

Two Remarks on the Property-Rights Literature

ERIC MASKIN
Harvard University

and

JEAN TIROLE
IDEI, GREMAQ, CERAS and MIT

First version received May 1998, final version accepted October 1988 (Eds.)

We first point out that the recent property-rights literature is based on three assumptions: (1) that contracts are always subject to renegotiation; (2) that the exercise of a property right confers a private benefit and (3) that parties are risk-neutral. Building on Hart–Moore (1999), we provide conditions under which an optimal contract consists of nothing more than an assignment of property rights.

We also examine the robustness of some of the literature's standard predictions about asset ownership to the introduction of mechanisms for eliciting parties' *ex post* willingness to pay for the assets (such as options or financial markets). To illustrate the issue, we revisit the Hart–Moore (1990) proposition that joint ownership is suboptimal, and argue that ownership by a single party is dominated by joint ownership with put options.

1. INTRODUCTION

Since the seminal work of Grossman–Hart (1986) and Hart–Moore (1990) (see also Hart (1995)), a literature has developed on the allocation of property rights in economic organizations. The typical model in this literature, say that of Grossman and Hart, assumes that a buyer and a seller plan to trade a yet undefined good that will be produced with a physical asset. Before this good is produced—or even before its nature can be specified—the parties have the opportunity to invest in the relationship. The seller can reduce his production costs and the buyer can enhance the utility he will obtain from consumption. There are three ways ownership of the asset can be assigned *ex ante*: to the buyer, to the seller, or to both parties jointly. Single-party ownership entitles the party in question to use the asset to trade with an outsider. This is important because it is assumed that parties are always free to renegotiate the terms of any contract they have previously signed. In particular, they can renegotiate after their investments have already occurred. And so ownership of the asset strengthens a party's bargaining position in such *ex post* negotiations. This gives the owner greater incentive to invest in the relationship. Thus although the two parties will end up trading with one another rather than with other parties, ownership matters. Joint ownership, by contrast, prevents either party from using the asset for third-party trading without the other's permission—which will not be given.

In this paper we make two points. We first argue that the methodology employed in the property-rights models is no different from standard complete-contract-cum-renegotiation methodology, once one has assumed, as property-rights models in effect do, that asset ownership is equivalent to the ability of an owner to “consume” the asset by himself.

Property-rights models assume that the hypothetical trades with outsiders are noncontractible. Thus, formally, an asset owner's utility from trading with an outsider is equivalent to a private benefit he derives by consuming the asset. Therefore a property-rights model is structurally identical to a "bilateral monopoly" model (in the tradition of Hart–Moore (1988) and Aghion–Dewatripont–Rey (1994), say), in which the buyer and seller have no outside options and can contract on three sorts of trades (corresponding to no consumption, consumption by the buyer, and consumption by the seller).

Building on this simple observation, we provide a foundation for property-rights models. Hart–Moore (1998) and Segal (1995, 1999) have described bilateral monopoly environments with many potentially tradeable goods, in which (a) the buyer and the seller cannot trade with outsiders and so property rights are irrelevant (the private benefit from self-consumption is equal to zero), and (b) when the number of goods tends to infinity, the buyer and the seller cannot gain from a contractual relationship.¹

By design, the Segal and Hart–Moore models offer no scope for property rights. One may wonder, however, whether the arguments used to obtain these "no-contract results" can be used to derive circumstances in which the optimal contract consists merely of an assignment of ownership. For this to be the case, the introduction of "self-consumption" opportunities must not interfere with the logic of the no-contract results. We give conditions under which there is no such interference, and a focus on property rights alone is justified. In these environments, *the three assumptions driving the conclusion that property rights suffice are (i) parties' ability to renegotiate, (ii) the equivalence of outside opportunities to self-consumption of the asset, and (iii) parties' risk-neutrality.*² Thus we would maintain that *these* assumptions are the lynchpins of the property-rights literature, rather than the unforeseeability of future contingencies, which is often stressed in the literature.³

Although one can exhibit environments in which a focus on property rights is justified, optimal property rights need not be unconditional. Our second goal is to argue that, although the property-rights literature has provided valuable insights, its conclusions may not be robust to alternative ways of eliciting the parties' *ex post* willingnesses to pay for the assets. For example, call and put options on property rights as well as value measurements in financial markets can affect the optimal allocation of property rights.

