reward to the agent in return for a certain decision/action/effort. Unfortunately, and this is the second characteristic of situations in agency theory, the principal cannot observe the agent's actions in full detail. The asymmetric information with respect to the agent's decision excludes simple agreements concerning pairs of action and payment.

External effects and asymmetric information prevail in very widespread situations of economic co-operation. The variety of examples include such important relations as those between employer and employee, stockholder and manager, or patient and physician.

From a methodological point of view, the principal-agent relation is closely related to risk sharing, hidden effort, monitoring, hidden characteristics, screening, and self selection. The purpose of this essay is to model and analyse these different features of agency theory in one unified approach. This formal approach is based on linear reward schemes, exponential utility functions, and normal distributions, and it will therefore be called LEN-Model. The LEN-Model allows for explicit presentation of endogenous parameters which

determine the agent's decision on effort, the **(p. 4)** chosen reward scheme, and the incorporation of monitoring signals. Hence several insights into how the pattern and design of co-operation depends on exogenous parameters such as the agent's risk aversion and the variance of environmental risk can be provided.

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1. A General View

1.1 Co-operation

Economics may be viewed as the science of co-operation with regard to the utilization of resources. The basic pattern of co-operation is the exchange of goods, services, information, risk, or rights. If two or more individuals agree to co-operate, each of them will and has to contribute something and is going to receive something in return. Because of this pattern of exchange, the market is a very important organization or set of rules according to which cooperation takes place. Though the market mechanism is not the **(p. 5)** only design to organize cooperation, markets are efficient if the commodities exchanged have no external effects and if all relevant information is public.

More complex arrangements, however, are required in the presence of external effects or imperfect information. External effects prevail in such cases as that of non-separable labor inputs and that of public goods. Likewise imperfect information, in the sense of uncertainty about the quality of the commodities (skill and effort of labor input, reliability in financial contracting), require a more sophisticated design of the rules of cooperation.

Both external effects and imperfect information are predominating in many situations of economic cooperation. Usually these effects will be mutual. Each of the cooperating individuals affects by her/his decisions the welfare of the others directly, and each individual has some limits to observe the actions of others in full detail. Reciprocally given externalities and common limits to observe explain why cooperation is so complex in real life and why so many different types of arrangements, forms of contracts, institutions, and organizational designs have evolved.

Many approaches have been made to analyze the variety of arrangements. Among the first papers on agency theory are A. A. Alchian and H. Demsetz (1972), S. A. Ross (1973), J. E. Stiglitz (1974), M.C. Jensen and W. H. Meckling (1976). The economics of the principal-agent relationship were further developed, among others, by S. Shavell (1979), B. Holmström (1979, 1982), S. J. Grossman and O. D. Hart (1983). Recent surveys were presented by R. Rees (1985), by J. W. Pratt and R. J. Zeckhauser (1985), and by K.J. Arrow (1986). Many financia1 impacts of agency theory can be found in A. Barnea, R. A. Haugen and L.W. Senbet (1985).

1.2 External Effects

For analytical purposes one has to restrict the view on a simple, single-directed case of external effects and asymmetric information. So, instead of many, consider two individuals only. One of them, the agent, makes his decision $x \in X$. This decision, in some sense, is made on the quantity/quality of what the agent is going to contribute to what could be called the team. By this decision making the agent does not only influence his own welfare (more effort in **(p. 6)** team work is connected to individual disutility, for example) but also that of the other individual called principal. (The principal participates in the result of team work which is a consequence of the agent's effort). Agent and principal have different values associated with the agent's actions. In other words, the external effects of the agent's decision making are negative: those modifications of his action which are preferred by the principal yield disutilities to the agent.

Under such conditions, the principal is likely to start negotiations with the agent and offer some compensation, perhaps in form of a payment, if the agent refrains from choosing an action the principal dislikes. This way, both individuals could reach an agreement (x, p) that commits the agent to a certain decision $x \in X$ in exchange for a certain pay p to be made by the principal. It will be easy for them to arrive at an efficient agreement, which therefore could be termed *first-best design of cooperation*. Note that the agent's welfare or utility $U(x, p)$ depends on pairs of action x and pay p (he prefers both lower levels of effort and higher payments). Likewise, the principal's welfare $V(x, p)$ depends on pairs of action x and pay p (she prefers more effort of her partner as well as to give a lower pay). The situation of bargaining on pairs (x, p) can best be illustrated in an Edgeworth-Box.

