THEORIES OF BEHAVIOR IN PRINCIPAL-AGENT RELATIONSHIPS WITH HIDDEN ACTION*

Claudia Keser[a] and Marc Willinger[b]

[a]IBM T.J. Watson Research Center and CIRANO, Montreal
[b] BETA, Université Louis Pasteur, Strasbourg and Institut Universitaire de France,

Current version : May 2002

Abstract: *In Keser and Willinger (IJIO, 2000) we found that many contracts offered by experimental subjects do not satisfy incentive compatibility. While the combination of incentive compatibility and a binding participation constraint would require that the agent incurs a net loss in the less favorable state for the principal, experimental subjects in the role of principals propose contracts in which the agent never risks to make a loss. We identified in the principals' decision making three basic principles that, combined together, describe a fair offers area into which a large number of the observed contract offers falls. These principles imply that net expected surplus is more evenly allocated between the principal and the agent than agency theory predicts. The aim of the experiments presented in this paper is to test the robustness of these principles when the effort costs increase and the net expected surplus becomes smaller, and to compare their predictive success to the predictive success of agency theory under the assumption either of a risk-averse or a risk-neutral agent. The results show that the fair offers prediction describes the observed contract offers better than agency theory as long as an important net expected surplus is created. However, when the effort costs are so high that the net expected surplus is negligible, standard agency theory does better than the combination of the three principles in predicting the observed contract offers.*

***** We would like to thank Kene Boun My for his help running the experiments. Helpful discussions with François Cochard, John Dickhaudt, Isabelle Maret, Phu Nguyen Van, Anne Rozan, François Salanié and Hubert Stahn are gratefully acknowledged. The experiments were run while Claudia Keser was working at the University of Karlsruhe. Financial support by the Sonderforschungsbereich 504 at the University of Mannheim is gratefully acknowledged.

1. Introduction

Modern contract theory has induced an important renewal of the treatment of transactions in economics. While the design of contractual arrangements was neglected by the traditional Arrow-Debreu model, and more generally by standard microeconomics, the design of optimal contracts is considered as central in contemporary labor economics, financial economics, public regulation or organizational design. The asymmetry of information, which is one of the fundamental driving forces of contractual design, requires adequate incentives for aligning conflicting objectives among economic agents. The well-known moral hazard problem with hidden actions provides a good illustration of the problems generated by information asymmetries among principals and agents, and how to solve them by designing optimal contracts.

While moral hazard is now taken into account in many models, curiously few attempts have been made for testing the predictive validity of the principal-agent model. One reason is that real word contracts incorporate many characteristics that are not taken into account by the theory. Many factors can therefore account for differences between observed contracts and contracts predicted by agency theory. Laboratory experiments allow us to generate the particular data that are needed for testing the main predictions of principal-agent relationships. Few attempts have been made in this direction. Notable exceptions are Berg et al. (1992), Epstein (1992), Anderhub, Gächter, and Königstein (1999), Güth, Klose, Königstein, and Schwalbach (1998), and Keser and Willinger (2000).

In this paper we present the results of an experiment designed to test the predictive validity of the standard principal-agent model with hidden actions. The experiment, which is based on a design introduced in Keser and Willinger (2000), allows us to test whether the experimental contracts satisfy the basic assumptions of agency theory: the participation constraint and the incentive compatibility constraint. The predictive validity of these constraints predictions is compared to the predictive validity of other behavioral assumptions, such as the loss avoidance principle identified in Keser and Willinger (2000). This principle requires that the principal assure the agent against any potential loss. In the experiment, a subject in the role of a principal is randomly matched with a subject in the role of an agent. They have the opportunity to make a contract. If the agent accepts the contract offered by the principal, he has to choose between two activities, one of which is more costly than the other. Each activity generates a stochastic gain that accrues to the principal. There are two possible gains, a high and a low one. The high gain is more likely if the agent chooses the high cost activity and the low gain is more likely if the agent chooses the low cost activity. The agent's choice is not observable by the principal. Thus, the principal, who has to pay the agent for his contractual activity, can only make the payment dependent on the realized gain but not on the activity chosen. The procedure of the interaction is such that the principal makes a contract offer to the agent that specifies a payment scheme. The agent can either accept the payment scheme offered by the principal and choose an activity, or reject the contract. In the latter case, the interaction between the principal and the agent immediately ends with zero earnings for each party.

Under the assumption of risk neutrality of both the principal and the agent, the game is solved by backward induction. We study a parametric version of the game, for which the subgame perfect equilibria are characterized by the contract offers that induce the high cost activity. For a particular set of parameters, in Keser and Willinger (2000) we found that most observed contract offers yield in both states, low and high gain, higher payments than predicted by the subgame perfect equilibrium solution. Furthermore, half of the observed payment schemes violate the incentive compatibility constraint that should induce the agent to choose the low cost activity. The agents tend to react in the way predicted by expected profit maximization. We showed that most of the observed contract offers satisfy the following three principles :

Appropriateness: The agent's wage payment is larger in the high gain than in the low gain state.

Loss avoidance: The payment in each of the two states covers the activity costs.

Sharing power: The principal's profit is at least equal to 50 percent of the net surplus of the contract.

The combination of these three principles defines a subset in the contract space, called the *fair-offers area*. In Keser and Willinger (2000) we observed that a very large number of contract offers belongs to this relatively small subset. Thus, the fair-offers subset provides a good description of the experimental data.

While two of the principles defining the fair offers area, appropriateness and sharing power, are not in conflict with standard agency theory, loss avoidance is clearly incompatible. According to agency theory, the principal can always implement the low cost activity by offering the agent a risk-free contract where the payment is at least equal to the cost of the least costly activity. If a profit-maximizing principal wants to implement the low cost activity he offers a flat wage equal to the cost of the low cost activity. However, if a profit-maximizing principal wants to implement the high cost activity, he must offer an incentive compatible contract such that the agent incurs a net loss in the bad state and a net gain in the good state. As he makes the participation constraint binding and thus keeps the agent at his reservation level, the entire expected net surplus of the contract goes to the principal These basic requirements of agency theory are almost always violated in the experiment by Keser and Willinger (2000). All of the observed contracts induce surplus sharing between the principal and the agent and only rarely do agents incur the risk of a loss. A plausible reason for observing such strong differences with respect to the predictions of agency theory is that in the experiment in Keser and Willinger (2000) the expected net surplus of a contract was quite high. In other words, there was a large difference between the activity costs and the expected gain for each activity. This might have encouraged principals to make generous contract offers. Principals might have feared the rejection of not so generous contract offers; an observation that has in made in very many experiments on the ultimatum bargaining game. It is therefore of interest to investigate whether contract offers are affected by the size of the expected surplus. More precisely, we are interested in whether the division of the expected surplus depends on its size. We implement the decrease of the expected surplus by taking the level of the activity costs as the treatment variable, keeping the difference between low and high costs constant. We expect that the smaller the difference between costs and expected gains, the better are the chances that we give to the game-theoretic prediction. This is due to a distributive aspect inherent in the agency problem, which is ignored in the game-theoretic solution. In other words, we expect that the smaller the "pie" (expected gain minus cost of activity) to be allocated between principal and agent, the better the predictive success of the game-theoretic solution. In our experiments to be presented in this paper, we consider four different levels of costs, from "very low" to "very high". We compare the fair-offers prediction to the standard agency prediction involving a risk-neutral principal and either a risk-neutral or a risk-averse agent. To describe the prediction of agency theory with a risk-averse agent but without the assumption of a precisely specified utility function, we define a subset within the contract space that contains all the contracts implementing high effort for any strictly increasing concave utility function. Our main finding is that the fair offers theory is a better predictor for the observed contracts than the standard agency theory, except for the highest cost level where the agency theory with a risk-averse agent yields the best predition. We will show that this result can be explained by the conflict between two objectives that the principal tries to satisfy simultaneously: loss avoidance and profit maximization.