To illustrate this point we consider a standard hold-up model of asset ownership, in which the property-rights model may not offer clear predictions about the pattern of ownership. More specifically, we reexamine Hart–Moore's (1990) well-known result that, in a buyer–seller relationship in which the parties invest in human capital, a single party should own both of a pair of complementary assets; ownership should not be divided. We show that the parties can actually attain the optimal, complete contracting outcome and raise their welfare relative to the single-owner contract by using a mechanism entailing more revelation of mutually-held information about asset value than is usually allowed in the literature. The optimal mechanism entails *joint* ownership and gives each party the opportunity to opt out at a prespecified price, with the further twist that a tax is then levied on the remaining owner and paid out to the community.

We then discuss the possibility of recontracting and collusion. It turns out that our joint-ownership contract achieves the optimum even if the buyer and the seller can recontract. On the other hand, it is not immune to the collusion between a party and the

1. See also Che–Hausch (1998) for a different result on the approximate optimality of the absence of contract.

2. Maskin and Tirole (1999) show that, if instead it is assumed that parties are risk-averse, the first-best can be obtained without the need to allocate property rights.

3. We do not claim that unforeseeability plays *no* potential role in property-rights foundations. It could, in principle, provide justification for assumptions (i) and (ii).

community. Although this sort of collusion seems unlikely, we also show that the simpler joint-ownership contract with options to sell one's share is optimal in the class of two-party contracts, which are by definition immune to collusion.

There is a close link between our point that optimal property rights need not be unconditional and the responses of Aghion *et al.* (1994), Chung (1991), Demski–Sappington (1991), Edlin–Hermalin (1997), Edlin–Reichelstein (1996), Hermalin–Katz (1993), Nöldeke–Schmidt (1995, 1996, 1997), Rogerson (1992) and Segal–Whinston (1997) to Hart–Moore (1988)'s bilateral monopoly model (which entails no property rights). These papers all argue that sophisticated and yet simple contracts can perform quite well (typically, yielding the first best) in this bilateral monopoly model. We make the same point for the property-rights literature.⁴ The analogy should not be surprising since, as we have already indicated, the property-rights model is formally similar to the bilateral monopoly literature.

For expositional ease, we take up the second point first. This is laid out in Section 2. Then Section 3 discusses foundations of the property-rights model.

2. CONDITIONAL PROPERTY RIGHTS

2.1. *A buyer–seller model*

The standard hold-up model (Williamson (1975, 1985)) has two risk neutral parties, a buyer and a seller, as well as a number of alternative competitive buyers and sellers to which the two parties can turn in case of dispute. There are two types of capital. First, there is a single physical asset, which is required for production (obviously, this is equivalent to the case of several, perfectly complementary physical assets that are all needed to produce). Second, each party invests in nontransferable “human capital,” that is, the seller learns how to use the physical asset efficiently and the buyer learns how to enhance the value he derives from the good produced by the asset. The alternative buyers and sellers, who are not part of the initial contract, do not invest in human capital.

The timing is as follows: At date 0, the buyer and the seller sign a contract; at date 1 they invest; at date 2 they observe each other's investment, and the seller may produce and sell one unit of a good that is valued by the buyer.

The seller's and buyer's investments in human capital, measured in monetary units, are denoted e_S and e_B , respectively. If the good is traded at date 2, the seller incurs cost $c(e_S)$ (decreasing in e_S), and the buyer receives value $v(e_B)$ (increasing in e_B). The outside opportunities can be described as follows: if the buyer takes possession of the physical asset and trades with an alternative seller, the latter incurs cost $c(0)$ (as he has not invested), whereas the buyer still obtains value $v(e_B)$: The original seller then has a zero payoff because the physical asset is indispensable for production. Similarly, if the seller takes possession of the physical asset and trades with an alternative buyer, the latter gets value $v(0)$ whereas the seller incurs cost $c(e_S)$. The original buyer then receives 0. We assume that $v(0) \geq c(0)$, and that the asset can be used only once. [In what follows, $v(e_B)$ and $c(e_S)$ could denote the expectations of random realizations of the value and cost, as long as all realizations of the difference between the valuation $\tilde{v}(e_B)$ and the cost $\tilde{c}(0)$ are positive, and similarly for the difference $\tilde{v}(0) - (\tilde{c}(e_S))$.] With no discounting, and provided that the buyer and seller trade with each other (which will always be the case on the equilibrium path) at some price p , the utilities are

$$u_S = p - c(e_S) - e_S \quad \text{and} \quad u_B = v(e_B) - p - e_B.$$

4. Indeed some of these papers use options (usually options to buy rather than to sell).

The efficient (first-best) investments, e_S^* and e_B^* , solve

$$\min \{c(e_S) + e_S\} \quad \text{and} \quad \max \{v(e_B) - e_B\}.$$

Neither investments nor *ex post* cost and value are verifiable by a court. Technically, they are “private benefits”. Nevertheless, if the good to be traded can be identified at date 0, it is straightforward to induce the efficient investments and thus obtain the first best: it suffices to specify in the contract that the seller will deliver one unit of the good and that the buyer will pay a fixed price \bar{p} , with a stiff penalty for anyone who does not abide by the agreement.

