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Abstract

This paper investigates conditions under which market contracting can, despite contractual incompleteness and renegotiation, ensure efficient investment in relationship specific assets when trade is a continuing process (as in employer-employee and long-term supply relationships), not the one-off event studied previously. It considers two cases, one with investments by only one party, the other with investments by both parties. The latter suggests an interpretation of Joskow's observations of long-term coal contracts. The analysis has implications for the ownership of assets, for which party should undertake specific investments, and for the design of damage measures for breach of contract.

I. Introduction

Many economic relationships benefit from investment in relationship specific assets or skills that make the value of continuing the relationship greater than the market alternatives available to the parties involved. Employment relationships may benefit from specific training and from employees relocating near their work place. Trade in intermediate goods may benefit from suppliers and purchasers buying equipment specially adapted to the needs of the other. As Marshall (1920) noted, the division of such quasi-rents is generally determined by bargaining.[1] But bargaining over these quasi-rents can lead to inefficient levels of specific investments. Once one party has made a specific investment, there is potential for the others to bargain away some of the return to that investment because they have become essential for that return to be generated. And if the investing party does not capture all the return from the investment, the level of investment will not in general be efficient, see Grout (1984).

Complete long term contracts can, as Becker (1975) recognized, overcome this inefficiency but there are good reasons why such contracts cannot always be used in practice.[2] Klein, Crawford and Alchian (1978) and Williamson (1985) regard the resulting inefficiencies as a major reason for taking such relationships out of the market context and organizing them within institutions (for example, firms), thus providing a theory of the extent and structure of firm organization. Grossman and Hart (1986) and Hart and Moore (1988b) have developed this into a theory of ownership of assets.

In this paper we argue that market contracting can, despite incompleteness,

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[1]On page 626, Marshall (1920) discusses the notion of a *composite quasi-rent* of a firm and on the following page states "there is nothing but bargaining to decide the exact shares in which the excess of its incomings over its outgoings for the time should be divided between employers and employed."

[2]Hart and Moore (1988a) have emphasized two. First, specifying all the relevant contingencies in a way that is enforceable in court may be difficult. In particular, the extent of the specific investments undertaken may be difficult for a court to verify. Second, a contract can always be renegotiated by mutual consent – the parties involved can agree to tear it up and, if they wish, replace it with an alternative contract. Anticipation of this acts as a further constraint on drafting because the parties know that certain provisions they might make in a contract would never in fact be carried out. Other recent papers concerned with incomplete long term contracts are Crawford (1988), Farrell and Shapiro (1989), Huberman and Kahn (1988) and Tirole (1986).

ensure efficient investment in relationship specific assets under much wider conditions than is generally thought provided some rudimentary long term contracts are enforceable. We are concerned with the economically important situation in which trade between the parties is potentially a continuing process, not just a one-off event. Examples of this, for instance employer-employee and long term supply relationships, are widely discussed in this literature. We study two cases, both with only two parties involved. In the first, the relationship specific investments are all made by one party. In that case, essentially all that is required from the long term contract is that it can specify enforceable payments conditional on whether the parties trade with each other, do not trade with each other, or break off the relationship by committing themselves to other partners. In effect, courts need only to be able to verify who actually trades with, or works for, who. Though not always possible, that is, in our view, a rather weak requirement that should be satisfied in many practical examples.

In our second case, both parties may make relationship specific investments but, for any given trading price, these investments yield benefits only to the party making them. Examples of such investments are a firm that gets all the productivity gains from training a worker as long as the worker does not get an increased wage as a result of training and a public utility that gets all the returns from building a rail line to a mine mouth as long as the pithead price it pays for coal is not thereby increased. We call investments of this type "self investments". Not all specific investments are self investments. A firm may pay removal expenses to an employee. At any given wage, it is the employee who benefits from that. An employee may think hard of ways to improve productivity in a factory which merely increase profits unless the employee gets a wage rise. In the case in which both parties make self investments, efficient levels of investment can be achieved even when the levels of investment are not themselves contractible but it requires rather more of the long term contract than where only one party makes specific investments.

Our results derive from a precise analysis of the opportunities that parties to a continuing relationship have open to them. For attaining efficient investment in the first of our cases, it is important that the non-investing party be able to break off the relationship and trade elsewhere. Thus the availability of opportunities outside the relationship is central. This is the opposite of Rogerson (1984) and Shavell (1984) in which it is the need for the parties to be free to break off the relationship when separation is efficient that is seen as an important reason for the level of investment being inefficient. It is also the opposite of other implementation and contracting problems (see, for example, MacLeod and Malcomson (1989)) in which the opportunity for agents to opt out hinders, rather than helps, the achievement of efficiency.

This analysis has a number of implications. One concerns ownership. Consider the example of slavery. Slavery prevents the slave opting out of the relationship with the slave owner. Unless the slave owner can always achieve what Williamson calls consummate performance from the slave, the absence of that opportunity reduces the incentive for efficient specific investment by the slave owner. For this reason slavery may be an inefficient form of ownership when specific investments are important. A similar argument can be applied to ownership of one firm by another. A second implication concerns the behaviour of wages. Becker (1975) suggested that the presence of firm specific human capital would result in a rising wage/tenure profile to reduce quits. Abraham and Farber (1987) and Altonji and Shakotko (1987) find no such tenure effects. Our analysis shows that, if all the specific investments are made by the firm, a contract to induce efficient investment would have the employee earning a wage equal to the market wage outside the relationship, which is entirely consistent with those findings. Another implication concerns which party should undertake specific investments when that is something they can chose. In our framework, achieving efficiency requires less from a long term contract if all specific investments are made by one party. This has implications for whether the coal mine or the public utility invests in the railway that links he two. A final implication of our results concerns, in the spirit of Shavell (1980, 1984) and Rogerson (1984), the design of provisions for breach of contract. We discuss this in detail later.

