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Contract-Specific Environments Leading to Unsophisticated Contracts

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Abstract

Given that moral hazard seems omnipresent, one might expect that many more contractual relationships should be governed by sophisticated incentive schemes than what we actually observe. By propagating the purely contract-theoretic approach, the present paper identifies contract-specific environments for the hidden action problem under which contracts that promise, at no incentives whatsoever, a flat rate to the agent cannot be outperformed by more sophisticated arrangements. Optimum contracts, however, are sometimes plagued by multiple equilibria. The paper reinforces Gale's and Hellwig's findings that a rather severe conflict between the game-theoretic and the contract-theoretic criterion should more carefully be taken into account than most authors currently do.

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Introduction

Most contractual relationships involve aspects of moral hazard in the sense that actions of agents, while remaining at least partly hidden to their principals, affect the results of their relationship. Given that moral hazard is at stake, contract theory would seem to suggest that all these relationships should be governed by incentive schemes which have payments to the agent being based on the actual results in a sophisticated way. Yet, in reality, one sees a substantial part of such contracts (including mine with the state of Nordrhine-Westphalia as a civil servant!), rather than being made conditional on the actual results, simply to promise a flat rate to the agent. The present paper explores whether the use of such unsophisticated flat rate contracts can be justified on purely contract-theoretic grounds.

For a basic outline of contract theory, the reader is referred to Hart and Holmström (1987). As for the present paper, the contract-theoretic approach is considered to proceed in the following three steps. First, the contract-specific environment of a given situation must be described. In particular, decision variables which are hidden action, parameter values which are hidden (or private) information, as well as aspects of the case that can be observed by the involved parties but cannot be verified by courts must be specified. The contract-specific environment fully captures a given situation as far as the limitations of contractual arrangements are concerned. If, for instance, an agent is involved whose action cannot be observed the contract-specific environment would be that of the traditional principal-agent problem. Or if the reservation price of a seller and the willingness-to-pay of a buyer become common knowledge among the two but cannot be observed by courts then the contract-specific environment corresponds to the one which Grossman and Hart (1986) have assumed to hold at the second stage of their model of relationship-specific investments. In any case, the contract-specific environment forms the primitive building-block on which the contract-theoretic approach rests.

As a second step, given any contract-specific environment, the full class of contracts which is at the disposal of rational parties must be described. Hereby, according to a commonly hold view, rational parties make their contracts conditional on aspects only which can be verified by courts. Such contracts will be referred to as verifiable contracts. At first glance, limiting the analysis to verifiable contracts may appear to be overly restrictive. Notice, however, that sophisticated game forms would qualify as long as they introduce sets of strategies out of which parties must select their preferred alternative in some verifiable way. Recall, for instance, the model of relationship-specific investment. Here contracts cannot be made conditional on reservation price or willingness-to-pay because these parameters are not verifiable. Yet, by designing the process of renegotiation properly, a surprisingly rich class of allocation functions can be implemented as has been shown by Aghion, Dewatripont and Rey (1990). In fact, the underinvestment effect which drives the model of Grossman and Hart disappears if parties commit to the proper renegotiation process. To capture the full class of verifiable contracts, the present paper explores the role which stages of communication may play if parties commit to them ex ante.

In a final step, the contract-theoretic approach predicts those contracts which rational parties can be expected actually to make use of. Hereby parties are assumed to evaluate different contracts according to the outcome which they lead to under rational play. In this way, each contract gives rise to a utility allocation, and the class of verifiable contracts as identified by step two leads to a set of feasible utility allocations. Parties are predicted to opt for those contracts whose utility allocations under rational play lie on the corresponding utility frontier.

Notice that the contract-theoretic approach in the above sense can only work if parties sign contracts at a stage early enough where they still are symmetrically informed (ex ante stage). It precludes situations of adverse selection where, by definition, parties only meet after having obtained private information (interim stage). As for situations of adverse selection, the impossibility result due to Myerson and Satterthwaite (1983) states that, no matter which mechanism parties voluntarily make use of, rational play cannot ensure an ex post efficient outcome. Yet the result does not predict any particular mechanism which parties can be expected to rely on. In fact, I am not aware of any general principle whatsoever according to which contracts should be selected if parties do not meet prior to the interim stage. Since, however, such a principle is available, namely the contract-theoretic approach in the above sense, provided that parties meet early enough, the present paper concentrates on corresponding environments.

In addition, excluding situations of adverse selection facilitates to justify why rational parties should rely on verifiable contracts only. The argument goes as follows. If, in case of a dispute, parties were to present a verifiable contract to the courts then, by assumption, the courts would enforce the payments which are due under the contract anyway. Therefore, to avoid legal costs, rational parties rather stick to the terms of the contract provided that these terms are verifiable. If, on the other hand, a contract is made conditional on terms that cannot be verified then the case may well be taken to the court. The court's decision may be uncertain and, at that stage, parties may have obtained private information on the merits of their case. At the ex ante stage, however, to capture the very notion of rational play, parties must be assumed to have some common prior which then allows them to predict rational decisions, including the one to go to court, that must be taken at later stages. Based on such a common prior, it is possible to write another contract which mimics rational play under the first one by introducing the proper steps of communication. If these steps are designed in a way such that they become verifiable, the new contract can be verified and, hence, rational parties will stick to its terms. Since the new contract avoids legal costs, it outperforms the old one. In this sense, non-verifiable contracts can be dispensed with if parties meet early enough.

Notice that the above argument would not be valid for situations of adverse selection. To be sure, here too, the existence of a common prior must be assumed in order to define rational play. Since, however, the stochastic process has already been evolving when parties first meet, it is too late for them to incorporate the prior into a contract. Indeed, in situations of adverse selection, legal disputes in front of courts cannot be avoided for sure. Moreover, given that litigation may be inevitable, the non-verifiable contract could, in principle, prove to be a suitable instrument to induce steps leading to court. In this sense, the case for concentrating on verifiable contracts becomes a stronger one if situations of adverse selection are not taken into consideration.