2.2. Property rights approach

Contract design becomes more complex if one does not know at date 0 the nature of the good to be traded at date 2. The previous fixed-price contract (or its generalizations to reflect variable quantities and uncertainty about preferences, see, *e.g.* Aghion *et al.* (1994) and Nöldeke–Schmidt (1995)) is no longer well-defined because it does not specify what sort of good the seller will deliver. The property-rights literature assumes that the only feasible contracts are *unconditional* ownership contracts; namely, the date-0 contract specifies that the physical asset belongs to the seller, to the buyer, or to both (in which case neither can use the physical asset to trade with an alternative partner without the other’s consent). The good to be traded is determined *ex post* through bargaining. We will adopt the widespread convention that bargaining leads parties to share the gains from trade equally (Nash bargaining).

Joint ownership, in this simple model, serves merely to prevent either party from exercising his outside option. That is, in the absence of trade, each party’s payoff is zero. Given Nash bargaining, the parties at date 2 split the *ex post* gains from trade, and each obtains $(v(e_B) - c(e_S))/2$ (gross of their investments). In other words, each party receives only 50¢ on each dollar of value enhancement or cost reduction. With such a low incentive, there will be underinvestment by both parties.

Under *buyer-ownership* (the case of seller-ownership is symmetric), the buyer can trade with an alternative seller at competitive market price $c(0)$ if the two parties do not agree on a trade. Although trade between the two parties is efficient and occurs on the equilibrium path, the outside opportunity affects the transfer price p ; equal division of the surplus implies

$$[v(e_B) - p] - [v(e_B) - c(0)] = p - c(e_S).$$

The buyer thus has net utility $u_B = v(e_B) - (c(e_S) + c(0))/2 - e_B$, and the seller has utility $u_S = (c(0) - c(e_S))/2 - e_S$. So, the buyer now has “full incentives” and chooses $e_B = e_B^*$, whereas half of the seller’s cost reduction is expropriated through bargaining, and so the seller invests the same amount as under joint ownership. Joint ownership is dominated because it precludes outside opportunities and therefore offers neither party further protection from expropriation.⁵

Remark. In the class of ownership contracts analyzed here, property rights matter only to the extent that there exist (viable) outside opportunities. For sufficiently high $c(0)$

5. Joint ownership may no longer be dominated by buyer- or seller-ownership if the parties’ investments improve the productivity of the assets (Hart (1995)). Also, even if the investments are in human capital, outside opportunities can be costly if the parties have a choice of specificity of the investment to the other party (Holmström–Tirole (1991)).

and low $v(0)$, there is no outside opportunity and so no way to improve on joint ownership in this class of contracts. Note also that because alternative partners are not part of the initial contract, ownership amounts to “self-consumption” of the asset, where self-consumption by the buyer gives him private benefit $v(e_B) - c(0)$, and self-consumption by the seller gives him private benefit $v(0) - c(e_S)$.

2.3. Option-to-sell contract

The issue in the buyer–seller model is how to induce both parties to invest efficiently. The determination of the good to be traded is not in itself difficult, because the good can be specified at date 2 through “bargaining” or “messages.” The following is a contract that incorporates elements from both the property-rights and implementation literatures.

Option-to-sell contract. The contract is registered with a court. There is joint ownership, and so neither party can use the asset without the consent of the other. At date 2, however, one party, drawn at random with equal probabilities, receives the right to sell his share in the joint venture at a pre-specified striking price. If selected, the seller has the right to sell his share in the joint venture at price $p_S = (v(e_B^*) - c(0))/2$. If selected, the buyer can sell his share at price $p_B = (v(0) - c(e_S^*))/2$. If a party exercises his exit option, the other party pays a tax t to the community of citizens. The two parties are otherwise free to bargain.