2. Experimental design

The experiment was run at two different sites, the University Louis Pasteur in Strasbourg (*France* thereafter), and at the University of Karlsruhe (*Germany* thereafter). At both sites observations were collected under the same procedure. Subjects were randomly selected from the existing local subject pool (of about 800 subjects in France and 1500 subjects in Germany). 8 sessions were organized in France and

6 sessions in Germany. Each session involved 16 participants, 8 principals and 8 agents, divided into two independent player groups of 4 principals and 4 agents who interacted with each other matched in pairs. A session was divided into 10 periods. At the beginning of each period, each of the four principals was randomly matched with one of the four agents of his group. In each group we observed 40 contracts, which correspond to an independent observation. Four different treatments, corresponding to cost situations I – IV as presented in Table 1 below, were implemented. Except for treatment I, we collected 4 independent observations per treatment and per country. For treatment I, we had already at the German site the 10 independent observations available on which Keser and Willinger (2000) was based.[1] We collected only four additional observations for treatment I at the French site. For the new sessions we observed a total of 160 contracts per treatment and per country. For treatment I in Germany, 500 observed contract offers were already available. Each contract offer has two components: the payment to the agent in case that state 1 occurs (a gain of 50 for the principal) and the payment to the agent in case that state 2 occurs (a gain of 100 for the principal). Gains, contract payments, and activity costs were expressed in points.

In any given period each principal had to make a contract offer to the agent. After each principal had made his offer, all offers were collected by the server of the computer network and sent to the agents on a random basis. Each agent, after receiving the contract offer, had to decide whether to accept or reject it. If he rejected both the principal and the agent received a zero payoff. If the agent accepted the contract offer, he had to choose among activity A and activity B. The choice of activity A implied a 50-50 chance for each state, while the choice of activity B implied a 20 percent chance for state 1 and a 80 percent chance for state 2 (see Table 1).

Points were accumulated on each subject's account and were on permanent display on their computer screen. After each period, each subject received summary data on the proposed contract, the realized gain, the agent's acceptance decision and the payment transferred to the agent. Note, however, that in case of acceptance the principal was never informed about the agent's activity choice. These summary data for all completed periods of the game were accessible by the hit of an option key.

[1] Those data were generated in 5 sessions involving 20 subjects that were divided into two independent player groups of 5 principals and 5 agents each.

Table 1:
Experimental design

	Probability of a gain of 50	Probability of a gain of 100	Agent's activity costs in situation	I low	II medium	III high	IV very high
Activity A	50%	50%	C_A	13	27	34	41
Activity B	20%	80%	C_B	20	34	41	48

Table 1 summarizes the parameters that we used for the different treatments of the experiment. Each treatment I-IV correspond to a pair (C_A,C_B), where C_A denotes the cost of activity A and C_B the cost of activity B. Note that the cost difference between activity A and activity B remains constant across treatments at the level of 7. Treatment I corresponds to a low, treatment II to a medium, treatment III to a high, and treatment IV to a very high cost level. In the remainder of the paper we shall identify treatments by the corresponding cost pair denoted by (C_A – C_B). The activity costs can also be interpreted as effort costs: a higher effort level (activity B) is associated with a greater likelihood of the larger gain, and involves higher costs.

3. Theoretical predictions

In this section we provide a formal statement of the three predictions that we test on our data. The first two fundamental predictions are subgame perfect equilibrium solutions. The principal and the agent play a sequential game in which the principal offers a contract that can be accepted or rejected by the agent. Conditionally on acceptance the agent chooses an effort level that produces a random outcome for the principal. If both players are expected payoff maximizers, the subgame perfect equilibrium solution of this game predicts an indifference subset of contracts implementing high effort. This *equilibrium under risk neutrality* is our first prediction. Our second prediction, the *equilibrium under risk aversion*, corresponds to the standard model of principal-agent theory, which assumes that the principal is risk-neutral and the agent is strictly risk-averse. Under the additional assumption that the principal knows the agent's utility function, a unique high effort implementing contract can be defined. In the experiment, however, it is an unrealistic assumption that the principal knows the agent's utility function. To account for this type of uncertainty and in order to derive a more relevant prediction with respect to the data, we derive the set of all possible equilibrium contract offers for the family of strictly increasing and strictly concave utility functions. Under this assumption we predict a subset of potential equilibrium contracts within the space of admissible contracts. One interpretation is that the experimenter is unable to observe the principal's belief about the agent's utility function. Another interpretation is that the principal himself is uncertain about the agent's utility function. We model the principal's uncertainty by assuming a uniform distribution over the set of all strictly increasing and strictly concave utility functions. Note that by allowing any strictly concave utility function we give the best possible chances for the standard agency model to be a good predictor of our data. We simply require that the observed contract offers lie in the set of contracts predicted by the equilibrium under risk aversion. The third prediction that we will test is the *fair offers hypothesis* proposed in Keser and Willinger (2000). Like the two subgame perfect equilibrium predictions, the fair offers hypothesis predicts a subset of the set of admissible contracts. We shall thus compare the predictions on the basis of the measure of predictive success proposed by Selten and Krischker (1983). In the following, we give a formal statement of each of the three predictions.

3.1 Equilibrium under risk neutrality

Let us call player X the principal and player Y the agent. As described in Keser and Willinger (2000) we analyze the interaction between the principal and the agent as a four-stage game. In the first stage, player X makes a contract offer (w_1, w_2) to player Y, which specifies a payment scheme contingent on the realized gain: w_1 is the payment to player Y if the gain is 50, and w_2 the payment if the gain is 100. In stage 2, player Y decides whether to accept or to reject the contract offer. A rejection ends the game immediately and both players earn zero profits. If player Y accepts the contract, he has to choose between activity A and activity B in the third stage. In the final stage, the gain is randomly drawn according to the probabilities induced by the activity chosen by player Y. In case of acceptance of the contract, the profit of player X is $g_i - w_i$, with $i \in \{1,2\}$ and the gain $g_i \in \{50, 100\}$, and the profit of player Y is $w_i - C_j$, where $j \in \{A, B\}$.