The contract-theoretic approach has parties evaluating contracts according to where they lead to under rational play. Contracts, in particular optimal ones, typically give rise to games in extensive forms which may be plagued by multiple equilibria. For that reason, an intriguing issue arises which has impressively been worked out by Gale and Hellwig (1989). Existing contract theory involves an implicit theory of equilibrium selection based on efficiency considerations at the ex ante stage. Game-theoretic analysis, on the other hand, may suggest a different outcome which is based on general principles of selection. Gale and Hellwig have established that such principles rest on strategic considerations which have little to do with overall efficiency of the outcome. In other words, the contract-theoretic selection criterion is in conflict with the game-theoretic method. The issue in general is still far from being settled.

For particular contract-specific environments, however, the issue is less bothersome because the following property may hold. Suppose that the outcome under an optimum contract if selected according to the contract-theoretic criterion of overall efficiency would also be selected under some new contract according to the game-theoretic criterion. Then parties relying on the new contract would be on the safe side because, under the new contract, the two criteria must lead to the same selection such that the issue can be neglected. The present paper introduces environments which are simple enough to have this nice property.

The game-theoretic approach to contract theory in the above sense has to be distinguished from the approach of implementation theory. Suppose we are given a social choice function. Implementation theory would then take off from a given solution concept such as Nash equilibrium, subgame perfect equilibrium, etc. To implement the given choice function, only those game forms are taken into account which have unique outcomes for the underlying solution concept. Other game forms are ruled out by the requirement of full implementability. The game-theoretic approach to contract theory, on the other hand, restricts the class of admissible game forms in no way. Instead, the theory of rational choice is imagined to prescribe, for any game, a unique outcome. Of course, game theory has not yet come up with such an encompassing theory of rational choice. But developping such a theory remains the ultimate goal. As far as the present paper is concerned, fortunately, it is only the following aspect of selection theory which matters. Take any two games whose payoff functions differ by constant additive terms only such that the two games are equivalent in a very strong sense. The argument of the paper goes through for any theory of rational choice which requires that the same equilibrium must be selected for the two games. All selection criteria I am aware off fulfill this requirement.

The basic allocation problem to be studied corresponds to the hidden action version of the principal-agent problem. At stage 0, the agent chooses an action before, at stage 1, nature selects the actual level of output resulting from the action. Output is a random variable which is affected by the agent's action in a stochastic way. Throughout the paper, it is assumed that the costs of the action are borne by the agent whereas the resulting output goes to the principal who then compensates the agent by some payment as specified by the contract.

This basic allocation problem is explored under various contract-specific environments. To begin with, section 1 revisits the environment of the traditional principal-agent problem. Hereby, the emphasis is on the purely contract-theoretic approach as described above. The tradtional setting presumes that the level of output can be verified by courts and, hence, that verifiable contracts can be made conditional on that level. It is this assumption which makes steps of communication redundant.

Section 2 investigates a setting involving higher transaction costs in the sense that output, while remaining observable by principal and agent, can no longer be verified by courts. Therefore contracts being made conditional on output would not be verifiable. However, given that principal and agent, both, become fully informed about actual output, communication could be expected to play a major role. It turns out, however, that this need not be the case. In fact, the outcome of rational play under any contract if selected according to the game-theoretic criterion can also be obtained as the outcome under a contract which just promises the appropriate flat rate of the agent. Under the contract-theoretic selection criterion, the same remains true provided that the class of feasible contracts does not include those under which parties commit themselves possibly to pay penalties to an outside party. If, however, such penalties are permitted and if the outcome is selected according to the contract-theoretic criterion then the first best solution can be achieved. Hereby, along the equilibrium path, penalties actually will not have to be paid if the contract is designed properly. At this point, the conflict between the contract-theoretic and the game-theoretic selection criterion becomes very obvious. The findings are similar to the ones of Gale and Hellwig (1989) except that the present paper establishes them for a much simpler setting.

Section 3 explores a contract-specific environment which, as compared to section 2, impedes contractual arrangements to a still higher degree. The output level is assumed to be private information of the principal. While the agent may receive a signal correlated with actual output, he never becomes fully informed. Under such an environment, if an outside party is allowed to be part of the deal but if, along the equilibrium path, no penalties actually will have to be paid, then the outcome, even if selected according to the contract-theoretic criterion, can also be obtained under some flat rate contract.

Section 4, finally, explores contracts which have penalties actually being paid with positive probability. If the outcome can be selected according to the contract-theoretic criterion it is possible to provide incentives at the first best level. From the principal's and the agent's as the active parties' viewpoint, however, this comes at costs amounting to the expected payments to the outside party. In any case, the solution providing incentives at first best levels would not survive the game-theoretic selection criterion such that, again, the conflict between the contract-theoretic and the game-theoretic method of selection arises at full strength. Yet, in contrast to section 2, the contract-specific environment of sections 3 and 4 has the conflict arising for contracts only which, along the equilibrium path, require payments to the outside party actually being paid. Since the active parties would have incentives to collude in order to avoid such payments, one might be tempted to rule out such contracts and, herewith, to avoid the conflict. However, without an exact notion of coalition-proofness for the present setting, the issue remains somewhat open.

At first glance, the contract-specific environments of the present paper may resemble those which Hermalin and Katz (1991) have studied. Yet, since they arrive at rather different conclusions, the environments must differ in substance as well. Recall that Hermalin and Katz do not admit outside parties as being part of the contractual arrangement. Under this assumption, the contract-specific environments of the present paper, not only, are free of the selection conflict, but also, have flat rate contracts as the optimum solution. Flat rate contracts, of course, perform rather poorly. But communication, no matter how sophisticated, would still be of no help. In contrast, Hermalin and Katz have shown that even the most simple form of renegotiation may introduce sufficient communication to improve welfare well beyond the level which would prevail under flat rate contracts. The differences are mainly due to the fact that they deal with other contract-specific environments. In particular, they assume that the action can be observed by principal and agent though not by courts. The present paper, in contrast, concentrates on environments where the action cannot be observed and where actual output fails to be verifiable. In any case, the exact description of the contract-specific environment is of utmost importance as the differences between their findings and ours make plain.

1. Traditional contract-specific environments

As far as the allocation problem is concerned, the following setting will be used throughout the paper. At stage 0, the agent chooses an action $a \in A$ at costs c(a). At stage 1, nature determines the level of output $x \in X$ randomly. Output as a random variable depends on the chosen action in a stochastic way. The costs of the action must be borne by the agent whereas the output accrues to the principal. Both parties are assumed to be risk-neutral and the agent's utility function is assumed to be additively separable such that the first best solution requires the action to be chosen as

$$a^* = \arg\max_{a \varepsilon A} E\{x|a\} - c(a).$$

Moreover, if the agent is given no incentives, then he chooses the action

$$a^0 = \arg\min_{a \varepsilon A} c(a). \tag{1}$$

To neglect trivial cases, it is assumed that $a^0 \neq a^*$. The fundamental problem which contract theory must face consists of two parts:

(i) Is there a contract which ensures that the agent chooses the first best action a*?

