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Game-Playing Agents: Unobservable Contracts as Precommitments

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Abstract

The players in most economically important games are agents, not principals. This raises the possibility of the principal's setting a *strategic* compensation scheme. The central question addressed here is whether *unobservable* agency contracts can serve as precommitments. I argue that, in terms of Nash equilibrium outcomes, the answer is no when it is common knowledge that there exists a contract that "solves" the standard agency problems and that the principal and agent have the same preferences over income and effort. However, I also show that when these conditions are not satisfied (as they typically will not be), provisions of the agency contract enacted solely to deal with incentive and risk sharing problems of the agency relationship may have the secondary effect of credibly precommitting the agent in the game he plays with other agents. I also briefly consider the effects of contract renegotiation.

JEL Classification: 022, 026

GAME-PLAYING AGENTS:

UNOBSERVABLE CONTRACTS AS PRECOMMITMENTS[1]

INTRODUCTION

The players in most economically important games are agents, not principals. In almost all significant industries, the managers making pricing and output decisions do not own the firms that they direct, or hold only some small fraction of the outstanding equity. Similarly, in many bargaining games, the seller is represented by an agent. In fact, most transactions in intermediate goods markets involve agents on both sides simultaneously (e.g., the purchasing agent of one company bargaining with the salesman of another).

A principal's use of an agent to play a game opens up the possibility of the principal's setting a strategic compensation scheme. That is, the principal may implement a reward function for the agent that has the effect of making him a "tougher" player in the game following the signing of the agency agreement. It is well understood that if: (a) only one principal has access to the use of an agent; (b) the agency contract cannot be renegotiated once signed; and (c) the contract is observable to the other players in the game; then the contract can serve as a form of binding precommitment that may give rise to first-mover or other advantages in the game against the other principals.[2]

The effects of simultaneous agency relationships among several players, and of contracts that are either renegotiable or unobservable to other players, are much less well understood. These cases are important ones to examine. Consider multiple agency relationships. As the examples in the opening paragraph make clear, many, if not most, interesting applications involve

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[2] For recent applications of this idea, see Bolton and Scharfstein [1990], Brander and Poitevin [1990], and Melumad and Mookherjee [1989].

several agency relationships simultaneously. In contrast with the single-agent case, when several principals hire agents simultaneously, there is no clear first mover.

Recently, several authors have examined the case of simultaneous contracting in settings in which contracts are observable and are not subject to renegotiation (e.g., Brander and Lewis [1986], Brander and Spencer [1985], Fershtman and Judd [1986, 1987], Fershtman, Judd, and Kalai [1991], Katz [1988], Rey and Stiglitz [1988], Ross [1987], Sklivas [1987], and Spencer and Brander [1983]). By in large, these analyses verify the intuition that benefits of precommitment are reduced; the competing parties' attempts to gain advantages through contract design often largely offset one another.

The assumption that the contract between a principal and her agent is observable to other players in the game is central to the analyses above. But this assumption often is an inappropriate one. Consider oligopoly. The contract between an executive and his firm may largely be an implicit, self-enforcing one. Even though the Securities and Exchange Commission requires firms to announce the amount of compensation paid to their top managers, knowing the actual payment made to an agent is not the same as knowing the rule by which the compensation was calculated, and it does not allow one to infer what the agent's incentives are. Even if there is an explicit agency contract, the other players may not be able to see it. While the agent could show a contract to the other players in the game, the agent and his principal could have a later contract that supersedes the first one.[3] It may well be too costly to write and enforce a contract among the agent and other players that says that there is no other contract between the agent and his principal; monitoring all possible payments made between the agent and his principal in response to the agent's behavior in one transaction may be impossible if the agent performs many other tasks for the principal as well. It is extremely unlikely, for example, that the potential buyer of a camera would take the time and expense to verify the salesman's compensation scheme.

[3] This assumption about the observability of the contract is not inconsistent with the assumption that the principal and agent write a binding contract between themselves. The contracting technology could be as follows. Any given contract that is brought to a third party ("the court") can be verified. Each contract is dated, so that if two contracts are put before the court, the later one wins. As long as the principal and agent disagree, one of them will find it to be in his self-interest to produce a copy of the most recent contract that is advantageous to that party.

In his seminal paper on game-playing agents, Myerson [1982] considered an extremely general model with unobservable agency contracts. His emphasis was on the difficulties of establishing the general existence of equilibrium, however, and he did not examine the commitment value of unobservable contracts. Bolton and Scharfstein [1990] examined the use of contracts as commitments in a particular model of financial predation. Their model exhibits a property that one would expect intuitively: Unobservable contracts are less effective precommitments than are observable contracts.

The contract between a principal and her agent also may be subject to renegotiation. Schelling [1960] noted that the possibility of renegotiation may limit the use of a contract as a precommitment in dealing with a third party.[4] Intuitively, renegotiation undermines commitment for the following reason. The essence of commitment is to bind oneself to carrying out actions that it would not be in one's self interest to take at the time of the decision. But when recontracting is costless and the principal and agent are symmetrically informed at all points, the principal and agent might be expected to renegotiate their contract if the game evolves to a point at which it no longer is in their joint interest to abide by it.

In this paper, I consider agency contracts that may be unobservable to parties outside of the agency relationship or that may be subject to renegotiation. I examine the consequences of these contracts in the following class of two-stage games. In the first stage, known as the *contract stage*, some or all of the principals hire agents to play a second-stage game on their behalf. A principal and her agent sign a contract specifying the agent's reward as a function of the outcome of the second-stage game. After this contract has been signed, the agent is matched against other players in the second-stage game, which is called the *market stage*.

The central question addressed below is whether unobservable contracts can serve as precommitments. I argue that, in terms of Nash equilibrium outcomes, an unobservable agency contract has no effects on the play of the second-stage game when it is common knowledge that

[4] Recently, several authors, including Hart and Tirole [1988], Dewatripont and Maskin [1990], and Fudenberg and Tirole [1990], have shown how renegotiation may undermine commitment in different settings.

there exists a contract that "solves" the standard agency problems and that the principal and agent have the same preferences over income and effort. These conditions are satisfied, for example, when residual claimant contracts are feasible, there is no problem of principal moral hazard under agency, and the principal and agent are risk neutral, have the same disutility of effort, and are symmetrically informed at the time of contracting. Under these conditions, the only nonstrategic agency problem is that of agent moral hazard, and this problem can be overcome by a residual claimant contract. Consequently, in equilibrium, the agent will behave as would his principal if she were to play the market stage game on her own behalf. When these conditions are not satisfied (as they typically will not be) and the agency contract is not subject to renegotiation, the use of an agent can affect the outcome. Under these circumstances, provisions of the agency contract enacted solely to deal with incentive and risk sharing problems of the agency relationship may have the secondary effect of credibly precommitting the agent in the second-stage game.

I also briefly consider the effects of contract renegotiation. In many ways, renegotiable contracts are similar to unobservable contracts -- a player outside of the agency relationship cannot "see" the true contract. I show that, as the intuition given earlier suggests, the possibility of renegotiation under complete information can undo the commitment value of an agency contract, observable or not. However, when the renegotiation takes place under incomplete information (what one might expect to be the typical case), an agency contract can have commitment value.

2. THE GENERAL MODEL

In this section, I present the general framework for the case of two principals. As a standard of comparison, I first lay out the model for the case in which both principals represent themselves in the market stage. I then lay out the model when one of the principals hires an agent to play the market stage on the principal's behalf. I refer to the principal who can hire an agent as "the" principal and to her agent as "the" agent. The principal who always represents himself is known as the "outside party" since he is outside of the agency relationship. This treatment is for expository convenience only. As will become clear, the basic results extend to an arbitrary number of principals, any combination of whom may hire agents.

Before laying out the formal assumptions, it is useful to outline the modeling philosophy behind them. There are a number of reasons why the use of an agent might affect the play of the market stage game, and I want to rule out several of them in order to focus the analysis on the effects that arise specifically because the principal and agent have an agency relationship.

If the principal were risk averse, then the use of an agent might provide risk sharing and lead the agent to pursue a riskier strategy than would the principal. Of course, a similar effect would arise if the principal continued to play the market stage game herself, but could purchase insurance. Moreover, at least in the case of executive compensation, it seems unreasonable to believe that the manager (agent) is insuring the firm's owners. Hence, I assume that the principal is risk neutral with respect to income.[5]

I also want to rule out the possibility that the principal and the agent have different preferences between income and leisure. If the principal and agent did not have the same marginal rate of substitution between income and effort as one another, and this fact were common knowledge among the three players, then the use of an agent clearly could affect play of the game. But rather than being an issue of agency per se, this would be a question of what type of player is best suited to play the market stage game, an issue that would arise even if all the players were principals.