Under the assumption of risk neutrality for both players, the game-theoretic solution implies that for the equilibrium contract both players maximize their expected profits. The game is solved by backward induction. Under risk neutrality the equilibrium contract offered by the principal implements activity B, for any of the four cost conditions. Table 2 shows the possible equilibrium contracts when offers are restricted to be integer-valued. Note that for cost situation 13-20 there is a unique integer-valued equilibrium contract.[2]

Prediction 1: Under the assumption of risk neutrality for both players, the subgame perfect equilibrium solutions of the game correspond to the payment schemes (w_1*, w_2*) shown in Table 2. For any of these contracts, the agent accepts the offer and chooses activity B.

Notice that all equilibrium contracts share the common property that the agent makes a net loss if state 1 occurs, regardless of the activity chosen. This is a direct consequence of incentive compatibility if the agent is kept as close as possible to his zero reservation utility (zero expected profit) in case that he rejects the contract. As we shall see, most of our observed contracts do not satisfy this fundamental property of agency theory.

Table 2:
Subgame perfect equilibrium contracts for a risk-neutral principal and a risk-neutral agent
(Equilibrium under risk neutrality)

Effort costs (low–high)	Predicted contracts
13–20	(0, 25)
27–34	(2, 42) , (6, 41) , (10, 40) , (14, 39)
34–41	(1, 51) , (5, 50) , (9, 49) , (13, 48), (17, 47) , (21, 46)
41–48	(0, 60) , (4, 59) , (8, 58) , (12, 57) , (16, 56) , (20, 55) , (24, 54) , (28, 53)

To derive prediction 1, we consider the *related game* for which there are no integer restrictions on the values of w_1 and w_2. The related game is solved by backward induction. First, we determine the agent's best reply to any contract offer. Then, we take into account the agent's best reply function to identify the principal's expected profit maximization contract offers.

[2] In Keser and Willinger (2000) we required a strictly positive expected profit for the agent (participation constraint). As we have given up this requirement here, the equilibrium contract is slightly different from the one in Keser and Willinger.

The agent's best reply function

The agent's best reply to a contract offer (w_1, w_2) is to *accept and choose activity B* if the participation and the incentive compatibility constraints for activity B are satisfied. The participation constraint (1) states that the agent's expected net profit if he chooses activity B must be at least equal to his reservation payment, which is to zero. According to the incentive compatibility constraint (2), the expected net profit if he chooses activity B must be at least equal to his expected net profit if he chooses activity A:

$$0.2(w_1 - C_B) + 0.8(w_2 - C_B) \geq 0 \;\Leftrightarrow\; w_2 \geq -0.25w_1 + (5/4)C_B \tag{1}$$

$$0.2(w_1 - C_B) + 0.8(w_2 - C_B) \geq 0.5(w_1 - C_A) + 0.5(w_2 - C_A) \;\Leftrightarrow\; w_2 \geq w_1 + (10/3)(C_B - C_A) \tag{2}$$

Similarly, the agent's best reply to a contract offer (w_1, w_2) is to *accept and choose activity A* if the participation constraint (3) and the incentive compatibility constraint (4) for activity A are satisfied:

$$0.5(w_1 - C_A) + 0.5(w_2 - C_A) \geq 0 \;\Leftrightarrow\; w_2 \geq -w_1 + 2\,C_A \tag{3}$$

$$0.5(w_1 - C_A) + 0.5(w_2 - C_A) \geq 0.2(w_1 - C_B) + 0.8(w_2 - C_B) \;\Leftrightarrow\; w_2 \leq w_1 + (10/3)(C_B - C_A) \tag{4}$$

If none of the participation constraint is satisfied, the agent's best reply is to refuse the contract offer.

The principal's calculus

The principal takes the agent's best reply into account when making a contract offer. Let us define the principal's expected profit if the agent chooses activity B by $\Pi_B(w_1, w_2) = 0.2(50 - w_1) + 0.8(100 - w_2)$. Similarly, let $\Pi_A(w_1, w_2) = 0.5(50 - w_1) + 0.5(100 - w_2)$ be the principal's profit if the agent chooses activity A. The principal maximizes his profit by extracting the maximum surplus from the agent, which means that he makes his contract offer such that the participation constraint is binding. If the agent chooses activity B, the maximum expected profit that the principal can obtain is, therefore, by offering one of the contracts that satisfies $w_2 = -0.25w_1 + (5/4)C_B$. Thus, the maximum expected profit with activity B is given by $\Pi^*_B(w_1, w_2) = 90 - C_B$. Similarly, the principal's maximum expected profit if the agent chooses activity A corresponds to contracts which satisfy $w_2 = -w_1 + 2C_A$. Thus, $\Pi^*_A(w_1, w_2) = 75 - C_A$. The principal implements activity B if $\Pi^*_B(w_1, w_2) > \Pi^*_A(w_1, w_2)$. This condition is always satisfied with the parameters of our experiments, since $C_B - C_A = 7$.

It follows that the subgame perfect equilibrium solution of the related game involves the principal inducing the agent to choose activity B. The contract offers (w_1*, w_2*) satisfy the incentive constraint for activity B and lie on the participation constraint. In the related game there exit an infinite number of subgame perfect equilibrium contracts and the principal might therefore implement any one of them. Since in the experiment subjects' were constrained to be integer numbers, we shall restrict our attention to equilibrium contracts with integer values, which are summarized in Table 2.

The multiplicity of equilibria in the risk-neutral case comes from the fact that the agent's participation constraint has the same slope as the principal's iso-expected-profit lines in the (w_1, w_2) space. With the restriction to integer numbers, the number of equilibrium contracts is increasing with the cost level. Note that in the case where the agent is risk-neutral, the equilibrium contracts are also Pareto-optimal contracts; the non-observability of the agent's effort affects only the risk sharing but not the expected profits of the two players.

3.2 Equilibrium under risk aversion

The analysis of the game for a risk-averse agent is similar to the one presented above, except that the agent's expected payoff is replaced by his expected utility of the payoffs. We assume throughout that the agent's utility function, u(x), satisfies u'(x) > 0 and u"(x) < 0 for all x. If the principal wants to implement activity B, his contract offer must satisfy the participation and the incentive compatibility constraints:

$$0.2u(w_1 - C_B) + 0.8u(w_2 - C_B) \geq u(0) \quad (5)$$

$$0.2u(w_1 - C_B) + 0.8u(w_2 - C_B) \geq 0.5u(w_1 - C_A) + 0.5u(w_2 - C_A) \quad (6)$$

In contrast to the risk-neutral case, the equilibrium contract is not necessarily socially optimal when the agent is risk-averse. More specifically, in our case with two effort levels, the required compensation scheme to implement high effort under non-observability, incurs a larger expected wage payment than under observability of the agent's effort. This may cause a welfare loss if the principal is better off by offering the less costly contract that induces low effort.