(ii) If yes, what is the class of payment schedules $\tau(x)$ which can be realized while leading to a*?

Hereby, $\tau(x)$ denotes the payment which the principal actually pays to the agent at output level x.

The solution of the above problems depends, of course, on the contract-specific environment. To begin with, let us consider environment A which presumes that, both, action a and output x can be verified by courts. Under environment A, contracts which make payments t(a,x) conditional on a and x are verifiable and, hence, will be kept by rational parties (see Introduction). Such a contract leads to payoffs

$$\Pi_A = t(a,x) - c(a) \text{ and } \Pi_P = x - t(a,x)$$

for the agent and the principal, respectively. Given contract t(a,x), an action â is consistent with rational play if

$$\hat{a} \; \varepsilon \; \arg\max_{a \varepsilon A} E\{t(a,x)|a\} - c(a)$$

holds. For any given payment schedule $\tau(x)$, consider the contract

$$t(a,x) := \begin{cases} \tau(x) & \text{if } a = a^* \\ \tau_0 & \text{otherwise} \end{cases}$$

where the constant τ_0 is sufficiently low such that

$$\tau_0 - c(a) < E \; \{\tau(x)|a^*\} - c(a^*)$$

holds for all $a \in A$. Then, obviously, $\hat{a} = a^*$ is the only action consistent with rational play. Therefore, under contract-specific environment A, while inducing the efficient action a^*, any payment schedule $\tau(x)$ can be realized and, hence, this environment can justly be claimed to correspond to the zero-transaction-costs-world of the Coase Theorem.

Consider, next, the contract-specific environment B, where the action a as well as the costs c(a) are hidden to the principal and to the courts but where the output level x becomes common knowledge among principal, agent, and the courts (i.e. x is verifiable). This, of course, is the traditional environment of the hidden action version of the principal agent problem. Under environment B, contracts making payments t(x) conditional on output x are verifiable. In this case, a payment schedule $\tau(x)$ provides incentives to choose the efficient action a^* under rational play provided that

$$a^* \varepsilon \arg\max_{a \varepsilon A} E\{\tau(x) \mid a\} - c(a). \tag{2}$$

One way to provide such incentives would be to make the agent a residual claimant by a contract of the form $t(x) = x - \pi_p^0$. There are further contracts which provide the same incentives. Nevertheless, condition (2) restricts the set of payment schedules. In particular, as is well-known, it would not be possible to have the agent fully insured.

While, under environment B, the output x is the only aspect of the allocation problem that can be verified, this does not mean that contracts being made conditional exclusively on x are the only ones which are verifiable. In fact, suppose the agent is asked to deposit a message r out of some prespecified set R after having choosen his action, but before learning the actual output level and suppose that this message must be submitted in a verifiable way. Then, if the payment t(r,x) conditions on, both, the message and the output level, the corresponding contract remains verifiable.

Of course, under the traditional environment B, communication is not needed to induce the first best action. Contracts made conditional on messages, however, could be expected to enrich the class of payment schedules which can be realized. Yet, under environment B, this turns out not to be possible for the following reason. Suppose we are given such a contract t(r,x) which is made conditional on both. Rational play is assumed to take the extensive structure of the framework into account. Therefore, if the agent had taken action a, he would plan to submit the message $r = r(a) \in R$. For this to be consistent with rational play it must hold that, for all $a \in A$,

$$r(a) \ \varepsilon \ \arg\max_{r \varepsilon R} E\{t(r,x)|a\}.$$

Moreover, the incentives are at their first best level provided that

$$a^* \ \varepsilon \ \arg\max_{a \varepsilon A} E\{t[r(a),x]|a\} - c(a).$$

For any given rational play [a*,r(a)] under the original contract t(r,x) in the above sense, there is a new contract $t^*(x) := t[r(a^*),x]$ which is made conditional on output only and which can easily be seen to provide the same incentives and payoffs. Indeed, for any action $a \in A$, it follows that

$$\begin{aligned} E\{t^*(x)|a^*\} - c(a^*) = E\{t[r(a^*),x]|a^*\} - c(a^*) \geq E\{t[r(a),x]|a\} - c(a) \geq \\ \geq E\{t[r(a^*),x]|a\} - c(a) = E\{t^*(x)|a\} - c(a) \end{aligned}$$

and, hence, that

$$a^* \varepsilon \ \arg\max_{a \varepsilon A} E\{t^*(x)|a\} - c(a)$$

which means that a* remains to be consistent with rational play under the new contract t*(x). In this sense, communication would be of no help under the contract-specific environment B of the traditional principal agent model, the reason being that the hidden information concerns an action which, under rational play, can be anticipated by the uninformed principal.

2. Output observable but not verifiable

In this section, it is assumed that the output level x, while remaining observable by the agent and the principal, can no longer be verified by courts. Moreover, it is still assumed that the action a and its costs c(a) are hidden to the principal as well as to the courts. The contract-specific environment is referred to as environment C. Notice that, under environment C, none of the purely allocative aspects can be verified. Therefore, communication may be needed to enrich the class of contracts. A contract

$$\gamma = [F,G: R x S \rightarrow \mathbb{R}] \tag{3}$$

has to specify message spaces R and S for the agent and the principal, respectively. In addition, it must specify the payments F(r,s) and G(r,s) which the agent receives and the principal must pay, respectively, if the messages $(r,s) \in R \times S$ have been submitted. Contract γ leads to the following payoff functions

$$\Pi_A = F(r,s) - c(a) \text{ and } \Pi_P = x - G(r,s)$$

for the agent and the principal, respectively. It is assumed that the contractual arrangement will not be subsidized by an outside party which means, that for all $r \in R$ and $s \in S$,

$$F(r,s) \leq G(r,s). \tag{4}$$

However, the principal and the agent as the active parties may commit themselves to pay a penalty amounting to G(r,s) - F(r,s) to some outside party which, herewith, is made part of the deal. The contract is called balanced if no such penalties occur, i.e. if $F(r,s) \equiv G(r,s)$. A contract which does not make use of communication and, instead, promises a flat rate t^0 to the agent is called a flat rate contract.