In addition to ruling out preference differences, I also want to exclude the possibility that the agent has different capabilities than the principal. Clearly, if the agent had a different market-stage strategy set than would the principal representing herself, agency could have significant effects on the market-stage game. To capture the notion of a fixed market-stage game, I assume that the agent has the same set of potential actions and the same information sets in the market-stage game as would the principal if she were to play the second-stage game on her own behalf.

To focus on the effects of delegation (rather than simply the effects of having a different

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[5] In what follows, I will consider the use of an agency contract to share risk, but the principal will provide insurance for the agent.

type of player play the market-stage game), I also assume that, if she represented herself, the principal would have the same prior at the start of the market-stage game as would the agent, and both would update their beliefs in the same way as the market game evolves. These assumptions are not entirely innocuous. In addition to ruling out irrational agents, they also rule out the use of "experts" as agents.

A final type of effect that I want to rule out is that stemming from irrational behavior by the agent and principal in their bargaining over an initial agency contract. Since Nash equilibria admit incredible threats, adding another round of moves (contract bargaining) can lead to unreasonable equilibria; e.g., the principal makes a bizarre contract offer because the agent has (incredibly) threatened not to accept anything else. Below, I will impose certain minimal rationality restrictions on this bargaining to avoid such equilibria.

Having ruled out all of these potential effects of agency, one might reasonably ask: What is left? The answer is that the basic structure of the agency problem often leads to the principal's inability to design a contract that fully harmonizes the private interests of the two parties. When this is so, the second-best contract under agency may distort the agent's behavior so that he will not act like a principal. In Section 3, I will argue that when contracts are available under which such distortions would not arise, agency with unobservable contracts will not affect play of the market stage. In Section 4, I will then examine conditions under which the agency contract does induce distortions and thus may affect play of the market stage.

A. THE PRINCIPALS-ONLY GAME

When she plays the market game on her own behalf, the principal chooses a strategy $\sigma_a \in S_a$. The outside party always represents himself, and he chooses a strategy $\sigma_b \in S_b$.[6] The outcome of the market stage is a random variable whose distribution depends on the strategies of the two players, $x = X(\sigma_a,\sigma_b)$. Similarly, the principal's actions are a stochastic function of these strategies, $a = A(\sigma_a,\sigma_b)$.

[6] The reader interested in such things should think of both S_a and S_b as being the unit simplexes generated by the (finite) sets of pure strategies available to the principal and outside party, respectively.

The principal's von Neumann-Morgenstern utility is $Z(I,\mathbf{a})$, where I is the principal's income. As discussed above, I assume that the principal is risk neutral with respect to income in order to focus on the incentive effects of agency rather than on the possibility of insurance. As also noted earlier, I want to focus on the case in which the principal and agent have the same marginal rate of substitution between income and effort as one another when the agent is introduced below. Thus, I rule out income effects in the principal's marginal rate of substitution between income and actions -- if income effects were present, changes in the principal's income would change her marginal rate of substitution, but not the agent's, leading to differences in preferences between the two parties. The need to rule out this type of income effect, coupled with the assumption of income risk neutrality, implies that the principal's utility can be expressed as $Z(I,\mathbf{a}) = I - y(\mathbf{a})$.

The principal owns an asset that generates a monetary payoff $M(\mathrm{x})$ when the outcome of the market stage game is x. Hence, the principal's utility is $M(\mathrm{x}) - y(\mathbf{a})$ when she plays the second-stage game herself. In order to simplify the notation, let $m(\sigma_a,\sigma_b) \equiv M[X(\sigma_a,\sigma_b)]$, and let $y(\sigma_a,\sigma_b) \equiv y[A(\sigma_a,\sigma_b)]$.

The outside party's (reduced-form) expected payoff from the market stage game is simply $\pi[\sigma_a,\sigma_b]$. Since he never hires an agent, there is no need to be explicit about actions and income.

A Nash equilibrium in the principals-only game consists of a pair of strategies, $\sigma_a^e \in S_a$ and $\sigma_b^e \in S_b$ such that

$$\sigma_a^e \in \underset{\sigma \in S_a}{\operatorname{argmax}} \quad \mathrm{E}\{\, m(\sigma,\sigma_b^e) - y(\sigma,\sigma_b^e) \,\}$$ [7]

and

$$\sigma_b^e \in \underset{\sigma \in S_b}{\operatorname{argmax}} \; \pi(\sigma_a^e,\sigma).$$

B. THE AGENCY GAME

Now, suppose that the principal hires an agent to play the market game on her behalf. In

[7] Throughout this section, expectations are taken with respect to the second-stage strategies of the players and any exogenous random variables.

the contract stage, the principal offers the agent a contract, r, chosen from some finite set of feasible contracts, R. r maps elements of the market-stage outcome (e.g., observable actions undertaken by the agent) into a monetary reward (income) for the agent. The principal's contract strategy is $\rho \in S_r$, where S_r is the set of mixed strategies generated by R.

The agent's strategy has two components: (1) an acceptance rule for the contract offer, $\delta(\cdot)$; and (2) a strategy for the second-stage game, $\sigma_a(\cdot)$. $\delta(r)$ is the probability that the agent will accept contract r. $\sigma_a(r) \in S_a$ is the agent's market-stage strategy conditional on accepting contract r. As before, the outside party chooses strategy $\sigma_b \in S_b$. Note that both S_a and S_b are the same as in the principals-only game. This assumption captures the idea that the principal hires an agent to play the same game as the principal would otherwise play herself.

Just as in the principals-only game, the outside party's payoff from the market stage game is $\pi[\sigma_a,\sigma_b]$. In particular, the outside party's payoffs do not depend directly on r. The principal's utility function also is unchanged. However, she now takes no actions in the market stage, and her pecuniary income is function of the agency contract. Thus, the principal's payoff is $m[\sigma_a(r),\sigma_b] - r[\sigma_a(r),\sigma_b]$ if the agent accepts contract r and 0 otherwise.

The agent's von Neumann-Morgenstern utility is $U(I,\mathrm{a})$. For reasons given above, I want to suppose that the agent's marginal rate of substitution between income and actions is identical to the principal's. The following assumption guarantees this: $U(I,\mathrm{a}) = u[I - y(\mathrm{a})]$. Hence, the agent's payoff is $u[r(\sigma_a(r),\sigma_b) - y(\sigma_a(r),\sigma_b)]$ if he accepts contract r. If the agent rejects the principal's contract offer, he receives a utility level normalized to $0 = u(0)$.

A Nash equilibrium in the agency game consists of a triple of strategies -- ρ^e, $<\delta^e(\cdot),\sigma_a^e(\cdot)>$, and σ_b^e -- such that

$$\rho^e \in \underset{\rho \in S_r}{\operatorname{argmax}} \sum_{r \in R} \rho(r)\delta^e(r)\, \mathrm{E}\{\, m[\sigma_a^e(r),\sigma_b^e] - r[\sigma_a^e(r),\sigma_b^e] \,\}$$

$$<\delta^e(\cdot),\sigma_a^e(\cdot)> \in \underset{\delta \in S_r,\ \sigma(r) \in S_a}{\operatorname{argmax}} \sum_{r \in R} \rho^e(r)\delta(r)\, \mathrm{E}\{\, u[r(\sigma(r),\sigma_b^e)] - y[\sigma(r),\sigma_b^e] \,\}$$

and

$$\sigma_b^e \in \underset{\sigma \in S_b}{\text{argmax}} \sum_{r \in R} \rho^e(r)\delta^e(r)\ \pi[\sigma_a^e(r),\sigma].$$

The formal statement of the conditions under which agency has no effects on the play of the market stage game given below is based on a comparison of the equilibria of the principals-only game with those of the market stage in the agency game. As noted earlier, one problem with this comparison is that Nash equilibria admit incredible threats, and adding another round of moves can lead to equilibria that rely on incredible threats and promises by the agent in contract bargaining. In order to avoid these unreasonable equilibria, define a *rational-agent Nash equilibrium* as a Nash equilibrium in which the only perfection requirement imposed is that the agent cannot make incredible threats or promises in his bargaining with the principal. That is, under a rational-agent Nash equilibrium, the agent's strategy, $<\delta(\cdot),\sigma_a(\cdot)>$, is a best response to σ_b and r for all values of r. One implication is that the agent accepts the contract offer if and only if the contract generates a higher utility level than the agent's next-best alternative. This is simply the individual rationality or participation constraint imposed in a standard agency problem.