This simple contract achieves the first best if the tax is large enough (see below for “how large”). Efficient bargaining implies that, for given investments e_B , and e_S , the seller and buyer end up trading with each other and thereby realizing joint *ex post* surplus $v(e_B) - c(e_S)$, whether the physical asset ends up belonging solely to the buyer (when the seller exercises his right to sell), to the seller (when the buyer exercises his right to sell), or to both (when neither party exercises his right).

Suppose the buyer invests $e_B < e_B^*$. (Over-investment is clearly unprofitable.) We claim that the seller, if selected, exercises his option to sell regardless of the level e_S of his investment. By doing so the seller gets p_S plus (under Nash bargaining) half the surplus $[c(0) - c(e_S)]$ that is created when the buyer returns to the seller instead of trading with an alternative seller. So, the seller obtains

$$p_S + \left[\frac{c(0) - c(e_S)}{2} \right] = \frac{v(e_B^*) - c(e_S)}{2},$$

which because $v(e_B) < v(e_B^*)$ is more than his payoff $(v(e_B) - c(e_S))/2$ from not exercising. Hence, the seller exercises, and the buyer obtains

$$v(e_B) - c(e_S) - \left[\frac{v(e_B^*) - c(e_S)}{2} \right] - e_B - t.$$

On the other hand, the buyer can guarantee himself $(v(e_B^*) - c(e_S))/2 - e_B^*$ by investing $e_B = e_B^*$ (he then avoids inducing the seller to opt out). So, with probability $(1/2)$ (the probability that the seller is selected), the buyer loses more than t by investing $e_B < e_B^*$.

With probability $(1/2)$, the buyer is selected, and regardless of the level of e_S (that is, whether or not the buyer exercises his option to sell), choosing e_B rather than e_B^* raises the buyer’s utility by at most

$$A = \max_{e_B} \left(\frac{v(e_B)}{2} - e_B \right) - \left(\frac{v(e_B^*)}{2} - e_B^* \right).$$

So, for $t \geq A$, the buyer prefers investing e_B^* to any $e_B < e_B^*$. Symmetrically, e_S^* is better for the seller than any $e_S < e_S^*$.

The logic behind the optimality of the option-to-sell contract is straightforward. Exercising the option is advantageous if, and only if, the other party has underinvested. Hence the option deters underinvestment.

Remark. Hart (1995, ch. 4) shows that, in this model, an option-to-buy contract improves upon an unconditional ownership structure, although it cannot achieve the first best.

2.4. Collusion and renegotiation

Hart (1995, ch. 4) argues that contracts should be immune to collusion and to renegotiation. The allocation obtained on and off the equilibrium path in the option-to-sell contract is efficient. So, recontracting is not an issue. What about collusion? When $e_B < e_B^*$, say, then the buyer and the seller have an incentive to collude in order to avoid the tax t . They could share the gain from collusion and increase their utility by $t/2$ each. But this does not affect the conclusion: By choosing $t \geq 2A$, the buyer loses enough by putting himself in a situation of “blackmail,” so that he still prefers investing $e_B \geq e_B^*$. There of course remains the issue of collusion between a party and taxpayers; we have implicitly assumed that collusion with a large number of unknown parties (the taxpayers) is infeasible. And, indeed, although collusion is an important constraint in some circumstances, it appears rather unlikely in this case. One may wonder, therefore, why the sort of tax we proposed, which in this context makes economic sense, is rarely observed in practice. In our view, this is where bounded rationality or robustness considerations (and the concomitant fear of paying too much money to taxpayers) should enter. Indeed, without them, the current approach to property rights seems to *predict* the existence of such a tax in the sense that it arises naturally as a solution to underinvestment. In other words, ruling out the above option-to-sell contract strikes us as arbitrary given the other assumptions of the literature.

It is nevertheless worthwhile to examine what can be achieved in the presence of renegotiation by contracts that rule out penalties paid to third parties. We shall say that a contract that induces the buyer to choose e_B such that $b_B v'(e_B) = 1$ has “incentive power” b_B for the buyer. Similarly, it has power b_S for the seller if it induces the seller to choose e_S with $b_S c'(e_S) + 1 = 0$. Hence, a contract gives rise to a pair of powers (b_B, b_S) . For reference, the straight joint ownership contract has power pair $(0.5, 0.5)$, buyer ownership $(1, 0.5)$, seller ownership $(0.5, 1)$, and the above option-to-sell contract $(1, 1)$. Using results in Maskin and Moore (1999), it can be shown that the highest possible symmetric power pair for a two-party contract when renegotiation is possible is $(0.75, 0.75)$.⁶ That is, the parties can keep at most three-fourths of the value they create at the margin.⁷