For the case of one party investments, Hart and Moore (1988a) also show that efficient levels of investment can be achieved with incomplete contracts. In their model, however, the scope for bargaining over the quasi-rents is limited by their assumption that trade is valuable only if it takes place at a particular date. Any delay destroys all the potential gains from trade. Delay is therefore a credible threat only for a party that would be worse off trading under the original contract than not trading at all and then that party has all the bargaining power. If neither loses from trade under the original contract, there is no renegotiation. There is thus not the same kind of sharing of the ex post gains from trade that occurs in, for example, a standard Rubinstein (1982) bargaining model in which each party can impose a cost on the other by delaying agreement without in the process completely destroying the potential gains from an agreement in the future. This assumption of Hart and Moore (1988a) is appropriate for certain economic contexts but it does not fit many of the examples that have been of concern in the literature. In particular, in employer-employee relationships and long term supply relationships delay does not typically destroy all the potential gains from trade. Moreover, unlike Hart and Moore, our result for this case is not limited to specific investment of the type we have called "self investment". It therefore covers a wider class of economically important situations.[3]

The second case we study is motivated by Joskow's (1988) observations concerning long term contracts for coal. Joskow found that in many cases contracts had long duration but, over their lifetime, the trading price was adjusted to reflect outside events (in particular observable changes in variables affecting costs), with the result that the price at which trade actually occurred did not get too far out of line with spot market prices. In the case in which both parties make specific investments of the self investment type, we show the following result. If the observable variables enable a long term contract to ensure that whenever it is efficient for trade to occur the price is not renegotiated, then the investments will be at the efficient level even though those

[3]Other recent papers that extend results in Hart and Moore (1988a) are Aghion, Dewatripont and Rey (1989) and Emons (1989). Neither study trading relationships that are potentially long term, rather than once-off.

levels do not themselves form part of the contract.

The essence of our argument is quite intuitive. It has to do with the way opportunities outside the relationship affect bargaining within it. We therefore devote the next section of the paper to a discussion of bargaining in continuing relationships with outside options. The remainder of the paper develops these ideas more formally.

II. Bargaining in Continuing Relationships and Outside Options

Consider a buyer and a seller for some product who can each period decide either to trade or not to trade one unit of the good. The value of trade to the buyer and/or the seller can be increased by investment in a specific asset. Suppose it is the seller who makes this investment. The essence of the argument for the seller's choice of investment being inefficient is as follows. Once she has made an investment, the value of trade is increased. Even if there is a long term contract that fixes the trading price, a buyer who can credibly refuse to trade can use that to bargain for a renegotiation of the contract and thus a share of that increase in value. Shavell (1984), Rogerson (1984), Williamson (1985), and Green and Laffont (1989) assume he will get some of it. If he does, the seller does not get all the returns from the investment and her choice of investment will not in general be efficient.

When trade is a one-off event and bargaining over the gains from trade is a standard alternating offers Rubinstein (1982) bargaining game, any increase in the gains results in the buyer getting some of that increase. There are, however, two reasons why that need not be true in more general models. First, if trade is a continuing process and if the buyer and the seller have agreed to a contract before the investment is made, it does not necessarily follow that a refusal to renegotiate by the seller will result in the buyer actually refusing to trade under the original contract. The contract may make it in his interest to trade at least for the period until the next offer is made. But anticipation of that will affect the seller's decision about whether to agree to renegotiation. If she knows the buyer will trade anyway under the original contract, she will refuse to renegotiate knowing that trade will still take place. That can go on for ever.

That in itself may not be enough to prevent the buyer getting some of the returns from the specific investment. Events can happen that make it unprofitable for the buyer to trade under the original contract. That is where the second reason comes in. At the trading stage, after the specific investment has been made, there are in fact 3 trading possibilities the buyer and the seller can contemplate at each point in time. Each can decide to trade at the contract price if the other will (we call this the T option), not to trade for the moment at the contract price (the N option), and to break off the relationship in such a way that the value of the specific investment is destroyed (the O, or outside, option). The crucial analytical difference between the N and the O options is that the N option retains the possibility of benefiting from the specific investment by trading in the future while the O option does not.

Some examples may make the practical difference clear. Suppose the specific investment is the transactions cost involved in an employee moving to a location near his workplace. The N option corresponds to refusing to work for the employer but staying in the same house (and possibly getting a job with another employer in the locality). The O option corresponds to taking a job in a different locality and moving house. If the O option is taken, the value of the specific investment is zero from then on. For the seller of an intermediate good, the N option corresponds to not trading this period or to selling this period's output on the spot market. The O option corresponds to making a long term contract to supply the output to another buyer. Again, if the O option is taken, the value of the specific investment becomes zero.

This distinction is important analytically because the values of the N and the O options affect the bargaining outcome in different ways. We know from Shaked and Sutton (1984) and Sutton (1986) that, in a standard Rubinstein bargaining model with alternating offers, the value of the N option acts as a status quo point. The payoff each agent would get from the game if no O option were available would be his or her status quo value plus some share of the additional gains from the relationship. So, if no O option were available, any increase in the gains from the relationship over and above the status quo values that results from additional specific investments will be shared between the agents. However, the value of the O option (at least in the form it takes in the present paper) affects an agent's payoff from the relationship only if it is greater than the value he or she would get in the absence of that option. It acts simply as a constraint on how low an agent's payoff can be. Thus, if one agent's payoff is equal to the value of the O option, the increase in the gains from the relationship that results from additional specific investment will, at the margin, all go to the other agent.

Since this is fundamental to our results it is worth emphasizing the rationale for it. Suppose the seller makes an offer to the buyer that is worth more than the buyer's O option. When deciding whether or not to accept that offer, the buyer will certainly not refuse and choose his O option instead because doing so would ensure that he could never get more than the value of his O option. Thus the seller never needs to take seriously the threat that the buyer will choose his O option rather than accept an offer that gives a higher payoff. It is not credible. That threat cannot, therefore, be used to lever more of the quasi-rent out of the seller. In contrast, the threat that the buyer will use the N option can be credible as a means of getting more than the value of the N option because it always leaves open the possibility of reaching agreement to share the gains from the relationship at a later date.