3. GAMES IN WHICH AGENCY DOES NOT MATTER

The fundamental point of this section can be stated loosely as follows: In the setting laid out in the previous section, the use of an agent has no effect if there exists a contract that perfectly internalizes the externalities between the principal and her agent. Under these conditions, the agent plays the second-stage game in the same way as would the principal, and the outside party acts accordingly. There are two forms that this internalization may take. One, there may be settings in which the principal's information is detailed enough and the contract space rich enough that the principal can order the agent to play any strategy that the principal desires -- the case of *perfect control*. Two, there may be settings in which the principal can offer a contract that harmonizes the principal and agent's interests without any need to observe what it is that the agent actually does -- the case of *perfect delegation*.

A. PERFECT CONTROL

Consider first the case of perfect control. When both σ_a and **a** are contractible, the following type of contract induces the agent to choose the market-stage strategy desired by the principal while transferring all rents to the principal:

$$r = \begin{cases} y(a) \text{ if } \sigma_a = \sigma_a^* \\ G_o \text{ otherwise} \end{cases}$$

where G_o is some constant that yields the agent less than his reservation utility level. Under this contract, the principal instructs the agent to play σ_a^*. If the agent complies with these instructions, the principal pays him his reservation wage for the specific action taken. If the agent does not follow the instructions, then the principal penalizes him. For example, in a Cournot duopoly game, the principal would pay the agent his reservation wage if he produced some given level of output and fine him otherwise. No matter what strategy the agent believes that the outside party is playing, a best response for the agent is to accept the contract and play σ_a^*. For that reason, I will say that the contract described above is a *full-insurance, forcing contract* which forces σ_a^*.

When full-insurance, forcing contracts are feasible, there essentially are no questions of agent moral hazard: The principal can order the agent to choose any given strategy at a cost that leaves the agent with no surplus in any state of the world. The following result states conditions under which the principal uses this control to order the agent to play the same strategy as would the principal if she played the second-stage game on her own behalf.

Proposition 1: *Suppose that: (1) both σ_a and* **a** *are contractible; (2) the agency contract is unobservable; (3) the principal's utility is* I - y(a)*; (4) the agent's utility is* u[I - y(a)], *with* u[·] *concave; (5) the outcome of the market stage game is independent of the principal's actions; and (6) at the time of contracting, the principal and agent are symmetrically informed. Then the set of second-stage outcomes supportable as rational-agent Nash equilibria in the agency game is identical to the set of second-stage outcomes supportable as Nash equilibria in the principals-only game.*

Proof: Suppose that some market-stage outcome were supportable as an equilibrium in the agency game but not in the principals-only game. Then it would have to be the case that there existed some contract r_o such that $\rho^e(r_o) > 0$ and

$$\sigma_a^e(r_o) \notin \underset{\sigma \in S_a}{\text{argmax}} \; E[\, m(\sigma,\sigma_b^e) - y(\sigma,\sigma_b^e) \,]$$

taking σ_b^e as given. The principal's expected payoff under this contract is:

$$E[\, m(\sigma_a^e(r_o),\sigma_b^e) - r(\sigma_a^e(r_o),\sigma_b^e) \,] \;\le\; E[\, m(\sigma_a^e(r_o),\sigma_b^e) - y(\sigma_a^e(r_o),\sigma_b^e) \,], \tag{1}$$

where the inequality follows from the agent's individual rationality constraint,

$$E\{\, u[r(\sigma_a^e(r_o),\sigma_b^e) - y(\sigma_a^e(r_o),\sigma_b^e)] \,\} \;\ge\; 0,$$

and the concavity of $u(\cdot)$.

If the principal offered the full-insurance forcing contract that supported $\sigma_a{}^*$, where

$$\sigma_a{}^* \in \underset{\sigma \in S_a}{\text{argmax}} \; E[\, m(\sigma,\sigma_b^e) - y(\sigma,\sigma_b^e) \,],$$

then the agent would accept the contract and play $\sigma_a{}^*$. The principal would earn

$$E[\, m(\sigma_a{}^*,\sigma_b^e) - y(\sigma_a{}^*,\sigma_b^e) \,] \;>\; E[\, m(\sigma_a^e(r_o),\sigma_b^e) - y(\sigma_a^e(r_o),\sigma_b^e) \,], \tag{2}$$

where the inequality follows from the definition of $\sigma_a{}^*$. Inequalities (1) and (2) imply that the principal would earn a greater payoff under this contract than under the candidate equilibrium contract, a contradiction. Therefore, the candidate equilibrium cannot, in fact, be an equilibrium. Hence, any market-stage outcome supportable as an equilibrium in the agency game must also be supportable as an equilibrium in the principals-only game.

Now, consider the other direction of inclusion. Suppose that $<\sigma_a^e,\sigma_b^e>$ is a Nash equilibrium strategy profile in the principals-only game. Suppose that the outside party chooses strategy σ_b^e in the market stage of the agency game, and the principal offers the full-insurance, forcing contract that supports σ_a^e. It is a best reply for the agent to accept the contract and play σ_a^e. Given that the principal is offering this contract and the agent is playing σ_a^e, it clearly is a best reply for the outside party to play σ_b^e. All that remains to check is that offering this full-insurance, forcing contract is a best reply for the principal.

Given the agent's individual rationality constraint, any other contract, $\hat{r}$, yields the principal

$$E[\ m(\hat{\sigma},\sigma_b^e) - \hat{r}(\hat{\sigma},\sigma_b^e)\ ] \ \leq \ E[\ m(\hat{\sigma},\sigma_b^e) - y(\hat{\sigma},\sigma_b^e)\ ], \tag{3}$$

where $\hat{\sigma}$ is the second-stage strategy induced by $\hat{r}$, and the inequality follows from the concavity of $u(\cdot)$.

Under the full-insurance, forcing contract that supports σ_a^e, the principal earns

$$E[\ m(\sigma_a^e,\sigma_b^e) - y(\sigma_a^e,\sigma_b^e)\ ].$$

By the definition of Nash equilibrium in the principals-only game,

$$\sigma_a^e \in \underset{\sigma \in S_a}{\operatorname{argmax}} \ E[\ m(\sigma,\sigma_b^e) - y(\sigma,\sigma_b^e)\ ].$$

This fact, coupled with Inequality (3), implies that it is a best reply for the principal to offer the contract that forces σ_a^e. Therefore, $<\sigma_a^e,\sigma_b^e>$ is supportable as the second-stage outcome of a rational-agent Nash equilibrium in the agency game. **Q.E.D.**

In practice, there are tremendous difficulties in writing full-insurance, forcing contracts. Except in special cases, such a contract would require a great deal of information on the principal's part. In order to enforce the contract, the principal typically would have to calculate the actions that the agent should have taken and then verify that the agent took them. To obtain this information, the principal often would have to engage in extensive and expensive monitoring of the agent. Moreover, writing and enforcing contracts with such detailed instructions could be very costly given the number of contingencies that the contract might have to cover and the difficulties of verification before a court.

Some of these difficulties might be less severe when the disutility of the market-stage actions is independent of the particular actions taken (i.e., $y(\mathbf{a}) \equiv k$, k a constant). This type of utility function could arise, for example, when the decision maker simply chooses a firm's output level or a tax authority's audit policy.[8] In this case, a full-insurance contract consists of a constant payment, and one might try simply paying the agent a flat fee of k and asking him to follow the principal's instructions. Even this type of contract, however, could be very costly to administer. Given this reward function, the agent is indifferent to the outcome of the second-stage game, and he might as well follow the principal's instructions. But such a contract is extremely susceptible to bribes. The outside party would have incentives to make payments to the agent to induce him to take actions favorable to them. Once one modeled this feature of the game, it would be necessary for the contract to contain detailed and explicit instructions, as well as provisions for punishing the agent if he failed to follow these instructions. Again, writing and enforcing such a contract could lead to tremendous contractual complexity and administrative cost.

B. PERFECT DELEGATION

Under some conditions, there is an alternative means of making the agent behave like a principal -- one that requires relatively little information. If there is no danger of adverse selection (i.e., the principal and agent are symmetrically informed at the time of contracting) or of moral hazard on the part of the principal, then the only incentive problems in the agency relationship arise from the choice of action by the agent. When the agent is risk neutral, these incentive problems can be perfectly overcome if it is possible to sell the asset to the agent for a fixed fee and make the agent a residual claimant (i.e., by offering a contract of the form $r(\mathrm{x}) = M(\mathrm{x}) - F$, where F is a constant).[9]

Using essentially the same line of argument used to establish Proposition 1, one can prove

[8] The former appears in Fershtman and Judd [1987], Ross [1987]), and Sklivas [1987], for example, while the latter appears in Melumad and Mookherjee [1989].

[9] Note that in some circumstances such a contract could be enforceable even when the court responsible for enforcing the contract cannot observe the realization of x or M[x]. All that is needed is some way to verify that the agent is receiving all of the profits at the margin. This might be accomplished by transferring physical possession of the asset to the agent.

the following result.