Note, however, that this result does not make strong predictions about the ownership structure. Indeed, the power $(0.75, 0.75)$ can be obtained for example by an *ex post* randomization between buyer and seller ownership, or through the “option-to-sell contract without tax,” in which each party is allowed to opt out (at the prices specified above)

6. Here, as throughout Section 2, we are restricting attention to contracts in which an outcome is an assignment of property rights (although the assignment can be made contingent on messages that the parties send). In Section 3 we present an environment in which this restriction is justified.

7. This finding may appear to conflict with Hart (1995, appendix chapter 4), who gives an example in which parties can do better than this by making the assignment of property rights contingent on parties' messages. However, in this example, investment is a zero/one decision, whereas in our setting it is a continuous variable. This continuous formulation places many more constraints on what sophisticated mechanisms can achieve.

and a coin is tossed if both parties attempt to exercise this option. Although the randomized ownership contract sounds far-fetched in practice, there does not seem much reason to rule it out on theoretical grounds. Thus, a choice between these two contracts (or any other contract implementing power vector $(0.75, 0.75)$) must await the introduction of further considerations (asymmetric information, bounded rationality, *etc.*). It is difficult at this stage to make clear predictions about the choice between individual and joint ownership, even if one rules out penalties paid to taxpayers.

2.5. Discussion

The lesson we draw is that the predicted ownership structure may look quite different from the one emphasized in the property-rights literature when information revealed about asset value is used. We do not view this conclusion as negating the approach of the property-rights literature. Nor does it necessarily invalidate the conclusion that complementary assets should be owned by a single party. While opt-out contracts do exist in partnerships (without the tax provision, though), they are less common than straight ownership. Our aim is rather to offer the cautionary tale that straight ownership is not explained by the current property-rights methodology.

2.6. Relationship to the (no-property-rights) bilateral monopoly literature

To bridge this section and the next, let us relate the property-rights model to the literature on bilateral monopoly initiated by Hart–Moore (1988). The environment studied by Hart–Moore includes a buyer with *ex post* value function $V(q, \omega)$ and a seller with *ex post* cost function $C(q, \omega)$, where q is the level of trade of a given good⁸ (0 or 1, or else continuous), and ω is the date-2 state of nature. The probability distribution of this date-2 state of nature is determined by the buyer's and the seller's date-1 investments e_B and e_S , as in this paper. Thus in the absence of the third party payoffs are

$$u_S = p - C(q, \omega) - e_S \quad \text{and} \quad u_B = V(q, \omega) - p - e_B.$$

We now observe that the property-rights and bilateral monopoly models are essentially the same. In fact, the property-rights model can be viewed as a bilateral monopoly model in which the traded good is the asset, and there are three possible “levels” of trade that can be prescribed by a contract: $q = q_S$ (the good is owned, *i.e.* “consumed” by the seller), $q = q_B$ (the good is owned by the buyer), and $q = q_0$ (joint ownership). (Note that efficient trade cannot be specified by a contract). Once we take renegotiation into account, we can express the cost functions as

$$\begin{aligned} C(q_S, \omega) &= c(e_S) - \left[\frac{v(e_B) + v(0)}{2} \right], & V(q_S, \omega) &= \frac{v(e_B) - v(0)}{2}, \\ C(q_B, \omega) &= \frac{c(0) - c(e_S)}{2}, & V(q_B, \omega) &= v(e_B) - \left[\frac{c(0) + c(e_S)}{2} \right], \end{aligned}$$

8. This model also encompasses Segal (1999) and Hart–Moore (1999). In those models, q is a vector of 0–1 trades. So, for example $q = (0, 0, 1, 0, 0, \dots)$ means that they trade good number 3. Such versions do not exhibit the monotonicity properties of the others, and elicitation of preferences is much harder. Indeed, for the models considered by Segal (1999) and Hart–Moore (1999), the optimal complete contract cannot improve on the absence of contract when renegotiation is feasible.

and

$$C(q_0, \omega) = -\frac{v(e_B) - c(e_S)}{2}, \quad V(q_0, \omega) = \frac{v(e_B) - c(e_S)}{2}.$$

From this point on, the property-rights model can be viewed as a standard complete contract model in which all three levels of trade are efficient. And we can apply, as we did in this section, the standard insights that options, auction markets and other instruments can be used to elicit the preferences over the tradeable good (the assignment of ownership).