Note that in contrast to most agency theory models, we do not assume that the utility of the wage payment and the disutility of effort are generated by a different variable. This seems reasonable in the context of our experiments, because payments and effort costs are measured in the same experimental units (points). We can therefore take the net profit (wage-payment minus effort costs) as the variable of the utility function. Implicitly we assume that subjects are able to aggregate the wage payment and the cost of effort to evaluate the net contingent profit of the contract. While theoretically justified, this assumption also seems to be empirically supported by the contract offers observed in Keser and Willinger (2000). As this assumption implies non-separability of the utility of the payment and the disutility of effort, it can be optimal for the principal, assuming that the agent is strictly risk-averse, to offer a contract that fully covers the effort costs.[3]

Prediction 2: If the agent is strictly risk averse, i.e. u'(.) > 0 and u''(.) < 0, and the principal is risk-neutral, the set of contracts which implement activity B satisfy restrictions i- iii (see Appendix):

i) $w_2 \leq -\frac{1}{4} w_1 + \frac{C_A + 15}{0.8}$

ii) $w_2 > -\frac{1}{4} w_1 + \frac{C_B}{0.8}$

iii) $w_2 > w_1$

The first of these conditions states that the principal implements activity B only if he expects a larger profit than by implementing activity A. The second condition states that the contract must satisfy the participation constraint, which implies that the contract always lies above the tangency line to the reservation indifference curve. The tangency line corresponds to the boundary case of linear (risk-neutral) utility. The third inequality follows from the monotone likelihood property: the principal offers a larger payment to the agent in case of the high gain as the likelihood of a high gain is larger for the more costly activity. Note that if the third inequality was not satisfied, the agent would prefer to choose the low effort

[3] The slope of the incentive compatibility curve for implementing activity B is given by : $\frac{dw_2}{dw_1} = \frac{0.5u'(w_1 - C_A) - 0.2u'(w_1 - C_B)}{0.8u'(w_2 - C_B) - 0.5u'(w_2 - C_A)}$. The sign of this expression can be positive or negative since $u'(w_1 - C_A) < u'(w_1 - C_B)$ by concavity of u(.). In contrast to this, under the assumption of separability dw_2/dw_1 is always positive.

(assuming that the participation constraint is satisfied) because this would be a stochastically dominating choice.[4]

Taken all together, conditions i-iii define an area in the set of contracts that we shall identify as the *equilibrium under risk aversion*.

3.3 Fair offers prediction

In the earlier experiment presented in Keser and Willinger (2000) we found that the observed contracts for cost level (13-20) were not correctly predicted by subgame perfect equilibria, neither with the assumption of a risk-neutral nor with the assumption of a risk-averse agent.[5] We showed instead that most of the observed contracts belong to a subset of contracts that satisfy the three principles outlined in the introduction: appropriateness, loss avoidance and sharing-power. Appropriateness means that the agent's payment is increasing with the principal's gain. This principle is also satisfied by the standard agency prediction, when the two effort levels (activities) satisfy the monotone likelihood property. Loss avoidance, however, which means that contract offers provide the agent full insurance against losses, contradicts the standard agency prediction. Sharing power states that the principal earns at least half of the net gain from the contract.

There are several alternative ways to define principles 2 and 3, since they depend on which cost is taken into account : C_A, C_B, or a combination of the two. For example, loss avoidance can be defined as giving at least the cost of low effort for w_1, and at least the cost of high effort for w_2 (condition 2c). In total 9 different combinations of these principles are possible. Each of these combinations of principles corresponds to a relatively small subset of the contract space, which we shall call (a variant of) the *fair-offers prediction*. The three underlying principles, with their variants, are formally defined as follows:

1) Appropriateness: $w_1 \leq w_2$

2) Loss avoidance: 2a) $w_1 \geq C_A$ and $w_2 \geq C_A$

2b) $w_1 \geq C_B$ and $w_2 \geq C_B$

2c) $w_1 \geq C_A$ and $w_2 \geq C_B$

[4] Conditions i-iii are necessary conditions.

3) Sharing power: 3a) $w_1 \leq C_A + (50 - C_A)/2$ and $w_2 \leq C_A + (100 - C_A)/2$

3b) $w_1 \leq C_B + (50 - C_B)/2$ and $w_2 \leq C_B + (100 - C_B)/2$

3c) $w_1 \leq C_B + (50 - C_B)/2$ and $w_2 \leq C_B + (100 - C_B)/2$

Prediction 3: A significant number of the observed contracts will lie within the areas of the fair-offers prediction.

4. Results

For the analysis of the contract offers we shall extensively rely on Selten's *measure of predictive success* (see Selten and Krischker, 1983 and Selten, 1991). The predictive success of a theory is measured by the difference $S = h - a$, where h measures the *hit rate* and a the *area*. In our experiment, the hit rate is defined as the percentage of contract offers that fall into the predicted area. The area corresponds to the percentage of points in the contract space that belong to the predicted area. Note that the area is a measure of parsimony of a theory. More parsimonious theories predict smaller areas. The most permissive theory predicts any possible contract in the contract space and has a measure of predictive success equal to zero. Each of the three predictions discussed in Section 3 corresponds to a specific area in the contract space.

4.1 Equilibrium under risk neutrality

To examine how well the equilibrium under risk neutrality predicts our data, we shall first distinguish between compatible and non-compatible offers. *Compatible offers* are contract offers which are compatible with the risk-neutral prediction in that they satisfy both the incentive constraint and the participation constraint for the agent to choose activity B. Similarly we call *non-compatible offers*, all contract offers which are incompatible with the risk-neutral prediction. Then we shall examine Euclidian distances to the equilibrium prediction.

4.1.1 Compatible offers

[5] The prediction for risk-averse agents in this earlier study was restricted to the class of utility functions with constant absolute risk aversion. In contrast to this, in the present analysis we consider the larger class of striclty increasing and strictly concave utility functions.

Table 3 shows the percentage of compatible offers per country and per treatment, the percentage of the compatible offers which were accepted and the frequency with which the agents chose activity B after acceptation. Overall, the percentage of compatible offers is below 50 percent for all treatments. In general the compatible offers were accepted and induced high effort.

There are some differences across the two countries. Notably German subjects seem to choose more frequently high effort conditional on the acceptation of a compatible offer. But these apparent differences across countries are not significant, neither for the percentage of compatible offers, the percentage of accepted compatible offers, nor with respect to the percentage of accepted contracts for which the agent chose high effort (permutation test, double-sided, 5 percent significance level). This allows us to pool the data across countries to test for differences across treatments.