Proposition 2: *Suppose that: (1) residual claimant contracts are enforceable; (2) the agency contract is unobservable; (3) the principal and agent both are income risk neutral, with von Neumann-Morgenstern utility* I - y(a)*; (4) the outcome of the market stage game is independent of the principal's actions; and (5) at the time of contracting, the agent and principal are symmetrically informed. Then the set of second-stage outcomes supportable as rational-agent Nash equilibria in the agency game is identical to the set of second-stage outcomes supportable as Nash equilibria in the principals-only game.*[10]

The intuition behind Propositions 1 and 2 is that the contract is unobservable and thus cannot directly affect the strategy of the outside party. Therefore, the contract must be nonstrategic in the sense that the principal chooses the best contract taking the outside party's strategy as given. These two results tell us that, in terms of Nash equilibrium, the use of an agent has no effect when the agency relationship is such that "nonstrategic" agency problems can be completely overcome and the principal and agent have similar enough preferences and capabilities.

While the arguments of this section have been framed in terms of a single agency relationship, none of the arguments made above relies on this setting. Propositions 1 and 2 remain valid even when there are multiple principal-agent relationships -- the proofs simply took σ_b as given, they did not ask whether it was generated by an agency relationship. Similarly, these results (and the arguments used to prove them) can straightforwardly be extended to cases in which there are more than two principals, some or all of whom hire agents.

C. UNIQUE EQUILIBRIUM

[10] A similar result can also be derived for forcing contracts that do not provide full insurance. Given the agent's risk neutrality, a forcing contract with $r = E[y(\sigma_a^*, \sigma_b)]$ when the agent complies would force σ_a^* at minimal cost to the principal given that the outside party is playing strategy σ_b.

Propositions 1 and 2 have their greatest power when there is a unique Nash equilibrium in the principals-only game. For instance, Proposition 2 implies:

Corollary: *Suppose that: (1) residual claimant contracts are enforceable; (2) the agency contract is unobservable; (3) the principal and agent both are income risk neutral, with von Neumann-Morgenstern utility* I - y(a)*; (4) the outcome of the market stage game is independent of the principal's actions; and (5) at the time of contracting, the agent and principal are symmetrically informed. If there is a unique Nash equilibrium in the principals-only game, then the use of a rational agent has no effect on the second-stage equilibrium outcome.*

Example 1 (Managerial Compensation and Cournot Oligopoly): This corollary is easily illustrated by the following example. Suppose that the principal owns a firm that produces output in a duopolistic product market; the other producer being the outside party. Each producer has identical constant marginal costs of production. There is no additional loss in generality from taking these costs to be zero (i.e., from subsuming them in the inverse demand function). The market inverse demand function is $P(\cdot)$, where for any market output level, X, $3P'(X) + XP''(X) < 0$. In terms of the earlier notation, $\mathbf{x} = (x_a, x_b)$ and $M(\mathbf{x}) = P(x_a + x_b)x_a$. Payoffs for the outside party are $P(x_a + x_b)x_b$. The conditions imposed on the cost and inverse demand functions imply that there is a unique Nash equilibrium in the principals-only game. Denote this outcome by $\mathbf{x}^e = (x_a^e, x_b^e)$.

As a standard of comparison, suppose that the contract were observable and could not be renegotiated. Moreover, suppose that a full set of forcing contracts were feasible (i.e., the principal could order the agent to produce any given level of output). In this event, the principal would simply force the agent to produce the Stackelberg leader output level. Given a more limited contract set, the goal of the principal would remain the same -- she would try to implement a contract that made her agent more aggressive and thus induce an output contraction by the outside firm.[11]

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[11] This is, essentially, the point made by Fershtman and Judd [1987], Ross [1987], and Sklivas [1987].

As the Corollary tells us, things are rather different when the contract is unobservable. To see this in the context of the specific example, suppose counterfactually that the equilibrium output levels in the agency game, (x_a^*, x_b^*), were not equal to (x_a^e, x_b^e). By the definition of Nash equilibrium in the agency game, x_b^* must be the outside party's best response to x_a^* given payoff function $P(x_a + x_b)x_b$. Hence, it would have to be the case that x_a^* were *not* a best response to x_b^* given the payoff function $P(x_a + x_b)x_a$. (Otherwise (x_a^*, x_b^*) would be an equilibrium in the principals-only game, and by hypothesis it is not). But then, if residual claimant contracts are feasible, the principal could offer the one with fixed fee $F = \max_x P(x + x_b^*)x$.[12] A risk-neutral, rational agent would accept this contract, and the principal would increase her payoff. This fact contradicts the claim that (x_a^*, x_b^*) can be an equilibrium outcome in the agency game.

D. WHAT ABOUT SIGNALLING THE UNOBSERVABLE CONTRACT?

Many readers have argued that somehow the Corollary must be invalid in games where the agent takes more than one round of actions in the second-stage game because the agent would be able to use his early-round actions to signal to the outside party that some strategic contract had been signed. For example, with multiple periods of production, the agent could try to use his early-round output levels to signal that he has a contract that makes him a tougher competitor much the way the incumbent in Milgrom and Roberts' [1982] model of limit pricing signals his unobservable production cost to a potential entrant. Observing this signal, it is argued, the rival duopolist would reduce his output.

This argument is incorrect because it ignores the fact that the agent could choose to mimic such behavior even if he had a nonstrategic contract. Suppose that, *in equilibrium*, the principal found it optimal to set a contract that made her agent a tougher player and then had her agent take actions in the second-stage game that signalled to the other player that this contract had been implemented. If it were profitable for the principal to impose such a contract and have the agent signal its existence, then it would be at least as profitable for the principal to sell the asset to the

[12] Alternatively, if forcing contracts were feasible, the principal could order her agent to produce $\text{argmax}_x P(x + x_b^*)x$.

agent for a fixed fee and have the agent falsely signal that the "tough" contract had been signed.

This intuition can easily be illustrated by extending the Cournot example above to two rounds of production.

Example 2 (Signalling and Entry Deterrence): Suppose that the principal's firm produces output in two periods, rather than one. The outside party continues to produce output solely in one period, the second. Think of the principal's firm as an incumbent, and the outside party's firm as a potential entrant. Let x_{it}, $t = 1,2$, denote the quantity produced by firm i in period t. Continue to make the cost and demand assumptions of Example 1, where $P(\cdot)$ now denotes per-period demand.

It is trivial to verify that in any Nash equilibrium of the principals-only game each firm produces its Cournot output level in the second period. The first-period output level has no effect on the entrant's second-period decision because the entrant has complete information about the incumbent's costs.[13] When the principal hires an agent under an unobservable contract, however, the outside party no longer knows the incumbent decision maker's costs. Can the agent use his first-period output choice to signal the terms of the contract to the outside party?

To make the signalling clear, it helps to consider a contract set that can be parameterized along a single critical dimension. Suppose that R consists of all contracts of the form

$$r(\mathrm{x}) = P(x_{a1})x_{a1} + P(x_{a2} + x_{b2})x_{a2} + d\{x_{a1} + x_{a2}\} - F.$$ [14]

In terms of its impact on the agent's second-period output choice, d is the critical parameter. This is the parameter that distorts the agent's behavior from the simple maximization of product-market profits. If d were observable and immutable, the principal would set $d > 0$ to make her

[13] Absent perfection requirements, there are multiple Nash equilibria. The entrant may use incredible threats to induce the incumbent to produce a variety of different output levels in the *first* period.

[14] This type of contract set would arise if the principal sold the output of her firm to the agent using a two-part tariff wholesale pricing scheme (as in Example 4 below), or if the principal hired the agent with a managerial compensation scheme that was a linear function of revenues and costs (as in Fershtman and Judd [1987], Ross [1987]), and Sklivas [1987]).

agent more aggressive. What happens when d is unobservable to the outside party? Can first-period output be used credibly to signal that $d > 0$? The answer is: No.

Proposition 3: *Suppose that the outside party cannot observe the agency contract. In any rational-agent Nash equilibrium of the entry-deterrence game,* d = 0 *and each firm produces its Cournot output level in the second period.*

Proposition 3 actually is a corollary of Proposition 2.[15] It is instructive, however, to prove Proposition 3 directly. Suppose counterfactually that the equilibrium outcome entailed $d^* \neq 0$, F^*, x_{a1}^*, x_{a2}^*, and x_{b2}^*. Consider what would happen if the principal deviated from the candidate equilibrium by proposing a contract with $d = 0$ and $F = F^* - d^*(x_{a1}^* + x_{a2}^*) + \delta$, where

$$\delta \equiv \underset{x}{\text{maximum}}\ P(x + x_{b2}^*)x - P(x_{a2}^* + x_{b2}^*)x_{a2}^*.$$

The facts that

$$x_{a2}^* \in \underset{x}{\text{argmax}}\ \{P(x + x_{b2}^*) + d^*\}x.$$

and $d^* \neq 0$ imply that $\delta > 0$.