3. THE FOUNDATIONS OF PROPERTY-RIGHTS MODELS

As discussed in Section 2.6, the property-rights literature does not justify its exclusive focus on property rights. This section uses the “widget model” of Hart–Moore (1999) as a building block to provide such a justification. For expositional simplicity, we follow Hart and Moore’s Section 2’s assumption that only the seller invests; as in their Appendix, however, the conclusion generalizes to two-sided investment.

The Hart–Moore (1999) framework is a bilateral monopoly model with a risk-neutral buyer and seller. It is assumed that there is a large number of possible “widgets” that the seller could make, but that only one of these is “relevant” in the sense that its value exceeds its cost. The model assumes that the seller’s *ex post* cost for the “relevant widget” is random (as we have observed, randomness does not affect the property-rights model, in which only the expected values matter). The cost of producing the relevant widget is either c_1 or $c_2 > c_1$. An increase in the seller’s investment e_S increases the probability $x(e_S)$ of realization c_1 .

There are N widgets. All widgets are *ex ante* identical. *Ex post* the widget which turns out to be the relevant one has cost c_i ($c_i = c_1$ or c_2) and deterministic value $v > c_2$ for the buyer. Each of the $N - 1$ other widgets has equal cost and value (and thus generates no social surplus if traded). The costs of these other widgets are $c_1 + (\Delta/N)$, $c_1 + (2\Delta/N)$, \dots , $c_1 + ((N - 1)/N)\Delta$, where $\Delta \equiv v - c_1$. The state of nature is defined by both the realization of c_i and by the mapping τ from widgets to costs and values. All permutations are equally likely.⁹

Consider this buyer–seller model with the additional possibilities (which, as we have discussed, correspond to seller and buyer ownership) that S could make a widget for his own consumption (this would give him benefit av and cost him ac_i , where $i = 1$ or 2 and $a < 1$), or that B could make a widget for his own consumption (this would give him benefit v and cost bc_2 , where $b > 1$). Only one widget can be produced overall. Let us suppose that renegotiation entails splitting surpluses equally.

Let us suppose first that no contracts are possible. Then there are three possible arrangements: (i) S owns the widget-machine (so that he can make a widget for his own consumption); (ii) B owns the widget-machine, or (iii) joint ownership (equivalent to no trade).

Under (i), the seller’s threat point is

$$a(v - c_i),$$

9. This assumption implies welfare neutrality of the optimal contract (see Maskin–Tirole (1999) for the definition of welfare neutrality).

and so, after renegotiation, his payoff is

$$\frac{1}{2}(1-a)(v-c_i) + a(v-c_i) = \frac{1}{2}(1+a)(v-c_i). \quad (1)$$

Under (ii), the seller's threat point is 0 and so, after renegotiation, his payoff becomes

$$\frac{1}{2}(v-c_i). \quad (2)$$

Finally, under (iii) the seller's threat point is a constant, as in case (ii). Hence, case (iii) does not differ from (ii) with respect to the seller's incentives.

Clearly, case (i) is the best arrangement for incentives. In that case, the seller makes prior investment e_s to maximize

$$\frac{(1+a)}{2}(v-x(e_s)c_1 - (1-x(e_s))c_2) - e_s,$$

with first-order condition

$$x'(e_s) \frac{(1+a)}{2}(c_2 - c_1) = 1. \quad (3)$$

We will now show that no contract can improve on the incentives obtained from simply assigning ownership to S (case (i)), at least when N is large.

As in Hart-Moore, let state $(1, \tau)$ correspond to the case where good 1 is the special widget (with cost c_1), good 2 has cost (and value) $c_1 + (\Delta/N)$, ..., and good N has cost (and value) $c_1 + ((N-1)/N)\Delta$. State $(2, \tau^*)$ corresponds to the case where good 1 has cost (and value) $c_1 + (\Delta/N)$, good 2 has cost (and value) $c_1 + (2\Delta/N)$, ..., good $N-1$ has cost (and value) $c_1 + ((N-1)/N)\Delta$, and good N is the special widget with cost c_2 .