The model in the present paper does not generate a standard Rubinstein bargaining game because trade can be a continuing process, not just a once-for-all sharing of a pie. But exactly the same principles apply to outside options. From this, it is straightforward to see how the existence of an O option enables the choice of specific investment to be efficient in the case in which only one party makes an investment. Suppose the seller makes the investment. All the buyer and the seller need to do is to agree a long term contract that ensures that the buyer does better from the O option than from the other options. That can be achieved by a breach payment from the seller to the buyer that is sufficiently large relative to the payments under the other options. (It is only the relative sizes of the payments that matter for this purpose.) Then, when it is efficient that no trade take place, the buyer will take his outside option. When it is efficient that trade take place, the seller and the buyer will renegotiate the trading price with the buyer receiving the value of his O option. But the value of the O option is, by definition of that option, independent of the level of the specific investment. Thus any increase in the gains from the relationship that results from the seller investing will go entirely to the seller. That will generate the efficient level of investment.

It is clear that a symmetric argument works if it is the buyer who makes the specific investment instead of the seller. It should also be noted that the argument works even if the seller's investment benefits the buyer directly, that is, it is not solely what we have called a "self investment". It is the buyer's total payoff that is given by the outside option. Thus, the more the buyer benefits directly from the seller's investment, the lower will be the trading price negotiated, leaving the buyer's payoff unchanged.

A related argument explains what is required for a long term contract to achieve efficient investments in the case in which both parties make investments of the self investment type. To induce efficient investments, we need each party to get all the returns from his or her own investment. With self investments, that will be the case provided the price at which trade actually takes place is independent of the level of the investments. If it were never efficient to separate then, in view of the argument above, a fixed price with breach only by mutual consent would ensure this. But, for reasons discussed in Rogerson (1984), such a contract will induce inefficient investment if it is ever efficient to separate. If, on the other hand, either party can separate unilaterally then, at a fixed price, there will be circumstances (a very high or very low price on the outside market, for example) in which one party would prefer to exercise the O option rather than continue the existing contract. Suppose a high outside market price makes the seller prefer the O option to the current contract. It may still be efficient that the relationship continue – if, for example, the buyer would still buy at the outside market price. Then the contract will be renegotiated with the seller receiving the value of her O option. But the value of that option is independent of the seller's specific investment. Thus renegotiation will result in the buyer getting the return from the seller's investment. Anticipation of this will also induce inefficient investment.

What a long term contract must do to prevent this is to ensure that, in all contingencies in which it is efficient that the relationship continue, the trading price is such that neither party prefers the O option. If the price can be made contingent on enough relevant variables to ensure this, then the levels of investment chosen by the parties will be efficient. Note that the contingent price has nothing to do with risk aversion. It acts simply to keep the parties' payoffs within the bounds of their O options. That is a possible interpretation of the coal contracts analyzed by Joskow (1988).

The remainder of this paper demonstrates these results formally. Section III sets out the model. Sections IV and V analyze the bargaining game played after the specific investments have been made. Section VI establishes the efficiency result for one sided specific investments. Section VII does this for the case of two sided self investments. Section VIII discusses some further implications of our results.

III. The Model

A buyer b and a seller s negotiate a contract for the long term supply of a good at the rate of either one unit or no units at each date. This is Stage I. We will specify precisely what aspects of a contract are enforceable when we deal with each of the different cases we consider. Roughly, the enforceable aspects will be a price for the good if trade occurs and penalties for breach of contract. The level of relationship specific investments made by either the buyer or the seller is, however, never part of the legally enforceable contract. As discussed in Hart and Holmström (1987), this can be because of the high cost of verifying the levels of these investments in court, or because of the complexity involved in specifying what these investments should be. We assume that there is no third party to act as a residual claimant.[4]

At Stage II, once the contract is signed, each agent chooses specific investments. There are potentially four types of specific investments. The buyer can make an

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[4]Given the way agents renegotiate in our model, the ex post agreement will always be ex post efficient. Thus, even if the contract required payments to a third party, the agents would ex post always agree to rescind them. See Eswaran and Kotwal (1984) for more on this.

investment that increases his own payoff at a given trading price. He can also make an investment that increases the seller's payoff at a given trading price. These will be denoted I_{bb} and I_{bs} respectively. Similarly, the seller can make an investment that increases her own payoff, and an investment that increases the buyer's payoff, at a given contract price. These are denoted I_{ss} and I_{sb} respectively. All investments are chosen from the interval $[0, \bar{I}]$, where $\bar{I}$ is a positive constant. For notational convenience, let $I_b = \{I_{bb}, I_{sb}\}$ and $I_s = \{I_{bs}, I_{ss}\}$, and denote the complete vector of investments by $I = \{I_b, I_s\} \in \mathcal{I} = [0, \bar{I}]^4$.

For examples of these different types of investments, consider a labour contract in which the buyer is the employer and the seller is an employee. The investment I_{ss} corresponds to a specific investment by the employee that raises her utility in the job. This might be the transactions costs in moving house close to the workplace or in making friends among co–workers. Leaving the job reduces the value of these. The investment I_{bs} might be that part of moving costs reimbursed by the employer or a subsidy for buying a new house. These are expenditures that do not directly affect the productivity of the worker in the firm. The investment I_{bb} corresponds to the cost of specific training incurred by the firm. Finally, I_{sb} corresponds to specific training costs incurred by the employee or efforts made by the employee to come up with ways of improving productivity in the job. Other examples arise in the case of supply of intermediate goods.

It is not hard to see why it may be difficult to write an enforceable contract contingent on the level of many of these investments. Monitoring the effort put into forming friends, finding a suitable house, or coming up with suggestions for improving productivity has obvious difficulties. So does verifying the value to the firm of any such improvements. It is with investments for which enforceable contingent contracts are not made that the problem of inducing efficient levels of investment is serious. We therefore assume that contract clauses contingent on the levels of any of these specific investments are not enforceable.