Any contract γ gives rise to a game in extensive form which, under rational play, is solved by backwards induction. At the last stage where messages have to be submitted, the agent can condition his message $r = r(a,x) \in R$ on the action and the output whereas the principal, to whom the action remains hidden, can condition his message $s = s(x)$ on output only. For this to be consistent with rational play it must hold that, for all $a \in A$ and $x \in X$,

$$r(a,x) \ \varepsilon \ \arg\max_{r \varepsilon R} F[r,s(x)] \tag{5}$$

and

$$s(x) \ \varepsilon \ \arg\min_{s \varepsilon S} G[r(\hat{a},x),s]. \tag{6}$$

Hereby, $\hat{a}$ denotes the action which the agent will choose in equilibrium and for which, hence, it must be true that

$$\hat{a} \ \varepsilon \ \arg\max_{a \varepsilon A} E\{F[r(a,x),s(x)]|a\} - c(a). \tag{7}$$

Proposition 1 (Contract-specific environment C). Suppose $[\hat{a},r(a,x),s(x)]$ is consistent with rational play under a balanced contract. Then there exists a flat rate t^0 such that, for all x,

$$F[r(\hat{a},x),s(x)] \equiv t^0 \tag{8}$$

and such that

$$\hat{a} \ \varepsilon \ \arg\max_{a \varepsilon A} t^0 - c(a). \tag{9}$$

<u>Proof:</u>

For any x and $\tilde{x} \in X$, it follows from (5) and (6) and from balancedness of the contract that

$$F[r(\hat{a},\tilde{x}),s(x)] \leq F[r(\hat{a},x),s(x)] = G[r(\hat{a},x),s(x)] \leq G[r(\hat{a},x),s(\tilde{x})] = F[r(\hat{a},x),s(\tilde{x})] \leq$$
$$\leq F[r(\hat{a},\tilde{x}),s(\tilde{x})] = G[r(\hat{a},\tilde{x}),s(\tilde{x})] \leq G[r(\hat{a},\tilde{x}),s(x)] = F[r(\hat{a},\tilde{x}),s(x)].$$

Since the first and the last term of the above sequence are the same, equality must prevail everywhere. In particular, it follows that, for all x and $\tilde{x}$,

$$F[r(\hat{a},x), s(x)] = F[r(\hat{a},\tilde{x}), s(\tilde{x})]$$

and, hence, that a rate t^0 must exist such that (8) holds.

Moreover, for any action $a \in A$, it follows from (7) and (8) that

$$\begin{aligned} t^0 - c(\hat{a}) &= E\{F[r(\hat{a},x), s(x)] | \hat{a}\} - c(\hat{a}) \geq E\{F[r(a,x), s(x)] | a\} - c(a) \geq \\ &\geq E\{F[r(\hat{a},x), s(x)] | a\} - c(a) = t^0 - c(a) \end{aligned}$$

and, hence, that (9) is established as well.

<u>Q.E.D.</u>

The proposition shows that the outcome of rational play under any balanced contract can also be obtained under the appropriate flat rate contract. In this sense, communication would be of no use. The intuitive argument behind the proposition is as follows. The actual level of output becomes known to the parties after nature irrevocably has selected it. Therefore, if the contract is balanced parties face, at the communication stage, a zero-sum game. This game may admit multiple equilibria. According to the Min-Max-Theorem, however, they all have to be payoff equivalent. The flat rate corresponds to the Min-Max-Value of this zero-sum game. Since the action $\hat{a}$ can be induced by a flat rate contract it must be the one which minimizes costs of the agent, i.e. $\hat{a} = a^0$ (c.f. (1)).

Let us now turn to contracts which allow for penalties actually being paid to some outside party. Suppose that $[\hat{a},r(a,x), s(x)]$ is consistent with rational play under contract γ (see (3)). Then, for all $x \in X$, the pair $[r(\hat{a},x),s(x)]$ is a Nash equilibrium of the game in normal form

$$\Pi_A = F(r,s) - c(\hat{a}) \text{ and } \Pi_P = x - G(r,s) \tag{10}$$

with strategy spaces R and S for the agent and the principal, respectively. This game corresponds to the subgame at stage 3 (communication stage) which is reached under rational play. From the viewpoint of that stage, this game has the same best response structure as the game

$$\Pi_A^0 = F(r,s) \text{ and } \Pi_P^0 = -G(r,s). \tag{11}$$

In fact, the payoff functions of the two games (10) and (11) differ by constant additive terms only which means that the two games are equivalent in a rather strong sense. In particular, of course, they have the same set $N = N(\gamma) \subseteq R \times S$ of Nash equilibria. No conflict of selection would arise if there were a unique Nash equilibrium (r^N,s^N) for the two games. Contracts, however, which are optimal in the sense of contract theory tend to be plagued by multiple equilibria as will be shown below. As a consequence, the selection issue can no longer be avoided. Let us begin with the game-theoretic approach. Since the two games (10) and (11) are equivalent in a very strong sense, every selection principle I am aware of would select the same Nash equilibrium (r^N,s^N) $\in N(\gamma)$ for both games. While there might be some dispute in the literature whether selection should solely be based on the best response structure, people widely seem to agree that constant additive terms should not affect the selection (c.f. Harsanyi and Selten (1988)). In other words, if we follow the game-theoretic route, the equilibrium selected for game (10) at stage 3 does not depend on actual output such that, for all $x \in X$,

$$r(\hat{a},x) \equiv r^N \text{ and } s(x) \equiv s^N.$$

This means that the appropriate flat rate contract would provide the same incentives and the same payoffs to the agent as the original one. Indeed, for all $a \in A$ and $x \in X$, it follows from (5) that

$$F[r(a,x),s(x)] \geq F[r(\hat{a},x),s(x)] \equiv F[r^N,s^N] =: t^0$$

and, hence, that the flat rate t^0 as defined above induces the agent to choose the same action $\hat{a}$ as under the original contract. The agent's equilibrium payoffs are also the same. Since a flat rate contract never involves payments to an outside party, the principal would, under the flat rate contract, be at least as well off as under the original contract. In this sense, from the game-theoretic selection viewpoint, including outside parties would be of no help for the principal and the agent as the active parties. No matter how poorly they may perform, flat rate contracts cannot be outperformed by more sophisticated arrangements provided that equilibrium selection rests on game-theoretic considerations.