If the agent accepted this contract and continued to produce x_{a1}^* in the first period, the outside party would still produce x_{b2}^* in the second period (he would have no way of detecting the change in the contract). And, by construction, a rational agent would accept this new contract. The new contract would yield the principal δ more profit than would the original, and therefore, (d^*,F^*) could not have been an equilibrium contract. The actual equilibrium contract must be nonstrategic (i.e., have $d = 0$), and first-period output cannot be used to signal otherwise.

E. MULTIPLE EQUILIBRIA AND THE USE OF REFINEMENTS

In many games, there are multiple Nash equilibria, whether or not an agent is hired. A natural question is whether refinements pass through from the principals-only game to the agency

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[15] There is no need to restrict attention to a risk-neutral agent in this example because there is neither any exogenous noise nor any mixing on the equilibrium path of the market stage game.

game the way Nash equilibrium does. Because the issues are much more complex, it is useful to frame the entire discussion within the context of a simple example.

Example 3 (Bargaining Through an Agent): Consider a bargaining game in which there is a single seller who has a single indivisible unit of the good to sell. The unit of the good has some alternative use for which it has a value to the principal of c. There is a single potential buyer who values the unit of the good at v, $v > c$. The values of v and c are common knowledge at the start of the game. There is only one round of bargaining. The buyer makes a bid of p_b, which the seller then either accepts or rejects. The outcome of the bargaining game is the transaction quantity, $x \in \{0,1\}$, and (if $x = 1$) the transaction price, p.

It is trivial to show that, if the principal plays the bargaining game on her own behalf, then the set of Nash equilibrium outcomes includes any price between c and v inclusive. Many of these outcomes are unsatisfactory in that they rely on implicit, incredible threats that can arise given the sequential timing of moves. Subgame perfection provides the obvious refinement. The unique subgame perfect equilibrium entails the buyer's bidding $p_b = c$ and the seller's accepting the offer.

Now suppose that the principal hires a risk neutral agent to play the bargaining game. Moreover, suppose that the contract between the principal and agent cannot be renegotiated. When both p and x are contractible, the principal has enough flexibility to specify the set of bids that the agent will accept: The sequential rationality of the agent implies that he must accept any bid such that $r(p_b,1) > r(p_b,0)$ and reject any bid such that $r(p_b,1) < r(p_b,0)$ in any rational agent Nash equilibrium.[16]

When the agency contract is unobservable to the buyer, the set of Nash equilibria again supports any price, p_o, from the interval $[c,v]$.[17] In particular, it is an equilibrium for: (1) the

[16] In order to avoid open set problems, I assume that the agent and the buyer behave in the way preferred by the principal when they are otherwise indifferent between two outcomes.

[17] When the agent's contract is observable and irreversible, there is again a continuum of equilibria, but only one that is subgame perfect. In this case, the principal is in effect able to move first in the bargaining game with the buyer by committing to a reservation price. The unique perfect equilibrium entails: (1) the principal's offering a contract such that $r(v,1) = 0$ and the agent is induced to reject any bid less than v; (2) the agent's accepting the contract; (3) the buyer's bidding v; and (4)

principal to set the contract $r_0(p,x)$ such that $r_0(p_0,1) = 0$ and p_0 is the lowest price for which $r_0(p,1) \geq r_0(p,0)$; (2) the buyer to bid $p_b = p_0$; and (3) the agent to accept both the contract and the bid, and to reject any lower bid. Notice that *all* of the players are sequentially rational in these equilibria in the sense that each player optimizes at each decision node given his or her beliefs and these beliefs are consistent with Bayes rule given the information sets and the equilibrium strategies. Therefore, the set of *perfect Bayesian equilibria* can support all prices between c and v inclusive when the agent bargains on behalf of the principal.[18]

The Bayesian updating requirement lacks power because the buyer does not observe any actions by the principal or her agent prior to the time of bidding. Hence, further refinement is necessary in order to obtain uniqueness. Intuitively, it is unreasonable for the principal to propose any contract for which $r(\hat{p},1) < r(\hat{p},0)$ for some $\hat{p} > c$ because it might lead the agent to reject a bid that it would be efficient to accept. Since the buyer cannot see the contract, the contract can have no direct effect on the buyer's bid, and the only time that the clause covering $\hat{p}$ would come into play is when the buyer actually bid $\hat{p}$, in which case the principal would want the bid to be accepted. A similar argument suggests that the principal should not offer a contract for which $r(\underline{p},1) > r(\underline{p},0)$ for some $\underline{p} < c$.

One can model this intuition through the use of trembles.[19] Suppose that there is some (small) probability that the buyer bids each price. Then for any contract that satisfies the agent's individual rationality constraint and which induces inefficient trade for some price, there is some other contract that satisfies the agent's individual rationality constraint, induces efficient trade, and yields the principal a strictly greater expected payoff given the buyer's strategy. Consequently, when only the buyer trembles, the equilibrium contract must induce the agent to accept any contract offer greater than c. Knowing this, the buyer will bid c, and the principal

the agent's accepting the buyer's offer. This outcome is at the opposite pole from the perfect equilibrium outcome when the buyer moves first.

[18] For an excellent discussion of perfect Bayesian equilibrium, see Fudenberg and Tirole [1989].

[19] Although the example has been treated as being continuous, there is a closely analogous discrete example in which use of trembles can be formalized rigorously.

gains no bargaining advantage through the use of an agent.

At natural question is whether this type of argument can be extended to show that the sets of trembling hand perfect equilibria are the same in the principals-only and agency games. The answer is: No. In Appendix A, I present an example in which the agent trembles in such a way that it is better for the principal to offer a contract that induces inefficient trade when the buyer trembles than to offer an efficient contract that the agent rejects when he trembles. Hence, to derive some sort of equivalence result, it would be necessary to put restrictions on the form that trembles by the agent might take.[20] While one could do this, the bottom line seems to be that refinements do not pass through well.[21] I will not worry about this point further, since the next section presents what I consider more meaningful reasons to suspect that agency relationships affect the play of games.

4. GAMES IN WHICH AGENCY MATTERS

In the previous section, I argued that, if contracts are unobservable, a risk-neutral principal's using an agent has no strategic effects when the two parties are similar in terms of preference and capabilities and there is a feasible contract that can completely overcome the "nonstrategic" agency problems. Under these conditions, the agent plays the second-stage game in the same way as would the principal. The set of conditions under which such contracts will exist is, however, very limited. In this section, I will consider several variants of a single example in which the information structure of the agency relationship is such that there is no feasible contract that can completely overcome the "nonstrategic" agency problems. In these cases, the use

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[20] There is another difficulty as well. Loosely speaking, trembles by the principal in terms of contract offer would induce trembles by the agent over his entire second-stage continuation *strategy*. Hence, one also would have to restrict attention to the equivalence of *normal form* perfect equilibria in the principals-only game and the second stage of the agency game. For an elementary discussion of normal form perfection, see Kreps [1990].

[21] A similar conclusion might be drawn from Caillaud and Hermalin [1991]. In the context of a signalling game, they show that several refinements that eliminate unwanted equilibria in the principals-only game have no effect in the agency game. They also show, however, that stronger refinements, such as "never a weak best response," do eliminate the unwanted equilibria in both games. Unfortunately, such forward induction arguments do not work for the bargaining game considered in the present paper -- in part because, unlike in Caillaud and Hermalin, the outside party observes nothing before bidding.

of an agent does affect the outcome of the market stage game -- the equilibrium contract induces the agent to behave differently than would the principal acting on her own behalf.

Example 4 (Vertical Contracting): Suppose that the principal produces a good that she sells through a downstream dealer, the agent. The agent sells this output in a Cournot duopoly where the other seller is the outside party. The principal and the outside party have equal, constant marginal costs of production, which are normalized to zero. The market inverse demand function is $P(X) = \theta - X$. Thus, when the principal's downstream output is x_a and the outside party's is x_b, the principal earns a gross profit of $M(x) = \{\theta - x_a - x_b\}x_a$, and the outside party earns $\{\theta - x_a - x_b\}x_b$.

Throughout the example, I will assume that the principal sells her output to the agent through a wholesale pricing scheme. Moreover, I assume that this scheme can be no more complicated than a two-part tariff. That is, the agent pays $w(x_a) = wx_a + F$, w and F constants.[22] F often is called a franchise fee in the vertical restraints literature. Expressed in terms of the agent's compensation, this assumption states that R comprises contracts of the form $r(\mathbf{x}) = \{\theta - x_a - x_b - w\}x_a - F$.