The choice of the level of investments is followed (at Stage III) by a realization of a state of nature that determines both the value of the relationship to the two parties, and the value of their alternative opportunities. The state is given by $\sigma = (\theta, \nu, \mu) \in [\underline{\theta}, \overline{\theta}] \times [\underline{\nu}, \overline{\nu}] \times [\underline{\mu}, \overline{\mu}] \equiv \Sigma$. The parameter θ represents shocks to the value of continuing the relationship, while ν and μ are the values (measured in flows per unit of time) of the outside options of the buyer and seller respectively. At this stage both the state of nature and the investment levels become common knowledge to the two agents. A complete description of the state of the relationship at the end of Stage III is thus given by $\omega \equiv (I, \sigma) \in \Omega \equiv \mathcal{I} \times \Sigma$.

Assumption 1: $\underline{\nu}, \underline{\mu} > 0$ and the distribution of σ is a measure $\chi(\cdot)$ on Σ that is independent of I.

Once the agents have observed the state of the world and the level of relationship specific investments, trade may begin. At this stage (Stage IV), the agents may if they wish renegotiate the terms of the contract signed at Stage I. We treat trade as a flow in continuous time and, for convenience, label the start of Stage IV as $t = 0$. In contrast to Hart and Moore (1988a), we suppose that renegotiation can occur at any time while trade is (or is not) taking place until such time as one of the agents decides to terminate the relationship permanently by taking up an outside option. During negotiations, agents can decide to supply the good or not under the terms of any previously agreed contract, or to break off the relationship by choosing an outside option. Thus, the contract signed at Stage I acts as a default contract until a new contract is agreed. In principle, the new contract can also be renegotiated and acts as a default until a further contract is agreed.

The sequence of events is illustrated in Figure 1.

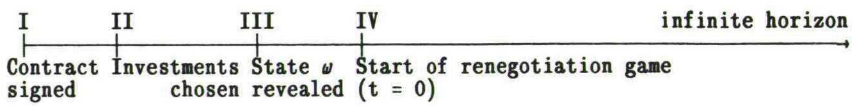

FIGURE 1: EXCHANGE GAME

The money value of the utility of the good to the buyer at any date at which trade takes place is denoted $v(I_b, \theta)$, the money cost to the seller of supplying the good $u(I_s, \theta)$.

Assumption 2: For all $\omega \in \Omega$, there exist positive constants $k \geq l > 0$ such that $v(I_b, \theta) \in [l, k]$ and $u(I_s, \theta) \in [-k, -l]$. Furthermore, for each $\theta \in \Theta$, $v(I_b, \theta)$ and $u(I_s, \theta)$ are differentiable in I_b and I_s.

The requirement that $v(I_b, \theta)$ is strictly positive and $u(I_s, \theta)$ strictly negative ensures that, at a zero price, the buyer would always prefer trade to no trade and the seller would always prefer no trade to trade. That is, the buyer gets utility from the good and the seller incurs a cost in supplying it. For notational convenience we sometimes write these money values as $v(\omega)$ and $u(\omega)$ (that is, as functions of the state ω) without however implying that I_s, ν and μ affect $v(\cdot)$ or I_b, ν and μ affect $u(\cdot)$. Assumption 2 also ensures that the gains from trade are bounded.

Since the state ω is common knowledge when the renegotiation game is played, the outcome of the complete exchange game will in general be a function of this state. An outcome of the renegotiation part of the game can be represented in the following way. Let $t^i(\omega)$ denote the time at which the outside option is taken by agent i for state ω, ($t^i(\omega)$ could be infinite), $p(t, \omega)$ the payment made by the buyer to the seller at time t, and $\tau(t, \omega) \in \{0, 1\}$ be 1 if trade takes place at time t and 0 if it does not. Then $z(\omega) = \{p(\cdot, \omega), \tau(\cdot, \omega), t^b(\omega), t^s(\omega)\}$ defines an outcome of the renegotiation game given state $\omega \in \Omega$. Let $t^*(\omega) = \min\{t^b(\omega), t^s(\omega)\}$. Then the ex post payoffs to the buyer and seller respectively from playing the renegotiation game are

$$(3.1a)\qquad V[\omega, z(\omega)] = \int_0^{t^*(\omega)} [\tau(t, \omega)v(I_b, \theta) - p(t, \omega)]e^{-rt}dt + \{e^{-rt^b(\omega)}\nu - e^{-rt^*(\omega)}p[t^*(\omega), \omega]\}/r$$

$$(3.1b) \qquad U[\omega, z(\omega)] = \int_0^{t^*(\omega)} [\tau(t, \omega)u(I_s, \theta) + p(t, \omega)]e^{-rt}dt + \{e^{-rt^s(\omega)}\mu + e^{-rt^*(\omega)}p[t^*(\omega), \omega]\}/r,$$

where r is the common discount rate of the two parties. We assume the agents are risk neutral. To calculate the ex ante payoffs at the time the investments are made for any given ex post outcome function $z(\cdot)$, we take the expected value of the ex post payoffs over all states and deduct the costs of the investments. These ex ante payoffs are

$$(3.2a) \qquad \hat{V}[I, z(\cdot)] = -I_{bb} - I_{bs} + \int_{\sigma\in\Sigma} V[\omega, z(\omega)]\, d\chi(\sigma)$$

$$(3.2b) \qquad \hat{U}[I, z(\cdot)] = -I_{sb} - I_{ss} + \int_{\sigma\in\Sigma} U[\omega, z(\omega)]\, d\chi(\sigma).$$

Since utility is transferable in this model, the total ex post surplus from the renegotiation part of the game is well defined and given by

$$(3.3) \qquad S(\omega) = \max\{v(I_b, \theta) + u(I_s, \theta), \nu+\mu\}.$$

The maximum ex ante surplus at the beginning of the relationship from choosing efficient levels of investments is given by

$$(3.4) \qquad S^* = \max_{I\in\mathcal{I}} \int_{\sigma\in\Sigma} [S(\omega)/r]d\chi(\sigma) - \sum_{i,j\in\{b,s\}} I_{ij}\,.$$

Obviously we are concerned only with the case $S^* > E\{\nu+\mu\}/r$ as otherwise specific investment is unnecessary for efficiency. We denote by I^* efficient levels of investment that solve (3.4). We assume that these investment levels are all either zero or in the interior of $\mathcal{I}$.