1.3 Asymmetric Information

Externalities alone cause no deviation from first-best designs of cooperation. Simple bargaining on pairs of actions x and payments p are excluded, however, if external effects occur in combination with asymmetric information. Assume that, for some reason or the other (one reason is presented in Section 2.1) the principal is unable to observe and to verify exact1y which action x the agent is or was realizing. Information is asymmetric because the agent, of course, knows which decision he is going to make. But now, if there is no unlimited trust, it does not make sense for the principal to negotiate on pairs (x, p). The agent could make any promise with respect to his action and depart from it later on just because the principal is unable to control or to monitor the agent's decision making.

(p. 7) Although there is asymmetric information with respect to the agent's decision x by assumption, there might exist some variables which are correlated to x and the values of which can costlessly be observed by both agent and principal. Such variables provide some or partial information on the agent's decision x. Denote variables that partially inform on action x by $y, z, \dots$ Depending on the particularities of the situation, examples for such variables are firstly the resulting *output* y of team work and secondly the *monitoring signals* z resulting from some control devices. Since the values of y and z can be observed by agent and principal without disagreement, reward schemes $p(.,.)$ can be defined that make the amount of pay $p(y, z)$ a function of these variables y, z. More details are presented in Section 2.5.

Now suppose the principal, unable to observe the agent's decision x in an exact and direct way, offers a certain reward scheme $p(.,.) \in P$, taken from a set P of feasible functions of variables y, z. The principal makes this offer without expecting any pretense or promise of the agent with respect to decision x. The principal just invites the agent to accept the scheme $p(.,.)$ and to make, then, a decision x in his own interest. Consequently, there will be no shirking. The agent, realizing that the actual pay $p(y, z)$ depends on the values of the variables y, z which are related to his action x, will make his decision as a response to the scheme p. Formally, the agent is now choosing an action $x = \phi(p)$ that depends on the reward scheme p. The agent's response is described by the function $\phi : P \to X$. In other words, the reward scheme sets an incentive, or, the agent's decision x is *induced* by the reward scheme p.

1.4 Induced Decision Making

One consequence of information asymmetry is that only designs of cooperation are possible where the action $x = \phi(p)$ is induced by payment p. This is a fundamental difference between the first-best situation discussed in Section 1.2, where agent and principal could negotiate on pairs (x, p) of action and payment without further restriction. Under imperfect or asymmetric information, there is the additional constraint that the agent's action must be induced by payment.

(p. 8) Denote by E the set of pairs (x, p) that are efficient with respect to the welfare U of agent and the welfare V of principal. Thus E is the set of first-best designs of cooperation. Further, let I be the set of pairs $(\phi(p), p)$ of action and payment, where the action is induced by payment. The set I contains all designs that are feasible under information asymmetry. The information asymmetry would cause no problem at all if both sets E and I were identical. Any first-best design of cooperation could then be realized through induced decision making. One could already be satisfied in some weaker sense if the sets E and I had one or some elements in common. In such cases, at least one or some first-best designs of cooperation could be reached through induced decision making. Situations where E and I coincide or have some common elements are usually referred to as *incentive compatibility*.

In all other cases, the fact that some of the relevant information is not public causes a deviation from first-best and efficient designs (set E). Then all designs in I are dominated by designs in E and, for that reason, are *second best* only.

Few attempts have been made to measure the disadvantage between first-best and second-best designs in terms of a real number. Such measures are called *agency costs* in the tradition of M. C. Jensen and W. H. Meckling (1976). In figurative terms, agency costs measure the distance between the set E of first-best designs, which are an utopian fiction in the presence of asymmetric information, and the set I of designs where the agent's decision is induced by a payment scheme. The distance between two sets, however, can be measured in many different ways such that a particular definition of agency costs can easily be criticized with regard to appropriateness. In particular, one has to be very careful when using agency costs to compare and evaluate alternative second-best arrangements.