Some additional notation will be useful in what follows. Let $x_i(\theta,w)$, $i = a,b$, denote the equilibrium output of downstream firm i when it is common knowledge that the realization of the demand parameter is θ and the agent faces a wholesale price of w. It is a simple matter to show that $x_a(\theta,w) = \max\{0, (\theta - 2w)/3\}$ and $x_b(\theta,w) = \max\{0, (\theta + w)/3\}$.

A. RESTRICTED CONTRACTS AND THE DIVISION OF RENTS

Propositions 1 and 2 rely on the feasibility of either forcing or residual claimant contracts. But neither form of contract may be available due to either legal or informational constraints.

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[22] The restriction to two-part tariffs is not essential to the qualitative results (although see Rey and Stiglitz [1988] for a possible justification of such a restriction). If one were to allow a more general quantity-dependent pricing scheme, one still would find points on the schedule at which the marginal price did not equal marginal cost and distortions would be induced. The key restriction is that the principal does not have sufficient information to simply force the agent to pursue a particular second-stage strategy *and* fully insure the agent against variations in either θ or the actions of the rival producer.

Suppose that the principal is restricted to selling her output at a constant wholesale price (i.e., $w(x_a) \equiv wx_a$, w a constant). In this case, the principal clearly must set the wholesale price greater than marginal cost in order to profit from the sale of her output. Knowing this fact, the rival firm would expand its output in the product market -- agency would have a negative strategic effect. The following result, proved in Appendix B, provides a detailed example:

Proposition 4: *Suppose that the principal is restricted to selling her output at a constant wholesale price. If θ is publicly observable at the time that the vertical contract is signed, then the equilibrium outcome in the agency game entails $w^e = 2\theta/7$, $x_a^e = \theta/7$, and $x_b^e = 3\theta/7$. In contrast, the equilibrium outcome in the principals-only game entails $x_a^e = \theta/3 = x_b^e$.*

Although agency has a negative strategic effect in this example, note that this result would be reversed under price competition. When the two downstream firms are engaged in differentiated-products Bertrand competition, the distortion in the agent's behavior induced by the agency contract would serve to sustain a more collusive outcome -- knowing that the (unobservable) wholesale price was positive would induce the outside firm to raise its downstream price. Hence, agency would have a positive strategic effect.

B. RISK SHARING

There are several other situations in which the agency contract will distort the agent's behavior and thus have indirect strategic effects. Suppose that *neither* the principal nor the agent knows the value of θ *at the time of contracting*, although they have the same prior beliefs about its value. Moreover, suppose that, if the agent accepts the contract, the agent and the outside party learn the value of θ before making their production decisions. Neither the principal nor the courts ever learns the value of θ, and thus the contract cannot be made contingent on θ.[23]

Proposition 2 tells us that the use of a risk-neutral agent would have no strategic effect

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[23] More generally, one might allow the agent's *report* of θ to influence the agent's compensation level (i.e., the dealer would be offered a menu of contracts). If the manufacturer did use a menu of contracts to sort dealer types, equilibrium still would entail wholesale pricing above cost for some realizations of θ. For an example of a related problem in which such a mechanism-design approach is taken, see Caillaud and Hermalin [1991].

when the principal can implement a two-part tariff -- the equilibrium agency contract would entail a positive franchise fee and a wholesale price equal to marginal cost, $w = 0$. When the agent is risk averse, however, marginal cost pricing is not the principal's optimal strategy. While marginal cost pricing does a good job of generating agent incentives, the agent bears all of the risk -- the principal's profits are equal to F no matter what the value of θ. This pattern of risk sharing is not an efficient one. Given her risk neutrality, if the principal could observe the value of θ, she would set F contingent on that value so that the agent would bear no risk. When the principal cannot base the vertical contract directly on the realization of θ, she has to rely on a signal of θ's value. The principal may be able to take the agent's choice of x_a as that signal.

The principal would like to compensate the agent for low realizations of θ. Since θ and the agent's choice of x_a are positively related, the principal can do this by simultaneously lowering F and raising w in a way that raises the agent's income for low unit-sales levels but lowers the agent's income for high unit-sales levels. In Appendix B, I prove:

Proposition 5: *If it is common knowledge that the agent is risk averse, the principal is either risk neutral or risk averse, and neither party knows the value of θ at the time of contracting, then there is no equilibrium in the vertical contracting game in which the wholesale price is set less than or equal to marginal cost with positive probability.*

It is well known that, in a nonstrategic setting, a risk-neutral principal will not hire a risk-averse agent under a contract with $w = 0$ (see, for example, Holmstrom [1979] and Shavell [1979]). In the standard principal-agent literature, the need to share risk leads to deviations from the first-best that reduce the level of profits that the principal can attain. In the present context, there is an additional negative effect due to the reaction of the product-market rival: Knowing that the wholesale price is positive will make the rival producer more aggressive. Of course, under pricing competition, the principal may benefit from the fact that the agent is risk averse.

C. EX ANTE ASYMMETRIC INFORMATION

The use of a risk-averse agent affects the second-stage outcome because it no longer is optimal for the principal to make the agent a residual claimant. Setting the marginal price in the two-part tariff equal to marginal cost also may fail to be optimal when the principal and agent are asymmetrically informed at the time of contracting.

First, suppose that it is common knowledge that the agent is better informed about the value of θ than is the principal. Consider the extreme case in which the agent knows the realization of θ at the time of contracting, but the principal never observes the value of θ. The value of θ determines the compensation necessary to attract the agent. One approach is to set w equal to marginal cost and set F sufficiently low that even the worst type of agent would receive at least his opportunity utility level. Such a scheme would, however, overcompensate a high-θ agent. On the other hand, higher values of F would risk turning away the agent for low realizations of θ.

The agency contract may provide a mechanism by which to elicit the agent's private information. The principal would like to make the agent's payment contingent on θ, but the principal cannot observe it directly. As in the case of symmetric uncertainty, the agent may signal his value of θ through his choice of x_a. Using the fact that a high-θ agent has greater sales, the principal can use the quantity sold as a metering device. It is optimal for the principal to set w greater than marginal cost to use the relationship between x_a and θ to extract rents from high-θ agents without driving low-θ agents from the market.

Proposition 6: *If the principal and agent are risk neutral, and it is common knowledge that only the agent knows the value of θ at the time of contracting, then there is no equilibrium in the vertical contracting game in which the wholesale price is set less than or equal to marginal cost with positive probability.*

A proof is sketched in Appendix B.

Now, suppose that it is common knowledge that, at the time of contracting, the principal is better informed than the agent: The principal observes the realization of θ at the outset, while the agent and the outside party learn θ after the agent has signed the contract but before making production decisions. The courts have absolutely no information about θ, so a contract contingent on θ is unenforceable. The following result is proved in Appendix B.

Proposition 7: *Suppose θ must take one of two values, 0 and $\overline{\theta}$, where $0 < \overline{\theta}$. There exists a perfect Bayesian equilibrium of the informed-principal example in which a low-θ principal offers a two-part tariff with* $F = 0 = w$, *and a high-θ principal offers a two-part tariff with* $F = 0$ *and* $w = 2\overline{\theta}/7$. *The equilibrium output levels in the agency game are $x_a^e(\theta) = \theta/7$ and $x_b^e(\theta) = 3\theta/7$. In contrast, the equilibrium output levels in the principals-only game are $x_a^e(\theta) = \theta/3 = x_b^e(\theta)$.*

The principal's private information is fully revealed to the agent under this equilibrium. A principal who observes the high value of θ signals this fact by offering a combination of wholesale price and franchise fee that she would find unattractive if θ actually had the low value -- by setting $w > 0$, the principal gives herself a stake in the agent's volume and makes credible her claim that her agent will have a profitable, high-volume operation. A principal with a low-value product admits this fact and offers a "null" contract. Knowing that these must be the equilibrium contracts, the outside party produces more output when $\theta = \overline{\theta}$ than he would in the principals-only game.

D. DOUBLE MORAL HAZARD

Up to this point, the principal has not been an active player in the second-stage game where she hires an agent: The principal's sole action in the market stage of the vertical contracting game has been to provide as much of the intermediate good as her agent demands. But suppose that the principal provides some complementary promotional effort (e.g., advertising or the quality of the product) for which it is impossible to contract explicitly (either because the actions cannot be well measured or observed, or because the market conditions on which these activities should be based are themselves unobservable to the courts) and which is conducted after the contract has been signed. When the principal's post-contracting effort affects downstream market revenues and explicit contracting over this effort is infeasible, setting the wholesale price above marginal cost may be the only way to get the principal to provide effort. If $w \leq 0$, the principal has no incentive to encourage sales by the agent. If the principal's action is sufficiently important to sales in the product market, the privately optimal wholesale price may again be greater than marginal cost.