IV. The Renegotiation Game

To determine the outcome function $z(\cdot)$ for the renegotiation game, we need to specify in detail the rules of that game. We assume it is an infinite horizon bargaining game with the first offer made at $t = 0$ and subsequent offers following at time intervals of Δ. We keep the game as symmetric as possible while allowing for potentially different bargaining strengths. At time $n\Delta$, where n is zero or an even integer and P_{n-1} is the contract in force at the start of period n, the following sequence of moves occurs if the relationship has not previously been terminated.

(n.0) Either the buyer or the seller is given the opportunity to offer a new contract, with probabilities π and $1-\pi$ respectively, where $\pi \in (0, 1)$.

(n.1) The agent chosen in step n.0 offers a new contract, denoted $\tilde{P}_n$.

(n.2) The responding agent chooses the action $y_n \in \{A, R, AO, RO\}$, where the action A is accept the new contract and continue the game, the action R is reject the new contract and continue the game, the action AO is accept the new contract but terminate the game by choosing an outside option, and the action RO is reject the new contract and terminate the game by choosing an outside option. If A or AO is chosen, $P_n = \tilde{P}_n$. If R or RO is chosen, $P_n = P_{n-1}$. Choosing the outside option is an irreversible decision to terminate the relationship under the conditions of the contract P_n and receive payoff at rate μ (for the seller) or ν (for the buyer) thereafter.

(n.3) If A or R was chosen in step n.2, the buyer chooses his trading action $x_n^b \in X \equiv \{T, N\}$, where T is an offer to trade, and N a refusal to trade, under the terms of the contract P_n.

(n.4) If A or R was chosen in step n.2, the seller chooses her trading action $x_n^s \in X$.

If A or R is chosen in step n.2 and both players choose T, trade occurs until $(n+1)\Delta$. If one player chooses N, then no trade occurs until $(n+1)\Delta$. In both cases, the game proceeds at $(n+1)\Delta$ with the above sequence of moves repeated.

The extensive form of the game for negotiating round n is illustrated in Figure 2.

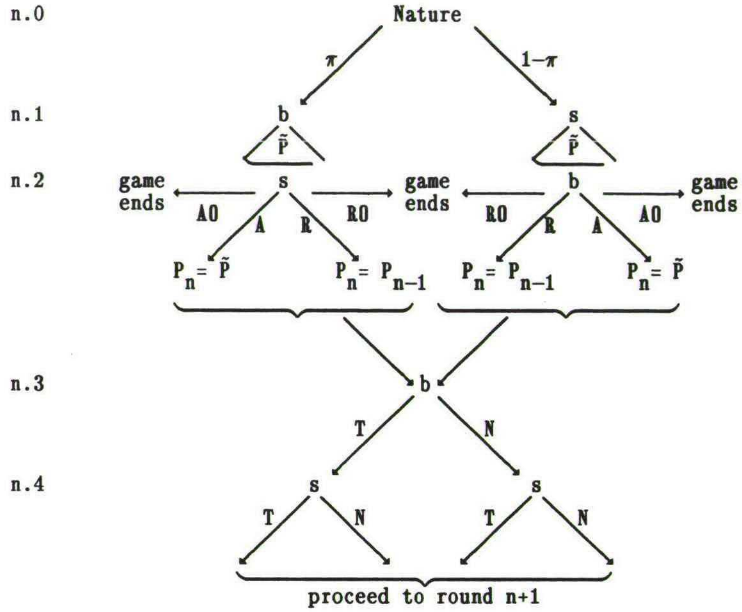

FIGURE 2: ROUND n OF RENEGOTIATION GAME

There are two ways in which the game is not completely symmetric. First, the probability of the buyer and of the seller having the opportunity to offer a new contract need not be the same. Differences in this provide a convenient way to parameterize the relative bargaining strength of the two agents. Second, in choosing trading strategies, the buyer moves first. In fact, for generic games, this second asymmetry has no effect on the set of equilibria.

Note that at each stage only the agent accepting or rejecting the offer of a new contract has the opportunity to terminate the game by taking up an outside option. As Shaked (1988) has shown, the timing of such opportunities is important. The present game corresponds to what Shaked (1988) calls a "bazaar", in which the move that precedes one party having the opportunity to take up an outside option allows the other to make a new offer. That seems to us the appropriate way to model the kind of long term relationship discussed here.

The important distinction between the N option and the NO option is that the latter destroys the value of the specific investments for ever after. The N option merely results in their yielding no return for a period of length Δ, but leaves open the possibility of returns from them after that. There is a similar distinction between the A and the AO options. Note also that a renegotiated contract can in principle be renegotiated again so that steps 0 to 4 are repeated for ever unless a player chooses to terminate the game.

A contract specifies the payments that must be made by the buyer to the seller for each verifiable event that occurs while it is in force. In the spirit of the incomplete contracts literature discussed in the Introduction, we assume that the verifiable events are whether or not trade occurs and whether or not the relationship has been terminated but, in the latter case, not which party decides to terminate it and in the former, not which party refused to trade if no trade occurred. A contract can thus be denoted by a vector $P = \{p^i\}$, for $i \in \{T, N, O\} \in \mathbb{R}^3$, where p^T is the payment made if trade occurs, p^O the payment made if the relationship is terminated, and p^N the payment made if no trade occurs but the relationship is not terminated. We place no restrictions on the signs or magnitudes of these. In the case of a renegotiated contract, the state ω is common knowledge to the buyer and seller at the time the contract is agreed so there is no need for the contract provisions to depend explicitly on the state. In the case of a contract agreed at Stage I, the payments specified cannot be contingent on the level of specific investments, nor on θ, nor on whether a party accepts or rejects any contract offered subsequently (the A and R choices made in step 2 above). In one of the cases we deal with below the payments can be conditional on the values of the outside options ν and μ but, since this will be clear from the context, we do not make that explicit in the notation.