Another and presumab1e less ambiguous way is to define agency costs as the decision-theoretic *value of perfect information*: How much would the principal at most be willing to pay for becoming able to observe the agent's decision correctly? Agency costs as value of perfect information provide an upper bound for monitoring costs. If there were the possibility to introduce a perfectly working monitoring device it would be rejected if the costs of the device surmount the information value, see Section 2.4.

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1.5 Hierarchy and Delegation

Note that no hierarchy was assumed so far. Neither was the principal assumed to be the boss nor the agent to be her subordinate as one might associate from the designations of the two cooperating partners. Consequently, the expression of a team seems to be much more appropriate. Agent is simply that member of the team who can vary his action/effort/behavior/input. Principal is that member of the team who cannot costlessly observe the agent's action/effort/behavior/input. Therefore, team members are bounded to schemes that set incentives. If person A buys insurance from company P, company P can hardly observe the care person A shows to avoid the accident, and nevertheless there is no hierarchical cooperation between A and P, see M. Spence and R. Zeckhauser (1971).

The relations between employer and employee as well as between stockholder and manager are very important examples for an agent-principal relation. Although most approaches are based on the identifications of principal and employer or principal and stockholder, resp., some aspects of these relations require to see the subordinate as principal and the superior as agent, see P. Swoboda (1987). In fact, the reward systems of hierarchical organizations sometimes provide more incentives for bosses than for subordinates.

Further, no formal contract was supposed to legalize the relation between agent and principal. Moreover, not necessarily it is the case that "the principal delegates some decision making to the agent", though the delegation of decision making provides a reasonable explanation of why the principal cannot observe the agent's doing in full detail. But there are many other situations different from the "delegation of decision making" where it is easy to see that the principal has some difficulties in controlling the agent's action/effort/behavior/input. One example is the situation of insurance mentioned above.

1.6 Hidden Effort, Hidden Characteristics

The elaboration of Agency Theory requires a closer look to a number of different issues. One major task is to present a variety of different situations where a principal cannot completely observe an **(p. 10)** agent. In addition, reasonable argumentations have to be given for this information asymmetry. One should distinguish two situations which were termed by K. J. Arrow (1986): hidden efforts and hidden characteristics.

In many cases agent and principa1 cooperate within an organization and they know each other quite well. Each of them might provide some inputs to the team, but the principal's inputs are not under discussion here. The input provided by the agent are labor or management services and what can hardly be observed by others is the agent's effort. Effort is not on1y diligence and sweat but could also refer to the agent's renunciation of consumption on the job. *Hidden effort* and *managerial discretion* thus refer to the same situation.

The total team output and hence the principal's we1fare depend on the agent's effort, but additionally also on some exogenous risk (state of nature). Although the principal knows the probability distribution of this risk, she might be unable to come to know which state nature was actually realizing. Consequently, she is unable to separate low effort from bad luck. If results turned out to be poor, the principal cannot conclude that the agent's effort must have been low. So it is the environmental uncertainty that explains why the principal is unable to deduce the agent's effort from the resulting team output.

As stated, the team members know each other. In particular, the principal knows the characteristics of her agent such as his skill and his attitude toward risk. Although the principal is unable to observe her agent's effort, she can predict the way in which the agent will behave under certain conditions. She can calculate the agent's response (function $\phi: P \to X$) to a certain reward scheme. The principal can thus study the impact of reward schemes on her own wealth, and., determine a reward scheme that is best with respect to her own interest and subject to the constraint that the agent's effort is induced by the reward scheme.

In the basic situation of hidden effort the reward will be a function of team output y. This can be generalized if there is a monitoring signal z, i.e., a statistic that is correlated to the **(p. 11)** agent's effort. The issue of *monitoring* is thus related to the situation of hidden effort.

A situation quite different from hidden effort is that of *hidden characteristics*. Here cooperation occurs across markets and the principal is unable to observe the agent's decision in time. A principal on the one side of the market gets into contact with many individuals, potential agents, on the other side. The principal has to make an offer in the moment of getting into contact with one of these agents. The agents, however, differ in their characteristics. Although the principal might know the distribution of characteristics, she usually will be uncertain about the particular type of agent. How to make an offer that is appropriate without knowing the individual characteristic?