E. SECTION SUMMARY

Although this section has merely considered several variants of a simple example, together these variants suggest a general result. When a producer hires an agent (either as a manager of the firm or as a downstream distributor), there are a variety of situations in which one would expect to see contracts that induce the agent to act as if the marginal cost of the item were greater than it actually is. Moreover, other players will take this fact into account. Thus, unobservable agency contracts can affect the play of the market stage game. Whether this effect is an added cost of agency or a benefit depends on the nature of the product-market game. A mark-up over marginal costs reduces the principal's profits under Cournot competition, while the mark-up raises profits under differentiated-products Bertrand competition. In either case, contracts that lead agents to act as if they have greater marginal costs typically raise prices and harm consumers.

One could apply similar arguments to the use of an agent as a bargaining representative.[24] In this setting, the result says that one would expect to see contracts that induced the agent to be a tougher bargainer than he otherwise would be, thus helping the principal. For instance, a salesman could make a credible claim that the terms of his employment do not allow him to sell a computer component below some set price.

5. RENEGOTIATION

The contract between a principal and her agent also may be subject to renegotiation. Intuitively, such renegotiation can undermine the commitment value of even an observable contract. In the extreme case where recontracting is costless and efficient, the principal and agent will renegotiate their contract if the market game ever evolves to a point at which it no longer is in their joint interest to abide by it.

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[24] A earlier draft of this paper did just that, obtaining a set of results that closely parallel those derived here.

Return to the earlier example in which the agent represents the principal in the sale of a single item. Recall that there is a unique subgame perfect equilibrium when the agency contract is observable and no renegotiation is possible. In this equilibrium, the selling price is v. On the other hand, there are lots of perfect Bayesian equilibria when the agency contract is unobservable and cannot be renegotiated, although I argued that the "sensible" equilibrium entails the buyer's bidding c.

Now, suppose that the principal and the agent can renegotiate their initial contract after the buyer has made his bid. I want to argue that the effects of this renegotiation depend critically on the information structure of the agency relationship. First, suppose that the principal can see what bid has been made, and consider what would happen if the buyer bid $p_0 > c$ where the initial contract, $\hat{r}$, had $\hat{r}(p_0,1) < \hat{r}(p_0,0)$. Seeing this bid, a rational principal would have to offer the agent a new contract, r^*, with $r^*(p_0,1) \geq \max\{\hat{r}(p_0,0), r^*(p_0,0)\}$, which the agent would then accept, along with the buyer's bid. Knowing this, the buyer will bid at the seller's cost, and the unique subgame perfect equilibrium entails $p = c$. The fact that the principal and agent can perfectly renegotiate completely undermines any commitment value that they might have gained through the signing of the original contract, observable or not.

Note the parallel between the effects of unobservable contracts and contracts that can be renegotiated. In each case, the outside party cannot see the agency contract that truly drives the agent's behavior. And in each case, there is no reason for the outside party to believe that the principal and agent will agree to an inefficient contract purely for strategic reasons.

One can take this analogy further to show that, in each case, imperfections in the agency relationship itself may allow the contract to play a strategic role. When the contract is unobservable but immutable, strategic effects arise when the contract distorts the agent's behavior as part of overcoming the basic incentive or risk-sharing problems present in the agency relationship. In the case of a contract subject to renegotiation, the initial contract can carry some weight when the principal and agent are unable to bargain efficiently during renegotiation.

One reason that renegotiation may be inefficient is that it may represent bargaining under incomplete information.[25] Suppose that principal cannot observe p_b. For instance, it may be that the principal is not present when the buyer and agent meet, and thus the principal cannot observe the true transactions price. The agent cannot, however, conceal the fact that he has sold the good (e.g., the principal periodically checks the inventory), so x is observable.

Consider the following outcome. The initial contract specifies that the agent has to pay the principal v if he sells the unit (the agent retains p_b collected from the buyer), and there is no monetary transfer otherwise. The buyer bids $p_b = v$, and the agent accepts both the principal's contract offer and the buyer's bid. It is easy to verify that this is a Nash equilibrium outcome when renegotiation is prohibited.

When renegotiation is feasible, the agent can report the buyer's bid to the principal once it has been made, and the principal must decide how to respond to this report. Formally, we can think of this renegotiation process as a direct revelation mechanism in which the agent makes a report, p_r, to which the principal responds as follows. Let $T(p_r)$ denote the net monetary transfer *from the agent* to the principal. And let $x(p_r)$ denote the probability that the principal allows/forces the agent to sell one unit of the good. Then given a bid of p_b, a risk neutral agent chooses his report to $\text{maximize}_{p_r}\, x(p_r)p_b - T(p_r)$.

Suppose that the principal responds to the agent's report as follows:

$$T(p_r) = \begin{cases} v \text{ if } p_r = v \\ 0 \text{ otherwise} \end{cases}$$

and

$$x(p_r) = \begin{cases} 1 \text{ if } p_r = v \\ 0 \text{ otherwise.} \end{cases}$$

In effect, there is no renegotiation under this mechanism. Intuitively, the principal interprets any report of a low bid as simply an attempt by an agent receiving a bid of v to earn rents by tricking

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[25] Alternatively, if there are multiple subgame perfect equilibria to the bargaining game between the principal and agent, then some of them may be inefficient even when the bargaining takes place under complete information. For a general discussion of inefficient equilibria in bargaining games of complete information, see Binmore, Osborne, and Rubinstein [1990].

the principal into lowering the wholesale price of the good. There is no credible way for an agent receiving a low bid to convince the principal that he is not lying.

The formal claim that there is no superior renegotiation mechanism can be seen as follows. Given the buyer's bid of v, the principal extracts all of the surplus and the outcome is efficient. Moreover, any mechanism for which $T(v) < v$ and/or $x(v) < 1$ would yield lower profits for the principal. When $T(v) = v$ and $x(v) = 1$, the incentive compatibility constraint for truthful reporting by an agent who receives a bid of v is $x(p_r)v - T(p_r) \leq 0$ for all $p_r \in [0,v]$, which implies that either $x(p_r) = 0$ or $T(p_r)/x(p_r) \geq v$ for all $p_r < v$. Therefore, given the buyer's strategy, there is no meaningful contract renegotiation that the principal would prefer to the mechanism given above.[26]

6. CONCLUSION

In this paper, I have used some simple models to explore the consequences of unobservable agency contracts in a game setting. Even with unobservable contracts, there is scope for use of an agent to affect the outcome. These effects arise when the agency contract plays two roles simultaneously. One role served by an agency contract is to give the agent incentives to act. By itself, this role for the contract is not enough to alter the equilibrium outcome of the (second-stage) game. But agency does affect the outcome when the contract also serves to share risk, to give the principal incentives to act, or to overcome problems of adverse selection.

This analysis establishes a special role for agency contracts as a means of precommitment. Schelling [1960] suggested that a principal might try to influence the outcome of a game by writing a contract in which she committed herself by promising to give money to an arbitrary third party under certain contingencies. He noted that the effectiveness of such contracts would be severely limited by the possibility of renegotiation. The discussion in Section 3 suggests that such contracts will also be ineffective when they are unobservable and the principal has no need to share risk with the third party: There would be no cause for the other players to believe that

[26] It should be noted that the strength of this result depends in part on the assumption of a continuum of bids and contracts. With discrete values, there might be some renegotiation *if* the buyer deviated, but the buyer still would not find it profitable to induce this renegotiation.

such an artificial commitment had been made, and thus it should not affect their actions. Other players will, however, recognize the need for a contract to govern a *bona fide* agency relationship. Given that the agent and principal have divergent interests and the agent is providing some service for the principal, some form of contract between them is needed.

APPENDIX A

To demonstrate the effects of trembles by the principal and agent, as well as the outside party, consider the following variant of the bargaining example presented in the text. Suppose $v = 1$ and $c = 0$, and the buyer must choose his bid from the pair $\{.1, .9\}$. Moreover, assume that the seller must choose her contract offer to the agent from the pair $\{r_0, r_1\}$, where

$$r_0(p,x) = \begin{cases} .05 \text{ if } x = 1 \\ -.05 \text{ if } x = 0, \end{cases}$$

and

$$r_1(p,x) = \begin{cases} .05 \text{ if } (x,p) \in \{(1,.9), (0,.1)\} \\ -.05 \text{ otherwise.} \end{cases}$$

Note that r_0 induces a rational agent to accept either bid, while r_1 induces the agent to accept the high bid, but reject the low bid.

I will now construct a sequence of strategy profiles that constitutes a trembling hand perfect equilibrium. Let γ_n denote the probability that the buyer bids .1 under the n^{th} element of his sequence of strategies. Suppose that the agent trembles as follows given that he has accepted contract r_i and the buyer has made a bid: With probability $1 - \epsilon_n$ the agent chooses the quantity that yields him payoff of .05, and with probability ϵ_n he chooses the quantity that yields him a payoff of -.05. The agent also trembles over the acceptance of the contract. Note that for $\epsilon_n < .5$, either contract satisfies the agent's individual rationality constraint. Suppose that the agent's trembles lead him to reject contract r_0 with probability ϵ_n and reject contract r_1 with probability $\alpha\epsilon_n$, where α is a positive constant.