Table 3:
Relative frequency of compatible offers, accepted compatible offers, and the choice of activity B in case of a compatible offer

Treatment	France			Germany		
	Compatible offers	Accepted	Activity B	Compatible offers	Accepted	Activity B
13-20	0.34	0.93	0.56	0.48	0.94	0.71
27-34	0.41	0.86	0.59	0.33	0.85	0.73
34-41	0.44	0.85	0.73	0.32	0.92	0.64
41-48	0.30	0.75	0.53	0.45	0.85	0.77

Pairwise comparisons of the different treatments reveal no significant differences in the percentage of compatible contract offers (Mann-Whitney U-tests, two-sided, 5 percent significance level). However, compatible offers are more frequently accepted in the 13-20 than in the 27-34 treatment and also more frequently accepted in the 34-41 than in the 41-48 treatment (Mann-Whitney U-tests, one-sided, 5 percent level). More generally, compatible offers are (significantly) more frequently accepted in the 13-20 treatment, than in other treatment. On the other hand, compatible offers in the 41-48 are more frequently rejected than in any other treatment, but the difference is not always significant. The percentages of accepted compatible offers that lead to high effort, are not statistically different across treatments (if we require 5 percent significance, Mann-Whitney U-tests, double-sided), except for the lower percentages in the 41-48 treatment. A possible reason for observing less acceptation when costs of efforts are very high could be lower shares of expected surplus offered to the agent. However, as we shall show in Section 5 (Table 11) below, the share of the principal's expected surplus does not significantly vary across treatments. When compatible offers are accepted agents tend to choose high effort as predicted by the subgame perfection equilibrium solution. Except for treatment 41-48 for which the two effort levels are equally likely to be chosen, the agents choose more frequently a high rather than a low effort (Binomial tests, one-sided, 5 percent significance level).

4.1.2 Non-compatible offers

Table 4 reports the relative frequency of non-compatible offers together with the relative frequency of non-compatible offers that were accepted and that led the agent to choose activity A. Non-compatible offers are more frequently proposed than compatible offers, and tend to be accepted. The frequency of non-compatible offers does not differ significantly between Germany and France (permutation test, two-sided, 5 percent level), for none of the treatments. Furthermore, after pooling across countries, we find that there is no significant difference across treatments for the frequency of non-compatible offers. However, with respect to the percentage of accepted offers, there are significant inter-cultural differences for treatments 27-34 and 41-48 (offers are more frequently accepted in France). Over all treatments the percentage of accepted offers is equal in both countries (permutation test, two-sided, 5 percent level). In most of the independent player groups, as predicted by best reply, activity A was the most frequent choice except for treatment 41-48, in which the subjects were equally likely to choose activity A and activity B. Thus, agents significantly tended to play best reply (Binomial test, two-sided, 5 percent level).

Table 4:
Relative frequency of non-compatible offers, accepted non-compatible offers, and the choice of activity A in case of a non-compatible offer

Treatment	France			Germany		
	Non-compatible offers	Accepted	Activity A	Non-compatible offers	Accepted	Activity A
13-20	0.66	0.89	0.53	0.52	0.81	0.72
27-34	0.59	0.93	0.70	0.68	0.79	0.66
34-41	0.56	0.78	0.51	0.68	0.78	0.80
41-48	0.70	0.85	0.48	0.55	0.74	0.74

From the analysis of compatible and non-compatible offers, we conclude that agents deviate from their part of the subgame perfect equilibrium prediction only in treatment 41-48. In the other treatments their behavior follows the best reply rule. Principals, however, propose contracts that deviate from the subgame perfect equilibrium prediction in more than 50% of the cases.

4.1.3 Euclidian distances

Over all treatments, only two of the 1640 observed contract offers correspond exactly to one of the subgame perfect equilibria with a risk-neutral agent. Therefore the corresponding measures of predictive success for subgame perfection are all negative. However, the measure of predictive success might be too stringent, because it does not take into account the fact that contract offers might be *close* to the predicted contracts. Subjects make errors, or make some rough evaluation that lead them to contract offers that are different from but still relatively close to the predicted contract(s). Furthermore, the distance from the predicted contract(s) can vary from one treatment to another. In order to account for such small deviations from the equilibrium contract, we calculated for each cost level (treatment) the average Euclidian distance between the observed contract and the *closest* predicted contract, defined as the predicted contract that minimizes the average Euclidian distance. The average Euclidian distances in each treatment are summarized in Table 5 for pooled date over France and Germany. Table 5 also reports the average contract offers observed in each treatment of the experiment. We observe that a higher cost level, implying a less important net expected surplus, leads to a smaller Euclidian distance in the aggregate. In other words, contract offers involving higher levels of effort costs come closer to the subgame perfect equilibrium prediction under risk neutrality.

Table 5:
Average contract offers and closest equilibrium offer under risk neutrality
as measured by average Euclidian distance

Effort costs	Average contract offer		Average Euclidean distance	Closest equilibrium contract	
	w_1	w_2		w_1*	w_2*
(13-20)	24.10	44.75	31.32	0	25
(27-34)	30.83	51.04	23.34	14	39
(34-41)	35.38	54.36	22.24	21	46
(41-48)	37.37	60.45	17.61	28	53

When we compare the two countries, it appears that the closest equilibrium contract, in each treatment, is the same. However, according to Table 6, contract offers are on the average closer to the equilibrium contract in France than in Germany. Let the null hypothesis state that the average Euclidian distances in France and Germany are equal. This null hypothesis cannot be rejected for treatments 13-20 and 27-34, but it is rejected for treatments 34-41 and 41-48 in favor of the alternative hypothesis that the average Euclidian distance is larger in Germany (permutation test, one-sided, 5 percent level). Therefore, the tendency to get closer to one of the predicted subgame perfect equilibria when costs are increased, is stronger in France than in Germany. The difference is essentially due to the fact that German student subjects made more generous offers than their French counterparts.

Table 6:
Average Euclidian distance by country

Effort costs	Germany	France
13-20	32.50	28.37
27-34	24.19	22.49
34-41	25.47	19.00
41-48	19.29	15.92

For the comparison of Euclidian distances across treatments, we can pool the Euclidian distances for France and Germany for treatments 13-20 and 27-34 only. Comparing these two treatments we can reject the null hypothesis that the contracts are at equal distance with respect to the closest subgame perfect equilibrium (Mann-Whitney U-test, two-sided, 1 percent level). The contracts are therefore closer to the (closest) subgame perfect equilibrium in the 27-34 treatment. Since pooling is not feasible for the two other treatments, we use the permutation test separately for each country instead. The null hypothesis cannot be rejected for the comparison between 27-34 and 34-41 for both countries; comparing 34-41 and 41-48 the null hypothesis cannot be rejected for the French data (permutation test, one-sided, 5%). However, the average distance in each country is clearly lower in treatment 41-48 than in treatments 13-20 and 27-34 suggesting that higher cost levels induce principals to offer contracts that are closer to the equilibrium contracts.

Table 7:
Average contingent contract offer per treatment and per country

Effort costs	w1		w2	
	Germany	France	Germany	France
13-20	24.27	22.46	45.87	41.93
27-34	32.93	28.73	50.59	51.48
34-41	39.78	30.98	55.13	53.59
41-48	38.84	35.90	63.26	57.64

The fact that contract offers are more generous in Germany than in France can be further investigated by analyzing each dimension of the contract separately. According to Table 7 average offers appear to be higher in Germany than in France, both with respect to the w_1 dimension and the w_2 dimension. There is only one exception, which corresponds to treatment 27-34 on the w_2 dimension. However, these differences are usually not significant. For w_1, the null hypothesis of no difference is rejected for treatments 27-34 and 34-41 (permutation tests, one-sided, 5 percent level), and for w_2 the null hypothesis is rejected only for 41-48 (one-sided and double-sided permutation test, 5%).[6]

To summarize the results so far, contract offers frequently violate the subgame perfect equilibrium solution for a risk-neutral agent, while agents tend to react in the way predicted by best response by choosing the predicted activity. Increased costs lead to contract offers that are closer to the contracts predicted by subgame perfect equilibrium solution. This tendency is stronger in France than in Germany.