Things change rather drastically if we switch to the contract-theoretic selection criterion of overall efficiency. Again, let $N(\gamma) \subseteq R \times S$ denote the set of Nash equilibria of game (10), or what amounts to the same, of game (11) and let $Z(\gamma) \subseteq \mathbb{R} \times \mathbb{R}$ denote the set of Nash outcomes (of game (11)) which, formally, is defined as follows:

$$z = (z_A, z_P) \in Z(\gamma) \text{ iff } \exists (r,s) \in N(\gamma) : z_A = F(r,s), z_P = -G(r,s).$$

Since the contract-theoretic criterion puts, beyond improving overall efficiency, no restriction on equilibrium selection it is useful to know which sets of equilibrium outcomes can be generated by appropriate contracts. The following proposition recalls the known result that, under contract-specific environment C, any subset of the payoff space can be generated as the set of Nash outcomes under the proper game.

Proposition 2 (Contract-specific environment C). Given any subset $B \subseteq \mathbb{R} \times \mathbb{R}$, there exists a contract $\gamma = [F,G : B \times B \to \mathbb{R}]$ such that $Z(\gamma) = B$.

<u>Proof</u>:
As message spaces, it is sufficient to consider $R = S = B$. Suppose the agent submits the message $z^A = (z_A{}^A, z_P{}^A) \in B$ whereas the principal submits $z^P = (z_A{}^P, z_P{}^P) \in B$. The contract is defined as follows. If both submit the same message $z^A = z^P = (z_A, z_P)$ then $F(z^A, z^P) = z_A$ and $-G(z^A, z^P) = z_P$ whereas, if they submit different massages $z^A \neq z^P$ then $F(z^A, z^P) = z_A{}^P - \epsilon$ and $-G(z^A, z^P) = z_P{}^A - \epsilon$, where $\epsilon > 0$ is some given real number. In words, if both propose the same outcome then this outcome is realized whereas if they differ then each party obtains, up to a penalty, what the other party has proposed for him. Obviously, for any Nash equilibrium, parties have to submit the same message whereas, for any $z \in B$, if both submit z then this must be a Nash equilibrium under the above contract.

<u>Q.E.D.</u>

The contract-theoretic selection criterion is based on efficiency considerations. Therefore, one might admit Nash equilibria only which are not Pareto-dominated within the set of all Nash outcomes. Since, however, the above proposition is applied to situations only where none of the outcomes are Pareto-dominated the issue need not be settled here. In particular, take any payment schedule $\tau(x)$ and apply the proposition to the set B which is defined as follows

$$z \in B \text{ iff there exists } x \in X : z = [\tau(x), -\tau(x)] .$$

Under the corresponding contract and using the contract-theoretic selection criterion, it would be consistent with rational play to select, for any $a \in A$ and any $x \in X$, messages $r(a,x)$ and $s(x)$ such that

$$F[r(a,x), s(x)] = G[r(a,x), s(x)] = \tau(x).$$

Hereby, use is made of multiplicity of equilibria in such a way that, for any output level x, the equilibrium is selected which has the principal paying $\tau(x)$ to the agent. Under such a selection procedure, incentives at first best level will be provided if the payment schedule $\tau(\bullet)$ satisfies condition (2). In particular, under contract-specific environment C, the agent can still be made the residual claimant provided that, out of a set of many Nash equilibria, the selection is based on the contract-theoretic criterion of overall efficiency. In contrast, under the game-theoretic criterion, communication would not help to improve the poor performance of flat rate contracts. The conflict of the two criteria arises at full strength.

3. Output as private information

In this section it is explored whether the conflict between the selection criteria tends to diminish as further obstacles to contractual arrangements are added to the environment. This turns out partly to be true. Now it is assumed that the principal alone learns the actual output level x whereas this level remains hidden to the agent and to the courts. To enrich the setting, however, the case is included where the agent still is better informed than the courts. To this end, the agent is assumed privately to observe some signal $\omega \in \Omega$ which may be correlated with the actual output. In any case, the assumption is kept according to which the agent's action a and its costs c(a) are hidden to the principal as well as to the courts. This contract-specific environment is referred to as environment D.

To keep the formal analysis as simple as possible, it is assumed that signal $\omega \in \Omega$ as well as the output level $x \in X$ are finite random variables. For any action $a \in A$, let $p(\omega,x|a)$ denote the joint probability of ω and x given that the agent has choosen action a. It then holds that, for all $a \in A$,

$$\sum_{\Omega} \sum_{X} p(\omega,x|a) = 1.$$

The class of verifiable contracts remains to be the same as under the previous environment (c.f. section 2). The case of perfect correlation is excluded because it has been studied in section 2. Instead it is assumed that, for all actions $a \in A$, the joint probability of signal ω and output level x has full support:

$$p(\omega,x|a) > 0 \quad \text{for all } a \varepsilon A, x \varepsilon X, \omega \varepsilon \Omega \tag{12}$$

Notice that the subcase where the output level is purely private information of the principal is contained in the above setting. It corresponds to the case where the agent always observes the same signal such that the set Ω just contains a single element. Such a signal, of course, is of no value to the agent.

Any contract γ (see (3)) leads to a game in extensive form which, again, is solved by backwards induction. At the message stage, the agent can condition his message $r = r(a,\omega) \in R$ on the action and the signal whereas the principal can condition his message $s = s(x) \in S$ on output only. For this to be consistent with rational play it must hold that, for all $a \in A$, $\omega \in \Omega$ and $x \in X$,

$$r(a,\omega) \varepsilon \arg\max_{r \varepsilon R} E_x\{F[r,s(x)]|a,\omega\} \tag{13}$$

and

$$s(x) \varepsilon \arg\min_{s \varepsilon S} E_\omega\{G[r(\hat{a},\omega),s]|\hat{a},x\}.$$

Hereby, â is an action which maximizes the expected profit of the agent at stage 0, i.e.

$$\hat{a} \in \arg\max_{a \in A} E_{\omega,x}\{F[r(a,\omega),s(x)]|a\} - c(a). \tag{14}$$

Notice that the subscripts of E refer to the random variables with respect to which the expected value is being taken.