In such cases of hidden characteristics the principal will look for *sorting devices* or install additional instruments that partially reveal hidden characteristics through *screening*. An important screening device consists of a set of payment schemes which allow for *self selection* through agents. Self selection schemes should be designed such that each agent has an incentive to reveal his type and his characteristics through choice. Such a scheme is presented in Section 2.6.

2. A Closer Look

2.1 Risk Sharing

A common situation of hidden effort is one in which the principal seeks help from the agent because her wealth depends on services the agent can provide. The agent can offer these services in various quantities and qualities upon which he alone decides. Formally, the agent chooses an element x from a set X of feasible actions. This decision, in its manifold aspects, is called effort. So far the external effects are outlined. On the other hand, the principal's wealth is not only affected by the agent's effort. Another factor is some kind of exogenous risk the probability **(p. 12)** distribution of which neither principal nor agent can control. Describe this state of nature by the random variable $\tilde{\theta}$. Thus the principal's gross wealth, denoted by $\tilde{y}$, can be viewed as a function of effort x and risk $\tilde{\theta}$,

$$(1) \qquad \tilde{y} = f(x, \tilde{\theta}).$$

It might be indicated to visualize this situation as one of production although sometimes this notion must be interpreted in a broad sense. Anyway, the principal's gross wealth $\tilde{y}$ will be called *output* or *result*. The only input upon which a decision can be made is the agent's *effort* x. If there were any other inputs, their quantities and qualities will be supposed to be either fixed or settled beforehand.

Of course, the principal wants to buy some input from the agent but, unfortunately, she cannot observe how much the agent is providing and how good he is performing. In other words, the principal is assumed to be unable to observe the agent's effort decision $x \in X$. One implication of the exogenous risk $\tilde{\theta}$ is that it gives a reason for the assumed *information asymmetry*. If the principal is not completely ignorant, she will usually know the production function f (how her gross wealth is affected by her agent's effort and the exogenous risk), and she will know the probability distribution of $\tilde{\theta}$. Later she will also observe the realization y of her gross wealth $\tilde{y}$. But, to speak in figurative terms, she might be too distant from the location of production in order to see which state θ nature realized. Consequently, the principal cannot infer the agent's effort from the knowledge of both technology f and result y. The information asymmetry rules out negotiations with the aim to close with an agreement on effort.

Assume that the realization y of the output can be observed by both agent and principal correctly and without costs. Hence the principal can offer a *payment scheme* $p(.,)$ where the actual payment $p(y)$ to be made to the agent depends on the realization y of output. Clearly, the principal will then keep the residuum $y - p(y)$ as her net wealth. Denote by P the set of such schemes $p(.)$ from which the principal is choosing one in order to offer it to her agent.

So far the agent need not make any committing declaration or contract in any legal sense. He will just realize the principal's offer, consider it in his decision-making calculations, and accept the money later when the realization y becomes known. Note, however, that for some reward scheme it could happen under a particular realization of output that the actual payment is negative. In such a case, the agent were to pay the corresponding amount to the principal. In order not to exclude such schemes from further consideration, the right will be assigned to the agent to decide whether or not to *accept* a payment scheme. If the agent accepts a payment scheme $p(.)$ he declares himself willing to make an eventual transfer in the case $p(y)$ is negative. But the agent is never supposed to make any promise with regard to his effort decision which could not be checked by the principal anyway.

Let $c(x)$ be the agent's *disutility of effort* in terms of a money equivalent. So to speak, $c(x)$ is the cost the agent has to pay by himself for the services he is going to provide as input. If the agent was offered and had accepted the payment scheme $p \in P$ and is now going to decide upon his effort $x \in X$, he is confronted with net wealth

(2) $$\tilde{w}(x, p) = p(f(x, \tilde{\theta})) - c(x) .$$

Since the result (1) is uncertain at that moment of decision making, the wealth w will be uncertain, too. In the particular case the scheme $p(.)$ is constant in y such that the agent receives a fixed wage rather than sharing the result, his wealth is free of risk. The welfare derived from wealth w can be formalized by the expected utility $E[u(\tilde{w})]$, or, what is done here, the agent's welfare U is expressed in terms of the certainty equivalent

$$(3) \qquad U(x,p) \quad := \quad u^{-1}\left(E[u(\tilde{w})]\right).$$

Thereby, u denotes the Neumann-Morgenstern utility function of the agent. He is supposed to be risk averse (u is concave), and hence the certainty equivalent U of wealth is below the expected value $E[\tilde{w}]$. The difference between the two entities was called *risk premium* by J. W. Pratt (1964).