4.2 The equilibrium under risk aversion versus the fair offers prediction

In this subsection we compare the predictive successes of the equilibrium under risk aversion and the fair offers theory. For this comparison we shall take into account all contract offers, whether or not they are accepted, since our aim is to evaluate the predictive value of principal-agent theory with respect to contract offers. Both theories predict a specific area in the contract space. Recall that in Keser and Willinger (2000) we found that contract offers for treatment 13-20 were more accurately predicted by the

[6] We tested for differences with respect to the closest equilibrium contract as measured by the Euclidian distance. However, for treatments 27-34 and 34-41 the test results hold for any equilibrium solution. For treatment 41-48, for five of the eight solutions there is no significant difference for neither of the dimensions, and two other solutions give the same results as the closest equilibrium solution.

fair offers hypothesis than by the subgame perfect equilibrium solution with either a risk-neutral or a risk-averse agent. The fair offers hypothesis combines the three principles, appropriateness, loss avoidance and sharing power. We measured the predictive success for all possible combinations of principles (fair offer sets). As in Keser and Willinger (2000), two of these combinations gave significantly better results than all other combinations: combinations 1-2a-3a and 1-2c-3a. Since the fair offer subset 1-2c-3a gives slightly better measures of predictive success than the fair offer subset 1-2a-3a, we shall use only the first one for the analysis of this section. In the fair offers subset 1-2c-3a, the agent receives at least the low cost in the bad state and at least the high cost in the good state, but less than half of the net surplus assuming high cost in both states. Table 8 summarizes the measures of predictive success for the particular variants of the principles that correspond to the selected combination. Appropriateness and sharing power have on average better measures of predictive success than loss avoidance. All measures are significantly different from zero (Binomial tests, one-sided, 10 percent level) with the exception of the success measure of loss avoidance in treatment 41-48. Overall, loss avoidance appears as the weakest of the three principles.

For each principle we tested for differences in measures of predictive success between France and Germany. The null hypothesis could not be rejected in most cases (permutation tests, two-sided, 5 percent level). The only exceptions are in treatment 27-34 (appropriateness and sharing power are stronger for France than for Germany) and 34-41 (loss avoidance is weaker for France than for Germany). In order to test for treatment effects we use the permutation test for each country separately. For Germany there is no significant difference in measures of predictive success across treatments for none of the three principles. However, the null hypothesis is rejected in several instances for France, for loss avoidance (34-41 has lower predictive success than 27-34) and for sharing power (27-34 has lower sharing power than 13-20 and 41-48 has lower sharing power than 34-41). Therefore, it seems that for France, loss avoidance and sharing power have a tendency to become weaker as costs of efforts are increased.

Table 8:
Measures of predictive success for the fair offer set 1-2c-3a, defined by :
$w_2 \geq w_1$, $w_1 \geq C_A$ and $w_2 \geq C_B$, $w_1 \leq (50 + C_B)/2$ and $w_2 \leq (100 + C_B)/2$

Effort costs	Appropriateness		Loss avoidance		Sharing power	
	Germany	France	Germany	France	Germany	France
13-20	0.491	0.489	0.239	0.257	0.733	0.772
27-34	0.445	0.489	0.333	0.289	0.646	0.671
34-41	0.433	0.458	0.443	0.081	0.586	0.649
41-48	0.489	0.483	0.320	0.157	0.551	0.582

There is no significant difference in measures of predictive success for appropriateness across treatments, neither for France nor for Germany (permutation test, two-sided, 5 percent level). Concerning loss avoidance, we found in the case of France that 34-41 has lower measures of predictive success than treatments 13-20 and 27-34, but all other comparisons of measures of predictive success are not significantly different. Sharing power has significantly lower measures of predictive success for 41-48 than the other treatments in both countries (permutation test, one-sided, 5 percent level).[7] In the case of France, we find that by increasing the level of cost the predictive success of sharing power becomes significantly lower, except by moving from 27-34 to 34-41.

Table 9:
Measures of predictive success for the equilibrium prediction
with a risk-neutral principal and a risk-averse agent

Effort costs	Germany	France
13-20	0.058	0.020
27-34	0.156	0.138
34-41	0.099	0.240
41-48	0.874	0.686

Table 9 shows the measures of predictive success that correspond to the equilibrium prediction under risk aversion. For treatments 13-20, 27-34 and 34-41, we cannot reject the null hypothesis of no difference for the measures of predictive success between France and Germany. The null hypothesis is rejected only for treatment 41-48 (permutation test, two-sided, 5 percent level). Since there is no significant difference in predictive success between Germany and France for treatments 13-20, 27-34 and 34-41 the measures can be pooled for each of these treatments, to test for difference across treatments. The measures of predictive success for treatments 27-34 and 34-41 do not differ significantly, but they are both significantly larger than for treatment 13-20 (Wilcoxon Mann-Whitney test, one-sided, 5 percent level). For treatment 41-48 the measures of predictive success are larger for Germany than for France. Simultaneously, all the measures of predictive success for 41-48 are larger than for any of the other treatments, irrespective of the country. Therefore if pooling were feasible, any test based on ordinal ranking would lead to the conclusion that the measures of predictive success are significantly larger for treatment 41-48 than for any of the other treatments. We can thus conclude that in treatment 41-48

[7] There is only one exception, which is the comparison with 34-41 in the case of Germany where the null hypothesis is not rejected.

contract offers differ significantly between France and Germany, and provide strong support in favor of the risk-aversion prediction.

We conclude that in the case of a high cost level contract, which induces only a negligible net surplus, equilibrium under risk aversion predicts better than fair offers. As the net surplus of a contract is very small, fairness considerations do not come into play in the decision of how to share that surplus.

For a direct comparison of the predictive success of the fair offer prediction and the risk-aversion prediction, ideally we should pool observations by treatment. Because of across country differences, such a pooling is possible only for treatments 13-20 and 27-34. For these two treatments we observe that the measures of predictive success are systematically larger for the fair offer prediction (Wilcoxon Mann-Whitney test, one-sided, 1 percent level). For treatment 34-41, we cannot pool the hit rates across countries for the fair offers hypothesis. However, we observe that, except for one case, the equilibrium under risk aversion has lower measures of predictive success than the fair offers prediction. Similarly, for treatment 41-48 the pooling of the hit rates across countries is not feasible. We observe however, that when the cost is very high, in most cases the equilibrium prediction under risk aversion has larger measures of predictive success than the fair offer hypothesis.