Recall that, under the previous contract-specific environment C, the first best solution was consistent with rational play under the appropriate contract and provided that the equilibrium could be selected according to the contract-theoretic criterion of overall efficiency. While failing to be balanced, the contract was such that, in equilibrium, no penalties actually had to be paid to the outside party. Under the present environment D, however, this is not possible. In fact, the outcome of rational play under any contract which, along the equilibrium path, avoids penalties actually being paid can also be generated by some flat rate contract. Therefore, as long as expected equilibrium payments to the outside party are zero, the selection issue does not arise. The following two propositions collect the findings.

Proposition 3 (Contract-specific environment D). Suppose $[\hat{a},r(a,\omega),s(x)]$ is consistent with rational play under some contract γ. Let

$$t^F := \inf_{a,\omega} E_x\{F[r(a,\omega),s(x)]|a,\omega\}$$

$$t^G := \sup_{x} E_\omega\{G[r(\hat{a},\omega),s(x)]|\hat{a},x\}.$$

Then $t^F \leq t^G$. Moreover if, in equilibrium, no penalties have actually to be paid, i.e. if for all $\omega \in \Omega$ and $x \in X$,

$$F[r(\hat{a},\omega),s(x)] = G[r(\hat{a},\omega),s(x)]$$

then $t^F = t^G$.

Proposition 4 (Contract-specific environment D). Let t^F and t^G be defined as in proposition 3 and suppose that $t^F = t^G = t^0$. Then, for all $\omega \in \Omega$,

$$E_x\{F[r(\hat{a},\omega), s(x)] \,|\, \hat{a},\omega\} \equiv t^0$$

and

$$\hat{a} \;\varepsilon\; \arg\max_{a \varepsilon A} \; t^0 - c(a).$$

Proof of Proposition 3:
Since subsidies have been ruled out (see (4)) it follows by definition that

$$t^F \leq E_{\omega,x}\{F[r(\hat{a},\omega), s(x)] \,|\, \hat{a}\} \leq E_{\omega,x}\{G[r(\hat{a},\omega), s(x)] \,|\, \hat{a}\} \;\leq\; t^G.$$

Moreover, to establish the second part of the proposition, let equilibrium payments be denoted by

$$f(\omega,x) \;:=\; F[r(\hat{a},\omega), s(x)] \;\text{ and }\; g(\omega,x) \;:=\; G[r(\hat{a},\omega), s(x)].$$

If Ω and X are seen as strategy spaces for the agent and the principal, respectively, then $f(\omega,x)$ and $g(\omega,x)$ give rise to two zero-sum games. Let $\alpha = (...\alpha(\omega)...)$ and $\beta = (...\beta(x)...)$ denote mixed strategies of these games and let value functions be defined as follows:

$$\varphi(\alpha,\beta) \;:=\; \sum_{\Omega}\sum_{X} \;\alpha(\omega)\; f(\omega,x)\; \beta(x)$$

$$\psi(\alpha,\beta) \;:=\; \sum_{\Omega}\sum_{X} \alpha(\omega)\; g(\omega,x)\; \beta(x).$$

Then, according to the Min-Max-Theorem, there exist two pairs of strategies (α^f,β^f) and (α^g,β^g) such that, for all strategies α and β,

$$\varphi(\alpha^f,\beta) \;\geq\; \varphi(\alpha^f,\beta^f) \;\geq\; \varphi(\alpha,\beta^f)$$
$$\psi(\alpha^g,\beta) \;\geq\; \psi(\alpha^g,\beta^g) \;\geq\; \psi(\alpha,\beta^g).$$

It is now easy to see that

$$\varphi(\alpha^f,\beta^f) \;\le\; t^F \;\le\; t^G \;\le\; \psi(\alpha^g,\beta^g). \tag{15}$$

Indeed, it follows from (13) that, for any $a \in A$ and any pair $\omega,\tilde{\omega} \in \Omega$,

$$E_x\{F[r(a,\omega),s(x)]\,|\,a,\omega\} \;\ge\; E_x\{F[r(\hat{a},\tilde{\omega}),s(x)]\,|\,a,\omega\}.$$

Multiplying this inequality with $\alpha^f(\tilde{\omega})$ and summing up over all $\tilde{\omega} \in \Omega$ leads to

$$E_x\{F[r(a,\omega)s(x)]\,|\,a,\omega\} \;\ge\; \sum_{\tilde{\omega}} \alpha^f(\tilde{\omega}) \sum_x f(\tilde{\omega},x)\frac{p(\omega,x|a)}{Q(\omega|a)} \;\ge\; \varphi(\alpha^f,\beta^f)$$

where

$$Q(\omega|a) \;=\; \sum_x p(\omega,x|a).$$

Due to the definition of an infimum it follows that $\varphi(\alpha^f,\beta^f) \le t^F$. By a similar argument it can be shown that $t^G \le \psi(\alpha^g,\beta^g)$. (15) is established. Finally if, in equilibrium, no penalties have actually to be paid then, for all $\omega \in \Omega$ and $x \in X$, $f(\omega,x) = g(\omega,x)$ such that the two zero-sum games defined by f and g must be the same. Again by the Min-Max-Theorem, it follows that $\varphi(\alpha^f,\beta^f) = \psi(\alpha^g,\beta^g)$ and, by (15), that $t^F = t^G$. Proposition 3 is established.

Q.E.D.

Proof of Proposition 4:

It follows from the definition of t^F as an infimum that, for all $\omega \in \Omega$,

$$t^0 \;=\; t^F \;\le\; E_x\{F[r(\hat{a},\omega),s(x)]\,|\,\hat{a},\omega\} \tag{16}$$

and, hence, that

$$t^0 \;=\; t^F \le E_{\omega,x}\{F[r(\hat{a},\omega),s(x)]\,|\,\hat{a}\} \;\le\; E_{\omega,x}\{G[r(\hat{a},\omega),s(x)]\,|\,\hat{a}\} \;\le\; t^G \;=\; t^0.$$

This implies that

$$t^0 = t^F = E_{\omega,x}\{F[r(\hat{a},\omega),s(x)]|\hat{a}\}$$

and hence, by the assumption (12) of full support, that (16) must hold with equality. The first part of Proposition 4 is established.