A contract can be thought of as a game form or mechanism, the outcome of which depends on players' strategies. Consider a contract in which, when parties play their equilibrium strategies in states $(1, \tau)$ and $(2, \tau^*)$, the prices of the special widgets are $p(1, \tau)$ and $p(2, \tau^*)$, respectively. Now suppose that the buyer plays the equilibrium strategy corresponding to $(2, \tau^*)$ and that the seller plays the equilibrium corresponding to $(1, \tau)$. Let q be the expected price paid by the buyer in the corresponding outcome. In that outcome, let α_i ($i = 1, \dots, N$) be the probability of good i , with $\alpha = \sum_i \alpha_i$. Let β be the probability of no trade, and let γ be the probability that the seller is assigned the widget-machine.

Now, in state $(2, \tau^*)$, the seller's payoff (when B plays his equilibrium strategy for $(2, \tau^*)$ and S plays his equilibrium strategy for $(1, \tau)$) will be renegotiated to

$$\begin{aligned} & q - \alpha_1 \left[c_1 + \frac{\Delta}{N} - \frac{1}{2}(v - c_2) \right] \\ & - \alpha_2 \left[c_1 + \frac{2\Delta}{N} - \frac{1}{2}(v - c_2) \right] \\ & \vdots \\ & - \alpha_{N-1} \left[c_1 + \frac{N-1}{N}\Delta - \frac{1}{2}(v - c_2) \right] \\ & - \alpha_N c_2 \\ & + \beta \left[\frac{1}{2}(v - c_2) \right] \\ & + \gamma \left[\frac{1}{2}(a+1)(v - c_2) \right] \leq p(2, \tau^*) - c_2, \end{aligned} \quad (4)$$

where the inequality follows from the fact, in state $(2, \tau^*)$ the seller can be no worse off from playing his $(2, \tau^*)$ -equilibrium strategy than from any other strategy.

In state $(1, \tau)$, the outcome from B playing his $(2, \tau^*)$ -equilibrium strategy and S playing his $(1, \tau)$ -equilibrium strategy will be renegotiated to

$$\begin{aligned}
 & q - \alpha_1 c_1 \\
 & - \alpha_2 \left[c_1 + \frac{\Delta}{N} - \frac{1}{2}(v - c_1) \right] \\
 & \vdots \\
 & - \alpha_N \left[c_1 + \frac{N-1}{N} \Delta - \frac{1}{2}(v - c_1) \right] \\
 & + \beta \left[\frac{1}{2}(v - c_1) \right] \\
 & + \gamma \left[\frac{1}{2}(a+1)(v - c_1) \right] \geq p(1, \tau) - c_1,
 \end{aligned} \tag{5}$$

where the inequality follows from the fact that renegotiation outcomes are Pareto-efficient, so what the seller gets when the buyer uses his $(1, \tau)$ -equilibrium strategy can be no better than what he gets when the buyer uses his $(2, \tau^*)$ -equilibrium strategy. From (4) and (5), we obtain

$$p(2, \tau^*) - p(1, \tau) \geq \left(1 - \frac{(\alpha + \beta)}{2} - \frac{\gamma(\alpha + 1)}{2} \right) (c_2 - c_1) - \frac{\alpha}{N} \Delta + \frac{\alpha_1(v - c_1)}{2} + \frac{\alpha_N(v - c_2)}{2}.$$

But, given any permutation $\hat{\tau}^*$, the same lower bound can be obtained for states $(2, \hat{\tau}^*)$ and corresponding state $(1, \hat{\tau})$. Therefore, since all permutations are equally likely, we obtain

$$p(2) - p(1) \geq \left(1 - \frac{(\alpha + \beta)}{2} - \frac{\gamma(\alpha + 1)}{2} \right) (c_2 - c_1) - \frac{\alpha}{N} \Delta. \tag{6}$$

where $p(i)$, $i = 1, 2$, is the expected price of the special widget when its cost is c_i . Now the seller's incentive problem is

$$\max_{e_s} (1 - x(e_s))(p(2) - c_2) + x(e_s)(p(1) - c_1) - e_s.$$

Hence

$$x'(e_s)[p(1) - p(2) + (c_2 - c_1)] = 1. \tag{7}$$

From (6) (ignoring $(\alpha/N)\Delta$ which will be small if N is large), we obtain from (7)

$$x'(e_s) \left[\frac{(\alpha + \beta)}{2} + \frac{\gamma(1 + a)}{2} \right] (c_2 - c_1) \leq 1. \tag{8}$$

But the left-hand side of (8) is at most as big as the left-hand side of (3) (when $\alpha = \beta = 0$ and $\gamma = 1$).

This shows that, when the number of goods is large, the parties cannot improve on an unconditional assignment of ownership.