Our first result establishes that, for any contract in force at $t = 0$, there exist unique Markov perfect equilibrium payoffs to the buyer and the seller in the renegotiation game (Stage IV) and characterizes those payoffs for the case in which the bargaining frictions become negligible in the sense that the time Δ between successive offers goes to zero. The essence of a Markov perfect equilibrium is that strategies are conditioned only on payoff relevant information, see Maskin and Tirole (1988). In the present game, the payoff relevant information is the contract currently in force at each stage of the game. This is captured in the following formal definition.

Definition: A Markov perfect equilibrium of the renegotiation game is a subgame perfect equilibrium with the property that the equilibrium payoffs at the beginning of period n depend only on n and on the contract P_{n-1} in force at the start of period n.

Note that this definition does not imply that a Markov perfect equilibrium is stationary, only that past actions affect the equilibrium through the contract agreed.[5]

Proposition 1: For any contract $P = \{p^T, p^N, p^O\}$ in force at $t = 0$, there exist (generically) unique Markov perfect equilibrium payoffs to the buyer and the seller in the renegotiation game. The limiting payoff to the buyer as $\Delta \to 0$, $V^*(\omega, P)$, is as follows.

Case (i): $v(\omega)+u(\omega) > \nu+\mu$ and either $v(\omega)-p^T \leq -p^N$ or $u(\omega)+p^T \leq p^N$.

$$(4.1)\ rV^*(\omega, P) = \begin{cases} \tau S(\omega)-p^N, & \text{if } \tau S(\omega)-p^N > \nu-p^0 \text{ and } (1-\tau)S(\omega)+p^N > \mu+p^0; \\ \nu-p^0, & \text{if } \tau S(\omega)-p^N \leq \nu-p^0; \\ S(\omega)-\mu-p^0, & \text{if } (1-\tau)S(\omega)+p^N \leq \mu+p^0. \end{cases}$$

Case (ii): $v(\omega)+u(\omega) > \nu+\mu$ and both $v(\omega)-p^T > -p^N$ and $u(\omega)+p^T > p^N$.

[5]It is worth emphasizing that, if the renegotiation game is taken to be a finite horizon (rather than an infinite horizon) game, Proposition 1 remains true when the term "subgame perfect equilibrium" is substituted for "Markov perfect equilibrium". In many respects, a finite horizon is the natural way to model the type of relationship studied here. For that case, however, the proofs are much more complicated, which is why we have restricted the present discussion to the infinite horizon case. Even for this case, the unique Markov perfect equilibrium is efficient and any distribution of the ex post surplus can be attained as a Markov perfect equilibrium by appropriate choice of contract. Thus the players lose nothing by restricting themselves to Markov strategies. In effect, the Markov property simply ensures that there can never be any ambiguity about which subgame perfect equilibrium will be played once the contract has been agreed.

$$(4.2)\ rV^*(\omega, P) = \begin{cases} v(\omega)-p^T, & \text{if } v(\omega)-p^T \geq \nu-p^0 \text{ and } u(\omega)+p^T \geq \mu+p^0; \\ \nu-p^0, & \text{if } v(\omega)-p^T < \nu-p^0; \\ S(\omega)-\mu-p^0, & \text{if } u(\omega)+p^T < \mu+p^0. \end{cases}$$

Case (iii): $v(\omega)+u(\omega) \leq \nu+\mu$.

$$(4.3) \qquad V^*(\omega, P) = (\nu-p^O)/r.$$

In each case, the payoff to the seller, $U^*(\omega, P)$, is

$$(4.4) \qquad U^*(\omega, P) = S(\omega)/r - V^*(\omega, P).$$

The proof of this proposition is given in the appendix. To understand the nature of the proposition and its relation to the existing literature on equilibrium in bargaining games, it is instructive to start by considering case (i). In that case, trade is efficient because $v(\omega)+u(\omega) > \nu+\mu$ but, because either $v(\omega)-p^T < -p^N$ or $u(\omega)+p^T < p^N$, one party loses by trading under the contract P and so trade will not take place unless that contract is renegotiated. Thus a refusal to trade acts as a credible threat point in bargaining over the renegotiation and in that bargaining each party receives a payoff equal to the value of the threat point ($-p^N$ to the buyer, p^N to the seller) plus a share of the surplus $S(\omega)$ that depends on their relative bargaining powers π and $1-\pi$, provided this payoff exceeds the value of his or her outside option after allowing for the payment p^O. This is the equilibrium outcome given by (4.4) and the top line of (4.1). If these payoffs give one party less than the value of his or her outside option then, because trade is efficient, the contract is renegotiated to give that party an equilibrium payoff equal to the value of his or her outside option and the other party receives the rest of the surplus. These are the outcomes given by (4.4) and the two lower lines of (4.1). Thus, as in Sutton (1986), the outside options act only as constraints on the set of feasible allocations, not as a status quo in the Nash bargaining sense. Next consider case (iii). With $v(\omega)+u(\omega) \leq \nu+\mu$, trade is no longer better than no trade, so the parties break up the match with each receiving the value of his or her outside option after allowing for the payment p^O.

So far, the equilibrium payoffs have a form similar to those in a bargaining game concerning a once-off division of a pie. The important difference that results from trade being a continuing process is case (ii). In case (ii), trade is efficient and it is in the interests of both parties to trade even if the contract P is not renegotiated. This makes a refusal to trade by one party no longer a credible threat because, if the other calls his or her bluff, the first party would do better to choose trade rather than no trade. Thus, unless one party or the other does better by choosing the outside option, neither will succumb to a threat by the other not to trade and the payoffs under the contract P will not be renegotiated. This is the equilibrium outcome given by (4.4) and the top line of (4.2). The lower two lines of (4.2) give the equilibrium payoffs for the cases in which one or the other outside option is binding. Again as in Sutton (1986), these options act only as constraints on the set of feasible allocations, not as a status quo in the Nash bargaining sense. By including case (ii), therefore, Proposition 1 extends the standard results for equilibrium in bargaining games to the situation in which trade is potentially a continuing (not just a once-off) process and there already exists a contract under which, in the absence of renegotiation, trade can take place.