As for the second part, take any action $a \in A$. It then follows from (14) that

$$\begin{aligned} t^0 - c(\hat{a}) &= E_{\omega,x}\{F[r(\hat{a},\omega),s(x)]|\hat{a}\} - c(\hat{a}) \geq \\ &\geq E_{\omega,x}\{F[r(a,\omega),s(x)]|a\} - c(a) \geq t^0 - c(a) \end{aligned}$$

as was to be shown.

Q.E.D.

4. Positive expected penalties

No matter according to which criterion equilibrium has been selected, rational play which actually avoids penalties being paid along the equilibrium path can be reproduced by flat rate contracts as has been shown in the previous section. In the present section contracts are explored which provide first best incentives though at the costs of positive expected payments to an outside party. Communication would still not allow to outperform flat rate contracts if equilibrium selection were based on game-theoretic criteria (c.f. section 2). Therefore, to outperform flat rate contracts the selection criterion has to be that of overall efficiency.

In essence, the contract-specific environment D is kept the same as before. However, to make things as simple as possible it is assumed that the output level $x \in X$ is purely private information of the principal. The agent receives no signal correlated with output. Moreover, the agent chooses his action out of a set of two alternatives only, i.e. $A = \{a_0,a_1\}$ where, by assumption, $c_0 := c(a_0) < c_1 := c(a_1)$. Therefore, under any flat rate contract, the agent would choose the action a_0. In the following it is shown how incentives could be provided which lead the agent to choose the costly action a_1.

Since the present section deals with the contract-theoretic approach to equilibrium selection, it is admissible to make use of the revelation principle. Therefore, without loss of generality, each party is directly asked to submit his private information. Hereby incentives are given to tell the truth. Under such a direct scheme, let us assume that the agent chooses the costly action $\hat{a} = a_1$ under rational play. Let $f_i(x)$ denote the payment which the agent receives if he claims having choosen the action a_i whereas the principal claims the output level to be x. The principal expects the agent, not only, to choose the action $\hat{a} = a_1$ but, also, to report it truthfully at the message stage. If the principal reports output level x then the direct contract requires him to pay a total amount of g(x) to the agent and to the outside party.

As for the principal, the incentive constraint is such that if x is the true value then it should never pay off to him to report any other value $\tilde{x} \in X$, i.e. $g(x) \leq g(\tilde{x})$. Similarly, if $\tilde{x}$ is the true value it should not be worthwhile to report x, i.e. $g(\tilde{x}) \leq g(x)$. Therefore, a real number g^0 must exist such that, for all $x \in X$,

$$g(x) \equiv g^0.$$

In other words, no matter what he reports, the principal always has to pay the same amount and, hence, telling the truth is consistent with rational play. To express the agent's incentive constraints, the short hand $p_i(x) := p(x|a_i)$ is used. Suppose the agent arrives at the message stage after having chosen the action $a = a_0$. It is consistent with rational play to report truthfully if

$$\sum_x p_0(x)\ f_0(x) \geq \sum_x p_0(x)\ f_1(x) \tag{17}$$

holds. Similarly it is consistent with rational play to report the action $a = a_1$ truthfully if

$$\sum_x p_1(x)\ f_1(x) \geq \sum_x p_1(x)\ f_0(x) \tag{18}$$

holds. (17) and (18) are the incentive constraints as far as the agent is concerned. Incentives to choose the action $\hat{a} = a_1$ require the following condition to be met:

$$\sum_x p_1(x)\ f_1(x) - c_1 \geq \sum_x p_0(x)\ f_0(x) - c_0. \tag{19}$$

Finally, since we do not allow for subsidies, it must hold that, for all $x \in X$,

$$f_1(x) \leq g^0. \tag{20}$$

Given any fixed payment g^0 which the principal is required to pay, we look for the contract which maximizes the agent's expected payoff:

$$\text{Max} \sum_x p_1(x)\ f_1(x) \quad \text{subject to (17)–(20).}$$

The above maximum problem is a linear program which can easily be solved by making use of duality theory. In fact, let $\alpha_{01} \geq 0$, $\alpha_{10} \geq 0$, $\beta \geq 0$ and $\lambda(x) \geq 0$ denote the dual variables associated with constraints (17) - (20), respectively. Then, after rearranging terms, the constraints of the dual program are as follows:

$$\alpha_{10} + \beta = \alpha_{01} \tag{21}$$

$$[p_1(x) - p_0(x)]\ \alpha_{10} = 0 \quad (\text{for all } x \varepsilon X) \tag{22}$$

$$\lambda(x) = p_1(x) + \beta[p_1(x) - p_0(x)] \geq 0 \quad (\text{for all } x \varepsilon X) \tag{23}$$

whereas its objective function is

$$\text{Min } g^0 - (c_1 - c_0)\beta \quad \text{subject to (21) – (23).}$$

Notice that constraints (21) - (23) always allow for a feasible solution. Therefore, according to the Duality Theorem for linear programs, the constraints (17) - (20) of the maximum problem have a feasible solution if and only if the minimum problem is solvable (in which case the maximum problem also must be solvable). Obviously, the minimum problem is solvable if and only if there exists at least one output level x for which $p_0(x) \neq p_1(x)$. In words, as soon as the action has some effect on the output level then the minimum problem and, hence, the maximum problem is solvable.

To arrive at solutions, let $\bar{x}$ be the output level which satisfies

$$p_1(\bar{x})/[p_0(\bar{x}) - p_1(\bar{x})] \leq p_1(x)/[p_0(x) - p_1(x)]$$

for all $x \in X$ for which $p_0(x) > p_1(x)$ is true. At any solution of the minimum problem it then must hold that

$$o < \beta = p_1(\bar{x})/[p_0(\bar{x}) - p_1(\bar{x})] = \alpha_{01} \text{ and } \alpha_{10} = 0.$$

Again due to duality theory, it follows that the constraints (17) and (19) as well as the constraint (20) for output levels $x \neq \bar{x}$ must be satisfied with equality such that the solution of the maximum problem can easily be seen to be

$$f_1(\bar{x}) = g^0 - (c_1 - c_0)/[p_0(\bar{x}) - p_1(\bar{x})]$$

whereas $f_1(x) = g^0$ if $x \neq \bar{x}$. Moreover, $f_0(x)$ must be chosen such that (17) holds with equality, for instance

$$f_0(x) \equiv g^0 - p_0(\bar{x})(c_1 - c_0)/[p_0(\bar{x}) - p_1(\bar{x})]$$

for all $x \in X$ would do the trick.