A more appropriate test can be carried out on the basis of the Wilcoxon signed rank test. We assume that for each group the hit rates obtained for the equilibrium under risk aversion and those for the fair offers predictions correspond to paired measurements. The null hypothesis that states that the two measurements are equal, is rejected for all treatments. For treatments 13-20 and 27-34 the difference in measures of predictive success is always of the same sign in favor of the fair offer prediction (Wilcoxon signed rank test, one-sided, 1 percent level). For treatment 34-41 all but one of the differences are of the same sign, again in favor the fair offer prediction (Wilcoxon signed rank test, one-sided, 1 percent level). Finally, for treatment 41-48 all differences are of the same sign in favor of the risk-aversion prediction. This leads to the conclusion that for effort cost levels that are high enough, the risk-aversion prediction outperforms the fair offer hypothesis.

Table 10 summarizes the comparison between the prediction of the fair offer set and the standard risk-aversion agent hypothesis.

Table 10:
Average measures of predictive success for the equilibrium under risk aversion and the fair offers prediction

	Risk aversion		Fair offers	
Effort costs	Germany	France	Germany	France
13-20	0.058	0.020	0.809	0.863
27-34	0.156	0.138	0.741	0.703
34-41	0.099	0.240	0.772	0.441
41-48	0.874	0.686	0.571	0.408

5. Discussion

In our experimental game, an increase in the effort cost level reduces the expected net surplus from accepting the contract offer. Our results show that for a very high effort cost level, the contract offers fall within the area predicted by the equilibrium under risk aversion. For the lower cost levels, however, the contract offers fall mostly outside the area predicted by the equilibrium under risk aversion and belong to the fair offers set instead. A possible interpretation of this phenomenon is that principals require a minimum level of expected profit, independently of the cost of effort. This would contradict the sharing power hypothesis that takes the effort costs into account in defining an upper threshold level for contract offers. If this interpretation is correct it implies that in the experiments principals have a psychological threshold level for the range of expected profits. This threshold typically differs from one principal to another. As the effort cost level is increased, more and more principals have to take a larger proportion of the expected surplus, in order to secure their threshold. By requiring a large share of the expected surplus, to secure the threshold expected profit level, the offers get closer to the contracts predicted by risk aversion and subgame perfection. This could also explain, why the average Euclidian distance becomes smaller as the level of cost is increased. However, this line of reasoning does not apply to our data as demonstrated below.

Let $S_j = \dfrac{\pi_j(50 - w_1) + (1-\pi_j)(100 - w_2)}{\pi_j 50 + (1-\pi_j)100 - C_i}$ be the principal's share of the expected surplus for a choice of activity j by the agent. Note that according to subgame perfection, S_j should be equal or very close) to 100% for the equilibrium contract. We observe that the principals take significantly less than

100% in every treatment. But on average they take a larger share of the expected surplus than the agents, both with respect to activity A and with respect to activity B (Table 11). French principals tend to take a larger share in comparison to the German principals. But, this difference is significant only for treatment 41-48 with respect to both activities, and for treatment 34-41 with respect to activity A (permutation test, one-sided, 5 percent level). But the most important fact is that an increase in the cost level generally does not affect the principal's proportion of the surplus.[8] We therefore conclude that principals require a constant share of the expected surplus rather than a constant level of expected profit independent from the cost of effort.

Table 11:
Principals' average share of the net expected surplus (all contract offers)

Effort costs	Low cost activity	High cost activity
13-20	0.657	0.706
27-34	0.710	0.768
34-41	0.735	0.805
41-48	0.767	0.813

It is interesting to look at contract offers that belong to the intersection between the fair offers area and the risk-aversion area. First, note that the relative size of this area with respect to the contract space is very small (less than 1% of the contract space) and varies only slightly when costs are increased. Furthermore, the relative size of the intersection with respect to the fair offers prediction is increasing with the cost level while the relative size of the intersection with respect to the equilibrium under risk aversion is decreasing with the cost level (see Table 12). We observe that the hit rate of contracts that fall into the intersection of both predicted areas increases with the cost level. The intersection of the two areas satisfies both loss-avoidance and profit maximization. More precisely, the intersection area is bounded from below by the low cost on the w_1 dimension, the high cost on the w_2 dimension, and from above by the requirement that the principal chooses a contract that implements the high cost activity only if his expected profit is larger than by implementing the low cost activity. The higher the cost level, the more contracts fall into this region despite the fact that fewer contracts satisfy loss avoidance. But as costs are increased more and more contracts satisfy the profit (threshold) maximizing condition. Overall this increases the number of contracts that fall into the region of overlap. Therefore, as costs are increased,

[8] Where pooling across countries was feasible we used the Wilcoxon Mann-Whitney test, and the permutation test was used when pooling was not feasible. The only case where the difference is significant is for treatment 34-41 compared to 27-34 with respect to activity A

principals try to satisfy two apparently conflicting objectives: avoiding losses for the agent and trying to maximize their own profits.

Table 12:
Percentage of contract offers within the intersection of the fair offers prediction and the equilibrium prediction under risk-aversion,
and relative size of the intersection with respect to each of the predictions

Effort costs	Germany	France	Overlapping area with respect to the fair offers prediction	Overlapping area with respect to the equilibrium under risk-aversion
13-20	0.080	0.044	0.136	0.471
27-34	0.106	0.100	0.220	0.293
34-41	0.125	0.094	0.303	0.234
41-48	0.594	0.425	0.364	0.171

Finally, there is another reason why the predictive success of the risk-aversion hypothesis increases with higher effort cost levels: as the effort cost is increased the frequency of contracts inducing a loss in the bad state increases (see Table 13). This tendency is particularly clear if we compare treatment 13-20 with treatment 41-48. The percentage of contract offers which induce a loss in the bad state for the agent is around 5 percent for treatment 13-20. For treatment 41-48 the rate is above one third for Germany and above a half for France. Simultaneously, we observe that at higher cost levels agents are slightly more likely to accept contracts that induce a loss in the bad state than at lower cost levels.

Table 13:
Number (percentage) of contract offers with $w_1 < C_A$,
and percentage of those accepted

	France		Germany	
Effort costs	#	Accepted	#	Accepted
13-20	7 (4%)	43%	46 (5%)	52%
27-34	36 (22%)	61%	22 (14%)	41%
34-41	78 (49%)	65%	16 (10%)	38%
41-48	83 (52%)	77%	55 (35%)	64%

This is consistent with the contract offers made by principals when the effort costs increase. When the expected net surplus is large, principals make more generous offers, and most of the very few contracts involving a loss are rejected by the agents. On the other hand, as the effort costs increase, the principal's offers become less generous, and simultaneously the contracts that involve a potential loss are more likely to be accepted by the agents. It is as if the conflict between the profit maximizing objective and the loss avoidance objective, would be solved in favor of loss avoidance at low cost and in favor of profit maximizing at high cost, and that the principal and the agent both agree on the implicit hierarchy of objectives with respect to the level of costs.