The "generic" qualification to the uniqueness of the equilibrium payoffs in Proposition 1 applies to the situation that falls between case (i) and case (ii). If $v(\omega)-p^T = -p^N$ and $u(\omega)+p^T > p^N$, the buyer is indifferent between trading and not trading under the contract P, while the seller strictly prefers trade. In this case both "trade" and "no trade" are equilibrium outcomes and they generate different equilibrium payoffs. The same applies to the case $v(\omega)-p^T > -p^N$ and $u(\omega)+p^T = p^N$. However, the cases $v(\omega)-p^T = -p^N$ and $u(\omega)+p^T = p^N$ are non-generic and agents can always select the contract P in such a way that this situation occurs with probability zero. For concreteness, we assume that, when one agent is indifferent, no trade occurs. In what follows we restrict attention to the limiting game as $\Delta \to 0$ for which an explicit solution is given in Proposition 1. Essentially the same results as in Sections VI and VII below apply to the non-limiting games but the proofs are much more messy.

V. Equilibrium With No Contract Ex Ante

In this section we consider what happens if the buyer and the seller do not make a long term contract at Stage I before they decide on the levels of the specific investments. Without an ex ante contract no payments are required in Stage IV unless the parties agree to a new contract. Having no ex ante contract is, therefore, equivalent to having a contract, denoted by $P^0 \in \mathbb{R}^3$, that specifies $p^i = 0$ for $i \in \{T, N, O\}$. Then, since $u(\cdot) < 0$, both agents must agree to a new contract at the beginning of stage IV specifying a strictly positive price for the good before the seller will agree to trade, so case (ii) of Proposition 1 never occurs. The following result then follows directly from Proposition 1.

Proposition 2: Consider the following 4 cases:

Case 1: $v(\omega)+u(\omega) \leq \nu + \mu$;

Case 2: $v(\omega)+u(\omega) > \nu + \mu$ and $\pi S(\omega) \in (\nu, S(\omega)-\mu)$;

Case 3: $v(\omega)+u(\omega) > \nu + \mu$ and $\pi S(\omega) \leq \nu$;

Case 4: $v(\omega)+u(\omega) > \nu + \mu$ and $\pi S(\omega) \geq S(\omega)-\mu$.

If no contract is agreed between the buyer and the seller at Stage I, their respective equilibrium payoffs, $V^*(\omega, P^0)$ and $U^*(\omega, P^0)$, from the limiting renegotiation game are given by

$$(5.1) \qquad rV^*(\omega, P^0) = \begin{cases} \nu, & \text{in cases 1 and 3,} \\ \pi S(\omega), & \text{in case 2,} \\ S(\omega) - \mu, & \text{in case 4,} \end{cases}$$

$$(5.2) \qquad rU^*(\omega, P^0) = S(\omega) - rV^*(\omega, P^0).$$

Note that case 1 occurs when separation is efficient. Case 2 occurs when trade is efficient and the outside options are not binding. Cases 3 and 4 occur when the outside options for the buyer and for the seller, respectively, are binding.

It is straightforward to see from Proposition 2 that, in the absence of an ex ante contract, the specific investments chosen will not in general be efficient. If, for example, case 2 occurs with probability 1, the buyer and the seller simply share the surplus generated by the investments in proportions π and $(1-\pi)$ and we know from Holmstrom (1982) that such a sharing rule is not efficient. For the present model, it follows immediately from (3.3) that efficient levels of investment must satisfy $\partial[S(\omega)/r]/\partial I_{ij} = 1$ for all i, j $\in$ {b, s}. But it is also immediate from (5.1) that, when case 2 occurs with probability 1, the buyer will choose his investment so that his marginal benefit $\partial[\pi S(\omega)/r]/\partial I_{bb} = 1$, which is inefficient. Similarly, the seller will choose her investment so that $\partial[(1-\pi)S(\omega)/r]/\partial I_{ss} = 1$, which is also inefficient. Since in no case does the investor's private return from investment exceed the social return, this inefficiency will persist whenever case 2 occurs with positive probability.

There are two other cases in which it is straightforward to see that the levels of investment will be inefficient in the absence of an ex ante contract. Whenever case 3 occurs, the buyer gets no return on any investment he makes. Thus, if it is efficient that he should invest and if case 3 occurs with positive probability, he will invest too little. Similarly, whenever case 4 occurs, the seller gets no return on any investment she makes. Thus, if it is efficient that she should invest and if case 4 occurs with positive probability, she will invest too little.

These remarks apply to the case in which there is no long term contract agreed ex ante between the buyer and the seller. The remaining sections of this paper examine the way in which long term contracts can overcome some of the inefficiencies.

VI. Efficient One Party Investment

In this section we show that, in the case in which one party makes all the relationship specific investments, the existence of an outside option ensures that the level of those investments will be efficient. This is the case that has received most attention in the literature. The papers by Shavell (1980, 1984) and Rogerson (1984) study the relative efficiency of different types of damage measures for breach of contract for this case. Both Rogerson (1984) and Shavell (1984) explicitly consider the possibility of renegotiation. Although they find that the type of damage measure affects efficiency, they are unable to find any measure that results in the first best.

The essential point is that the existence of an outside option allows the construction of a contract that gives the investing party all the returns to the investments. We analyze the case in which the buyer makes the investments. The case in which the seller makes the investments is entirely symmetric.

Assumption 3: The efficient investment levels satisfy $I^*_{ss} = I^*_{sb} = 0$.