Given the strategies of the agent and the buyer, the principal's expected profit from offering contract r_0 is

$$(1-\epsilon_n)[\ (1-\gamma_n)(1-\epsilon_n).9 + \gamma_n(1-\epsilon_n).1 + (2\epsilon_n-1).05\ ],$$

and her expected profit from offering contract r_1 is

$$(1-\alpha\epsilon_n)[\ (1-\gamma_n)(1-\epsilon_n).9 + \gamma_n\epsilon_n.1 + (2\epsilon_n-1).05\ ].$$

From the argument made in the text, we know that the equilibrium contract must be the efficient one, r_0, when only the buyer trembles -- this contract yields greater profit when the buyer bids .1 than does the other contract and the principal must propose it in equilibrium.[27] In fact, it is straightforward to show that the following outcome can be supported as a trembling hand perfect equilibrium outcome (i.e., allowing for trembles by all parties): the principal offers r_0, the agent accepts the contract, the buyer bids .1, and the agent accepts the bid. One sequence of strategy profiles that supports this outcome consists of those strategies described above for the buyer and agent with $\gamma_n = n/(n+1)$, $\epsilon_n = 1/(n+1)$, and $\alpha = 1$. For the principal, let ρ_n denote the probability that the principal offers contract r_0 and take $\rho_n = n/(n+1)$.

The result that the efficient contract can be supported as an equilibrium outcome should not be surprising. More surprising is the fact that the inefficient contract can also be supported as part of a trembling hand perfect equilibrium under which the principal offers r_1, the agent accepts the contract, the buyer bids .9, and the agent accepts the bid. One sequence of strategy profiles that supports this outcome is the one in which $\gamma_n = 1/(n+1) = \epsilon_n$, $\alpha = .5$, and $\rho_n = 1/(n+1)$. Intuitively, the principal offers r_1 even though it does badly when the buyer trembles (and bids .1) because r_0 does even worse in terms of trembles by the agent (he rejects r_0 twice as often as he rejects r_1). Hence, trembling hand perfection alone is not sufficient to eliminate equilibria with inefficient agency contracts.

APPENDIX B

Proof of Proposition 4: Consider first the agency game. Define $x_a(\theta,w,\omega) \equiv \arg\max_x \{\theta - x_b(\theta,\omega) - x - w\}x$. ω can be interpreted as the outside party's beliefs about w. Simple calculations show that $x_a(\theta,w,\omega) = \max\{0, (2\theta - 3w - \omega)/6\}$.

Given the outside party's beliefs, the principal chooses her contract offer to $\text{maximize}_w\ wx_a(\theta,w,\omega)$. The solution is $w(\omega) = \{2\theta - \omega\}/6$. The outside party's expectations must be fulfilled in equilibrium, which happens if and only if $\omega = 2\theta/7$. The equilibrium strategies are

[27] One can see this fact by taking $\epsilon_n = 0$ in the expressions for the principal's expected profits.

as follows. The principal offers a contract with $w^e(\theta) = 2\theta/7$, the agent accepts any wholesale price and produces $\hat{x}_a^e(\theta,w) \equiv \max\{0, (2\theta/7 - w/2)\}$, and the outside party produces $x_b(\theta) = 3\theta/7$.

The equilibrium in the principals-only game is simply the standard linear-demand, Cournot equilibrium. **Q.E.D.**

Proof of Proposition 5: Suppose, counterfactually, that some $w \leq 0$ is played with positive probability in equilibrium. Consider the effects of the principal's simultaneously raising w by dw and lowering F by dF such that

$$dEU = - \int_{\underline{\theta}}^{\overline{\theta}} u'[I(\theta)] \{x_a(\theta,w)dw + dF\} h(\theta)d\theta = 0, \tag{4}$$

where $h(\cdot)$ is the density function for the distribution of θ over its support $[\underline{\theta},\overline{\theta}]$, and $I(\theta) \equiv \{ \theta - x_a(\theta,w) - x_b(\theta,w) - w \}x_a(\theta,w) - F$. The change in the principal's expected utility is

$$dEZ = \int_{\underline{\theta}}^{\overline{\theta}} z'[J(\theta)] \{ x_a(\theta,w)dw + dF + wdx_a\}h(\theta)d\theta, \tag{5}$$

where $z(\cdot)$ is the principal's utility of income function and $J(\theta) \equiv x_a(\theta,w)w + F$. By the concavity of $z(\cdot)$ and the monotonicity of $J(\theta)$ and $x_a(\theta,w)$ with respect to θ, Equation (5) implies that

$$dEZ > z'[J(\hat{\theta})] \int_{\underline{\theta}}^{\overline{\theta}} \{ x_a(\theta,w)dw + dF \}h(\theta)d\theta + \int_{\underline{\theta}}^{\overline{\theta}} z'[J(\theta)]\, wdx_a\, h(\theta)d\theta, \tag{6}$$

where $\hat{\theta}$ is implicitly defined by $x_a(\hat{\theta},w)dw + dF = 0$. By the concavity of $u(\cdot)$ and the monotonicity of $I(\theta)$ and $x_a(\theta,w)$ with respect to θ, Equation (4) implies that the first integral in Inequality (6) is positive. Since $w \leq 0$ and $dx_a \leq 0$, the second integral in Inequality (6) is non-negative. It follows that the right and, hence, left sides of Inequality (6) are positive. But this implies that the principal would be better off by raising w, a contradiction. Therefore, $w > 0$ with probability one in any equilibrium. **Q.E.D.**

Proof of Proposition 6: Suppose, counterfactually, that the profit-maximizing two-part tariff entails $w = 0$ and $F = F_o$. Then there must exist some θ_o such that $h(\theta_o) > 0$ and

$$\underset{x}{\text{maximum}}\ \{\theta_o - x - x_b(\theta_o,0)\}x - F_o = 0,$$

since otherwise the principal could increase profits by raising F.

Now raise w and lower F such that $x_a(\theta_o,0)\mathrm{d}w = -\mathrm{d}F > 0$. For infinitesimal changes, there is no change in the set of agent types who accept the contract. The change in the principal's expected profits is

$$\int_{\underline{\theta}}^{\overline{\theta}} \{x_a(\theta,0)\mathrm{d}w + \mathrm{d}F\}h(\theta)\mathrm{d}\theta > 0.$$

The inequality follows from the fact that $x_a(\theta,0) > x_a(\theta_o,0)$ for all $\theta > \theta_o$. Since $w = 0$ by hypothesis, there is no first-order effect on principal profits from the cutback in x_a induced by the rise in the wholesale price. If w were less than marginal cost, the cutback in x_a would raise principal profits by even more. Therefore, the equilibrium contract cannot entail a wholesale price that is less than or equal to marginal cost. **Q.E.D.**

Proof of Proposition 7: The proof is by construction. Suppose that the agent's beliefs are as follows. If the principal offers contract (w,F) with either $w = 0$ and $F = 0$, or $F > 0$, then the agent infers that the principal has observed $\theta = 0$. Otherwise, the agent infers that the principal has observed $\theta = \overline{\theta}$. The outside party believes that $w(\theta) = 2\theta/7$.

Given the agent's beliefs, a principal who observes θ can be thought of as choosing her contract offer to:

$$\underset{w,F}{\text{maximize}}\ F + wx_a(\theta,w,2\theta/7).$$

$$\text{subject to} \quad F \leq 0.$$

Since $x_a(\underline{\theta},w,\omega) = 0$ for all $w > 0$, there is no way for the low-θ to earn a profit given the agent's beliefs. Hence, offering the contract with $F = 0 = w$ does as well as any other. A high-θ principal clearly will set $F = 0$. As shown earlier in the proof of Proposition 4, the solution to the principal's problem entails $w(\theta) = 2\theta/7$.

Consider a deviation by the high-θ principal. By construction, the strategy played under the candidate equilibrium by a high-θ principal maximizes her profits subject to the constraint that the agent believes her to be a high-θ principal. And clearly the principal cannot gain from a deviation that induces her agent to believe that she actually is a low-θ principal. Hence, there is no profitable deviation from the candidate strategy given the agent's beliefs. It is evident that the agent and the outside party are playing sequentially rational strategies given their beliefs. All players' beliefs are confirmed along the equilibrium path. Therefore, there exists a perfect Bayesian equilibrium of the informed-principal example in which the equilibrium contracts are those described in the statement of the proposition. The equilibrium output levels are straightforwardly calculated. **Q.E.D.**

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