6. Conclusion

In the experiment reported in this paper we test a simple version of the principal-agent model with hidden action. The treatment variable is the cost of effort. According to the standard prediction, the principal designs the incentive compatible contracts in such a way as to appropriate all the expected surplus generated by the agent's effort, i.e. the agent receives only his reservation utility, whatever the cost of effort. Our results tend to show that this conclusion is true only when the expected surplus his negligible, a situation which correspond to a very high cost of effort. When the effort cost level is very low, an large net surplus is generated by the contractual relationship. Similar to experiments on, for example, ultimatum bargaining, we observe a more or less equitable share of this surplus—in contrast to what agency theory predicts. However, when effort costs are so high that the generated net surplus becomes negligible, equity considerations do not play a substantial role any more and principals care only for their own profits. In such a situation agency theory under the assumption of risk aversion for the agent yields a relatively good prediction of actual human behavior.

6. References

Anderhub, V., Gächter, S., and Königstein, M., (1999), "Efficient Contracting and Fair Play in a Simple Principal-Agent Experiment", *working paper*, July 1999.

Berg, J.E., Daley, L.A., Dickhaut, J.W., and O'Brien, J., 1992. Moral hazard and risk sharing: experimental evidence. *Research in Experimental Economics* **5**, pp. 1–34.

Cachon, G.P., and Camerer, C.F., 1996. Loss-avoidance and forward induction in experimental coordination games. *Quarterly Journal of Economics*, pp. 165–194.

Epstein, S., 1992. Testing principal-agent theory, experimental evidence. *Research in Experimental Economics* **5**, pp. 35–60.

Fehr, E., Gächter, S., and Kirchsteiger, G., 1997. Reciprocity as a contract enforcement device: experimental evidence. *Econometrica* **65**, pp. 833–860.

Grossman, S., and Hart, O., (1987), "An analysis of the principal-agent problem", *Econometrica*, 51, 1987, 7-45.

Güth, W., Klose, W., Königstein, M., and Schwalbach, J., (1998), " An Experimental Study of a Dynamic Principal-Agent Relationship ", *Managerial and Decision Economics*, *27,* 1998, 327-341.

Holmström, B., (1979), "Moral Hazard and Observability", *Bell Journal of Economics*, 10, 74-91, 1979.

Keser, C., and Willinger, M., 2000. Principals' Principles when agents' actions are hidden. *International Journal of Industrial Organization,* **18**, 1, pp. 163–185.

Selten, R., 1991. Properties of a measure of predictive success. *Mathematical Social Sciences* **21**, pp. 153–167.

Selten, R., and Krischker, S., 1983. Comparison of two theories for characteristic function experiments. In: Tietz, R. Editor, 1983. *Aspiration Levels in Bargaining and Economic Decision Making* Springer Verlag, Berlin, pp. 259–264.

APPENDIX

Let u(x) be the agent's utility function and assume that for all x, $u'(x) > 0$ and $u''(x) < 0$. We show that the contracts for which the Principal implements activity B, must satisfy the three restrictions i, ii and iii[9] below:

i) $$w_2 \leq -\frac{1}{4} w_1 + \frac{C_A + 15}{0.8}$$

ii) $$w_2 > -\frac{1}{4} w_1 + \frac{C_B}{0.8}$$

iii) $w_2 > w_1$

Step 1: First, note that the principal can never implement activity B by offering a contract such $w_2 = w_1$. Indeed, for such a contract the agent maximizes his expected utility by choosing the least costly activity. Since $C_A < C_B$ and $u(w - C_A) > u(w - C_B)$, the agent chooses activity A. Therefore, the principal can implement activity A by offering the riskless contract (C_A, C_B). Furthermore, (C_A, C_B) is the profit maximizing contract for implementing activity A.

Step 2: Restriction i means that the principal implements activity B only if the expected profit from that activity is larger than the expected profit from the implementation of activity A. Since, for activity A the principal maximizes his profit with the contract offer (C_A, C_A) the following inequality holds for implementing activity B : $0.2(50 - w_1) + 0.8(100 - w_2) \geq 75 - C_A$. This is equivalent to inequality i.

Step 3: In order to implement activity B, the principal must satisfy the agent's participation constraint: $0.2u(w_1 - C_B) + 0.8u(w_2 - C_B) \geq u(0)$. Without loss of generality we assume that $u(0) = 0$. The slope of the participation constraint for activity B is given by $\frac{dw_2}{dw_1} = -\frac{1}{4}\frac{u'(w_1 - C_B)}{u'(w_2 - C_B)}$. Since $u'(x) > 0$, the

[9] More generally inequalities ii and iii are, respectively :

ii) $w_2 > -\frac{\pi_B}{1-\pi_B} w_1 + \frac{C_B}{1-\pi_B}$

i) $w_2 \leq -\frac{\pi_B}{1-\pi_B} w_1 + \frac{C_A + (\pi_A - \pi_B)(R_2 - R_1)}{1-\pi_b}$

participation constraint curve is strictly decreasing and convex ($\frac{\partial}{\partial w_1}\frac{dw_1}{dw_2} > 0$), with slope (- ¼) at the point $w_2 = w_1 = C_B$. For the participation constraint to be satisfied, contract offers must be such that $w_2 \geq -\frac{1}{4}w_1 + \frac{C_B}{0.8}$ where $w_2 = -\frac{1}{4}w_1 + \frac{C_B}{0.8}$ is the equation of the tangency curve to the participation constraint at the point (C_B ,C_B).

Step 4: Next we show that the incentive compatibility constraint for implementing activity B is never satisfied for contracts such that $w_1 > w_2$. To show this assume that the inequalities (1) and (2) below are satisfied simultaneously.

$$0.2u(w_1 - C_B) + 0.8u(w_2 - C_B) \geq 0.5u(w_1 - C_A) + 0.5u(w_2 - C_A) \quad (1)$$

$$w_1 > w_2 \quad (2)$$

We show that this assumption leads to a contradiction. (1) can be rewritten as :

$$0.8u(w_2 - C_B) - 0.5u(w_2 - C_A) \geq 0.5u(w_1 - C_A) - 0.2u(w_1 - C_B) \quad (3)$$

Some additional rewriting of (3) leads to :

$$\begin{aligned} &-0.3\big(u(w_1 - C_A) - u(w_2 - C_B)\big) - 0.5\big(u(w_2 - C_A) - u(w_2 - C_B)\big) \\ &\geq 0.2\big(u(w_1 - C_A) - u(w_1 - C_B)\big) \end{aligned} \quad (4)$$

Since $C_B > C_A$ and $w_1 > w_2$, and since $u(.)$ is strictly increasing, all utility differences in (4) are strictly positive, hence the contradiction. We conclude that the incentive compatibility constraint can be satisfied only for contracts such that $w_2 > w_1$.

---

where π_A is the probability of state 1 if the agent chooses activity A, and π_B is the corresponding probability for activity B. R_i is the principal's profit in state i, and C_A, C_B are the costs of activity A and B respectively. The following inequalities are assumed : $R_1 < R_2$, $C_A < C_B$, and $\pi_B < \pi_A$.