Acknowledgements. The authors are grateful to Oliver Hart, Jean-Jacques Laffont, John Moore, and a referee for helpful discussions and comments. Section 3 of this paper owes much to the recent paper by Hart and Moore (1999).

REFERENCES

- AGHION, P., DEWATRIPONT, M. and REY, P. (1994), "Renegotiation Design with Unverifiable Information", *Econometrica*, **62**, 257–282.
- CHE, Y. K. and HAUSCH, D. (1998), "Cooperative Investments and the Value of Contracting: Coase vs. Williamson", *American Economic Review* (forthcoming).
- CHUNG, T. Y. (1991), "Incomplete Contracts, Specific Investments, and Risk Sharing", *Review of Economic Studies*, **58**, 1031–1042.
- DEMSKI, J. and SAPPINGTON, D. (1991), "Resolving Double Moral Hazard Problems with Buyout Agreements", *Rand Journal of Economics*, **22**, 232–240.
- EDLIN, A. and HERMALIN, B. (1997), "Contract Renegotiation in Agency Problems" (Mimeo, University of California, Berkeley).
- EDLIN, A. and REICHELSTEIN, S. (1996), "Holdups, Standard Breach Remedies, and Optimal Investment", *American Economic Review*, **86**, 478–501.
- GROSSMAN, S. and HART, O. (1986), "The Costs and Benefits of Ownership: A Theory of Lateral and Vertical Integration", *Journal of Political Economy*, **94**, 691–719.
- HART, O. (1995) *Firms, Contracts, and Financial Structure* (Oxford: Oxford University Press).
- HART, O. and MOORE, J. (1988), "Incomplete Contracts and Renegotiation", *Econometrica*, **56**, 755–785.
- HART, O. and MOORE, J. (1990), "Property Rights and the Nature of the Firm", *Journal of Political Economy*, **98**, 1119–1158.
- HART, O. and MOORE, J. (1999), "Foundations of Incomplete Contracts", *Review of Economic Studies*, **66**, 115–138.
- HERMALIN, B. and KATZ, M. (1993), "Judicial Modification of Contracts between Sophisticated Parties: A More Complete View of Incomplete Contracts and their Breach", *Journal of Law, Economics and Organization*, **9**, 230–255.
- HOLMSTRÖM, B. and TIROLE, J. (1991), "Transfer Pricing and Organizational Form", *Journal of Law, Economics and Organization*, **7**, 201–228.
- MASKIN, E. and MOORE, J. (1999), "Implementation and Renegotiation", *Review of Economic Studies*, **66**, 39–56.
- MASKIN, E. and TIROLE, J. (1999), "Unforeseen Contingencies and Incomplete Contracts", *Review of Economic Studies*, **66**, 83–114.
- MOORE, J. (1992), "Implementation in Environments with Complete Information", in Laffont, J. J. (ed.), *Advances in Economic Theory* (Cambridge: Cambridge University Press) 182–282.
- NÖLDEKE, G. and SCHMIDT, K. (1995), "Option Contracts and Renegotiation: A Solution to the Hold-Up Problem", *Rand Journal of Economics*, **26**, 163–179.
- NÖLDEKE, G. and SCHMIDT, K. (1996), "Debt as an Option to Own in the Theory of Ownership Rights", in Picot, A. and Schlicht, E. (eds.) *Firms, Markets and Contracts* (Heidelberg: Physica) 1–17.
- NÖLDEKE, G. and SCHMIDT, K. (1997), "Sequential Investments and Options to Own" (Mimeo, University of Bonn).
- ROGERSON, W. (1992), "Contractual Solutions to the Hold-up Problem", *Review of Economic Studies*, **59**, 577–793.
- SEGAL, I. (1995) *Essays on Commitment, Renegotiation, and Incompleteness of Contracts* (PhD thesis, Harvard University).
- SEGAL, I. (1999), "Complexity and Renegotiation: A Foundation for Incomplete Contracts", *Review of Economic Studies*, **66**, 57–82.
- SEGAL, I. and WHINSTON, M. (1997), "The Mirrlees Approach to Implementation with Renegotiation (with Applications to Hold-Up and Risk-Sharing)" (Mimeo).
- WILLIAMSON, O. (1975) *Markets and Hierarchies: Analysis of Antitrust Implications* (New York: Free Press).
- WILLIAMSON, O. (1985) *The Economic Institutions of Capitalism* (New York: Free Press).