To summarize, the contract which solves the maximum problem is as follows. It is sufficient to ask the principal to reveal his information. His report does not affect what he must pay and, hence, he cannot gain by reporting falsely. Rather, according to the contract-theoretic selection criteria, his indeterminacy between telling the truth and reporting falsely is resolved according to what enhances overall efficiency. In order to provide the incentives for the agent to choose the costly action $\hat{a} = a_1$, the principal must bindingly commit himself to tell the truth. This means that the principal, while being indifferent as to how the agent and the outside party share his payment among them, is actually decisive on how to share it. Notice that at the stage where the principal learns the output level the agent irrevocably has chosen his action. Therefore he might try to bribe the principal never to report such that part of the principal's payment must be given to the outside party. If such attempts are expected to be successful, the original contract would be anticipated not to be coalition-proof and, hence, it may not be signed in the first place. In other words it might not be feasible to involve an outside party as required by the above contract such that flat rate contracts remain difficult to be outperformed. If, however, it is feasible and if the principal can commit himself, while being indifferent, always to tell the truth, then the agent can be induced to choose the costly action $\hat{a} = a_1$. For this to be worthwhile from the principal's and the agent's as the active parties' viewpoint, the expected surplus under the costly action must exceed the surplus under the other action by the expected penalty for the benefit of the outside party, i.e. the condition

$$E\{x|a_1\} - c_1 \geq E\{x|a_0\} - c_0 + p_1(\bar{x})(c_1 - c_0)/[p_0(\bar{x}) - p_1(\bar{x})]$$

must be met. If it is met then the contract-theoretic selection criterion would predict contracts which provide incentives to choose the costly action in the above way, whereas the game-theoretic criterion would lead to the conclusion that flat rate contracts cannot be outperformed. The conflict is present at full strength.

Concluding remarks

In the tradition of Coase and his disciples, it is common to argue that the degree of efficiency which parties can achieve is simply a matter of transaction costs. In particular, if transaction costs are zero then, under any assignment of property rights, rational agents are predicted to realize a first best outcome. If, however, transaction costs are present, parties may end up with a solution below the Pareto frontier. The basic difficulty which, so far, transaction costs economics has not come close to resolve stems from the fact that the very notion of transaction costs, while serving as a primitive concept of the theory, has never been clearly defined. As a formal approach, it has been proposed to deal with the zero-transaction-costs world of the Coase Theorem by making use of solution concepts of cooperative game theory whereas, to capture positive transaction costs, it is best to rely on concepts from non-cooperative game theory. I have argued elsewhere (see Schweizer (1988)) why such a dichotomous approach fails to solve the problem. Instead the idea was propagated to include, in addition to purely allocative decisions, feasible steps of negotiation and then to deal with all cases in a purely non-cooperative way. Hellwig (1988), along similar lines, sees "...no way to avoid the issues and to replace the explicit analysis of strategic interactions by a direct assessment of transaction costs".

Yet, the purely non-cooperative method has neither come to grips with a convincing theory of transactions. Here the problem is that non-cooperative games cannot be solved unless they happen to be of a very simple structure. Since, however, apparently slight changes of order of moves and of other specifications of games are known sometimes to lead to unexpectedly drastic changes of the predicted outcome, simplifying the game in order to make it tractible can hardly ever be claimed to be without loss of generality. In any case, the purely non-cooperative approach would require to describe the vast set of strategies which parties have at their disposal in a general bargaining-type situation. I cannot imagine that this task could be achieved, let alone, that the corresponding game could be solved. Rather it is the shortcut of the contract-theoretic approach, namely the cooperative selection of the contract at the ex ante stage, which currently seems to be the most promissing approach to a theory of transactions.

In principle at least, the contract-theoretic method can deal with any situation where parties meet early enough to still be symmetrically informed. Of course, uncertainty may be involved. But the symmetry of such uncertainty among parties is needed in order to allow for a cooperative selection of the optimum contract. Because it is up to the parties to design the contract and, hence, the game they are going to play, the contract-theoretic approach overcomes the difficulty of what might be the overall game to capture strategic interaction. It is this difficulty which the purely non-cooperative approach is plagued by. Moreover, the contract-theoretic method successfully avoids any notion of transaction costs as a primitive ingredient. Instead, it introduces the contract-specific environment as a basic concept. To be sure, specifying the exact environment for any given situation remains a difficult task. But the very concept of contract-specific environment serves well to classify various settings in a systematic way without having to rely on the notorously difficult assessment of transaction costs as would be required by the Coasean approach.

Unfortunately, the contract-theoretic approach is not without difficulties of its own. First, by stressing the meaning of rational play to the extreme, it often predicts highly sophisticated incentive schemes which might not easily be recognized as contracts in any real sense. Second, optimal contracts tend to be plagued by multiple equilibria such that the selection issue arises in a bothersome way. While Gale and Hellwig (1989) have worked out this issue at length, mainstream contract theory still largely ignores it. The present paper has shown that modifying the contract-specific environment of the hidden action problem leads to examples where the above two difficulties are closely intertwined. In fact, if rational play is governed by game-theoretic selection theory then the familiar contracts which promise, at no incentives whatsoever, a flat rate to the agent cannot be outperformed by more sophisticated schemes. If, in contrast, the selection is based on the contract-theoretic criterion of overall efficiency and if, in addition, outside parties can be made part of the deal to absorb penalties then it becomes feasible to provide incentives at first best level. True enough, the scheme may fail to be coalition-proof because it would introduce strong incentives for the principal and the agent to withhold their information in order to avoid that penalties actually must be payed. Yet, in a situation of multiple equilibria, it seems difficult to come up with an exact notion of coalition-proofness which admissible game forms have to satisfy. As a matter of fact, here, a more general issue is at stake which consists of identifying the subclass of game forms that qualify as contracts in the true sense. While many authors are quick in restricting this subclass in an ad hoc fashion, it proves much more difficult to find general principles. Introducing such principles would be a virtue of its own. Moreover, by restricting the class of admissible game forms, the equilibrium selection issue, as a desirable byproduct, might also lose some of its weight. Reflecting the present state of the art, however, the present paper reinforces Gale's and Hellwig's view which requires that the selection issue should more seriously be taken into account that most authors currently do.

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