(p. 14) A second implication of the exogenous uncertainty $\tilde{\theta}$ introduced in (1) is that it raises the issue of risk sharing. The more a payment scheme lets the agent share the uncertain result $\tilde{y}$, the more risky becomes his wealth (2). Suppose the principal wants to set an incentive to her agent by offering a considerable result sharing. The agent is not only requiring a compensation for his disutility of effort $c(x)$. Because of his risk aversion, the agent needs also a higher risk premium in order to maintain a certain level of welfare.

That risk premium may turn out to be inefficient from a risk-sharing point of view. Suppose the principal is risk neutral so she could bear all the risk without requiring a premium. The principal keeps all the risk with her residuum $\tilde{y} - p(\tilde{y})$ if the scheme $p(.)$ is constant such that the agent receives a fixed wage independent of the uncertain result. Such a fixed-wage payment, however, will set no incentives.

2.2 Induced Effort

How will the agent respond to a payment scheme $p(.)$? He will choose his effort such that his welfare (3) is maximized. Let $x^* \in X$ denote an optimal decision,

(4) $$U(x^*, p) = \max\left\{U(x,p) \,\middle|\, x \in X\right\}.$$

The effort chosen depends, among other things, on the payment scheme and hence we write $x^* = \phi(p)$. Omit questions of existence and uniqueness (for some of the problems involved see S. J. Grossman and O. D. Hart (1983)), and solve (4) for each $p \in P$. This yields the response function $\phi: P \to X$ that describes the way in which the agent responds to reward schemes. In other words, ϕ describes how effort is induced. Note that under scheme p the agent can and will attain the welfare $U(\phi(p), p)$.

The decision on effort is not the only choice to be made. Distinguish four consequential choices. The *first* choice is made by the principal who selects a payment scheme $p \in P$ and suggests it to the agent. The *second* decision is made by the agent when he either accepts or refuses the scheme suggested. The agent makes his decision on acceptance in view of some other opportunities he might have and the best of which guarantees a certain reservation welfare m. Evidently, the agent is accepting a payment scheme p only if the welfare attained is not below the reservation level,

(5) $$U(\phi(p), p) \geq m.$$

For that reason, the inequality (5) is called *reservation constraint*. If the agent refuses, the principal will presumably suggest another payment scheme. So there might be some bargaining and the first two decisions turn out to be interrelated. To make here a clear statement, we proceed on the assumption that the agent accepts a scheme p if and only if the reservation constraint (5) is satisfied. The reservation level m is thereby either belonging to the data or is resulting from negotiations. In short, m is considered as an exogenous parameter.

The *third* decision: If the agent accepted a reward scheme p he is going to choose his effort $x^* = \phi(p)$. The *fourth* and final step of that sequence is the realization of the state of nature, more precisely, the realization y of $\tilde{y}$ becomes known to both principal and agent. Only now the actual payment $p(y)$ can be made. This ends the cooperation.

Nothing was said hitherto about the first decision in that chain of four choices. How will the principal choose a scheme p from set P?

The principal's wealth is the residuum $\tilde{y} - p(\tilde{y})$, and her welfare (again expressed in terms of a certainty equivalent) is

$$V(x, p) = v^{-1}\left(E\left[v(\tilde{y} - p(\tilde{y}))\right]\right). \tag{6}$$

Where v denotes the Neumann-Morgenstern utility function of the principal. The welfare (6) depends on the agent's effort x since the result $\tilde{y}$ depends on x.

One of the stronger assumptions in the hidden-effort situation is that the principal knows all relevant characteristics of the co-operating agent. The relevant characteristics of the agent are: utility function u, disutility $c(.)$, set of feasible effort decisions X, and the reservation level m. With that knowledge the principal can calculate the way ϕ in which the agent will respond **(p. 16)** $x^* = \phi(p)$ to reward schemes $p \in P$. This assumption simplifies the principal's decision to

(7) maximize $V(\phi(p), p)$ with respect to $p \in P$ subject to the reservation constraint (5)

A solution of (7) will be denoted by p_m^*. As was indicated by the subcript m, the reservation level usually has a major impact on the scheme selected. Of course, the optimal scheme also depends on data such as the technology f, the agent's risk aversion $-u''/u'$, and the variance $Var\left[\tilde{\phi}\right]$ of the exogenous risk.

A final remark is made on the assumption according which the principal knows the agent's characteristics and is thus in the position to *predict* her agent's decision making although she is, due to the information asymmetry, unable to verify her calculations by observation. What makes then the difference between the ability to predict and the ability to observe? Suppose the principal selects the scheme p and predicts, by herself, that the agent will respond with effort $x^* = \phi(p)$. What the agent will do in fact is to choose exactly that effort x^*. The problem is not that there could be any difference between what the principal predicts and what the agent really does. The principal's prediction is always correct.

Rather than that the true problem is: both individuals cannot freely negotiate in order to agree upon any pair (x, p) of effort and payment. Suppose, for a moment, both individuals would agree to realize a particular pair $(\bar{x}, \bar{p})$ where $\bar{x} \neq \phi(\bar{p})$. Then the principal, unable to observe the agent, can predict that the agent will realize the effort $x^* = \phi(\bar{p})$ in disaccord with the agreement. And the selfish agent will, in fact, make his decision x^* as predicted. Consequently, both individuals are restricted in their cooperation to those specific pairs (x^*, p), where effort is induced by the payment $x^* = \phi(p)$. For that reason, there is no need and no sense to discuss on effort at all. Agent and principal just speak on payment schemes p and none of them has doubts about the corresponding effort induced. Since they do not settle effort, there is no *shirking*.

The discussion between agent and principal on the payment scheme was modeled here in that way: The principal selects, from all **(p. 17)** payment schemes which guarantee the agent a certain welfare $U \geq m$, that scheme p_m^* which maximizes her own welfare V. The resulting design of cooperation is characterized by the pair (x_m^*, p_m^*) of induced effort $x_m^* = \phi(p_m^*)$ and payment p_m^*. By variation of the parameter m one gets the elements of the set I of second-best designs defined in Section 1.4.

3. The LEN-Model

The hidden-effort situation as outlined in the last section cannot be solved in its general form. In order to study how the induced effort and the selected payment scheme depend on the data and parameters of the model, we further specify functions and variables. The set of specifying assumptions suggested here is called Linear-Exponential-Normal-Model, since

(L) output $\tilde{y}$ is a linear function of risk $\tilde{\theta}$, and feasible payment schemes $p(.) \in P$ are linear functions of output,

(E) the utility function u of the agent is exponential; likewise the principal has constant absolute risk aversion,

(N) the risk $\tilde{\theta}$ 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), (6) can be expressed as expected value minus half the variance times risk aversion (G. Bamberg and K. Spremann (1981)). A simple version of the Len-Model is:

$$\tilde{y} = f(x, \tilde{\theta}) \quad := \quad x + \tilde{\theta}\,, \quad x \in X \quad := \quad [0, 1/2]\,,$$

$\tilde{\theta}$ normal, $E[\tilde{\theta}] = 0$, $Var[\tilde{\theta}] = \sigma^2$

$p \in P$ if and only if $p(y) = r + s \cdot y$

$u(w) = -\exp(-\alpha \cdot w)$, $\alpha > 0$

v linear (principal is risk neutral)

$c(x) = x^2$.

(p. 18) The agent's effort has one dimension only and the result $\tilde{y}$ is the sum of effort x and the one-dimensional random variable $\tilde{\theta}$. The agent has constant risk aversion denoted by $\alpha = -u''/u' > 0$ and the principal is risk neutral $-v''/v' = 0$. In order to describe increasing marginal disutility of effort, the function $c(x)$ is supposed to be quadratic.

— Work in progress — Next section will be reconstructed soon. KS —