In Hart and Moore (1988a) and the other literature cited above, it is assumed that all specific investments are of the "self investment" type, which is equivalent to assuming I^*_{bs} is also zero. That is not, however, necessary for efficiency.

Proposition 3: Let Assumption 3 be satisfied and let V^* and U^* be any pair of numbers satisfying $V^* + U^* = S^*$, where S^* is the efficient ex ante surplus defined in (3.4). Then there exists a contract P which, agreed upon at Stage I, results in unique equilibrium payoffs in the exchange game of V^* to the buyer and U^* to the seller.

Proof: Define the contract $P = \{p^T, p^N, p^O\}$ by

$$\begin{aligned} E\{\mu\} + p^O &= rU^*, \\ u(\omega) + p^T &< \underline{\mu} + p^O, \\ (1-\pi)S(\omega) + p^N &< \underline{\mu} + p^O. \end{aligned} \tag{6.1}$$

Then from Proposition 1, whichever case applies,

$$V^*(\omega, P) = [S(\omega) - \mu - p^O]/r. \tag{6.2}$$

For cases (i) and (ii) of Proposition 1, this is immediate. For case (iii), it follows from the fact that $S(\omega) = \nu+\mu$ for this case. Thus the buyer's ex ante payoff $\hat{V}[I, z(\cdot)] = E\{S(\omega)/r\} - U^* - I_{bb} - I_{bs}$. It then follows from Assumption 3 and the definition of S^* in (3.4) that investment levels that maximize the buyer's ex ante payoff generate total ex ante surplus S^* and thus that the buyer's unique ex ante payoff is $S^*-U^* = V^*$. ▮

Efficiency is possible in this case because of the existence of an outside option for the seller. The long term contract used in the proof ensures that the seller's outside option is binding in all states of the world. The seller's payoff is thus always equal to the value of her outside option. Since the value of that outside option is independent of the level of investments undertaken by the buyer, the seller is unable to bargain away any of the returns on those investments. Thus the buyer gets all the returns and therefore invests efficiently. If the seller does all the investment instead of the buyer, a precisely symmetric argument works.

The contract used in the proof is actually rather simple, despite the large number of contingencies that would be required for a contract to be complete in the technical sense. In effect, it requires only three levels of payment to be specified, one if trade between the parties takes place, a different payment if either the buyer or the seller commits to trading with an outside party instead, and a third if neither of those occurs. Moreover, since only the relative sizes of these payments matter for incentive purposes, the contract can always be designed so that they are all positive or all negative, with an appropriate side payment at Stage I to achieved any desired distribution of gains. Thus the contract can always ensure that payments for breach are to be made by whichever party courts can most easily force to pay.

That contract is very different in design from those implicit in the discussion of legal remedies for breach of contract. The standard legal remedies of expectation damages, reliance damages, restitution damages and specific performance, are intended to compensate the party who makes specific investments (reliance expenditures, in the legal terminology) when the other agent refuses to trade on the terms originally agreed.[6] The contract used here is designed, in contrast, to ensure that the noninvesting party would never lose by refusing to trade on the terms originally agreed. By doing that, it ensures that the noninvesting party cannot capture any of the returns to

[6]Briefly, the different damage measures are as follows. Expectation damages make the defaulting party pay an amount that puts the other party in the position he would have been in had the contract been performed. Reliance damages require the defaulting party to compensate the other party for his relation specific investments (reliance expenditures) and to return all previous payments. Restitution damages require the defaulting party to return only the payments that have been made between the contracting parties. Specific performance requires the transaction to be carried out on the original terms if at least one party wishes.

the investment.

The original contract is, of course, never intended to be actually carried out. It will always be renegotiated to ensure that trade takes place if that is efficient. Indeed, the trading price will always be renegotiated upwards if it is the buyer who makes the investments. Despite the fact that this may look like the seller exploiting the buyer's irrevocable investment in the relationship, it is actually a central part of inducing the buyer to choose the efficient level of investment. Our model therefore provides cases in addition to the ones discussed by Huberman and Kahn (1988) in which actual, not just potential, renegotiation plays a non–trivial role in improving resource allocation.

There are in fact some cases in which efficient investment can be achieved even in the absence of a long term contract.

Proposition 4: Let Assumption 3 be satisfied and let V^* and U^* be any pair of numbers satisfying $V^* + U^* = S^*$, where S^* is the efficient ex ante surplus defined in (3.4). Then, if cases 2 and 3 in Proposition 2 occur with probability zero for all possible investments, the ex ante payoffs of V^* and U^* for the buyer and seller respectively can be attained as equilibrium payoffs in the limiting exchange game even if no long term contract is possible.

Proof: If cases 2 and 3 of Proposition 2 never occur, then with no long term contract $U^*(\omega, P^0) = \mu$. Therefore the buyer always receives the full returns from any investment. Since the renegotiation game always ensures ex post efficiency, the investment chosen by the buyer will thus also be efficient. Moreover, V^* and U^* can be achieved by a single payment from the buyer to the seller at Stage I with value equivalent to $U^*-E\{\mu\}/r$ at date 0. ∎

One situation in which cases 2 and 3 of Proposition 2 never occur is when π is close to (though not necessarily equal to) 1 so that the buyer has almost all the bargaining power in the renegotiation. Then, since $\mu > 0$, case 4 of Proposition 2 applies whenever $v(\omega)+u(\omega) > \nu+\mu$.

It is instructive to compare the implications of Proposition 4 with Becker's (1975) discussion of firm specific investments in labour markets. Suppose the seller is a worker, the buyer a firm providing specific training, and μ the wage in a competitive labour market. With a competitive labour market the firm will never offer the worker an ex ante payoff greater than $U^*= E\{\mu\}/r$ in date 0 value. When cases 2 and 3 of Proposition 2 occur with probability zero then, in the absence of a contract, the worker will get only a payoff of μ/r, either by taking a job outside the firm at wage μ if separation is efficient or by negotiating a wage μ with the firm if it is not. Thus the firm gets all the returns from the specific training and, by Proposition 4, investment in this will be efficient. Thus, as noted by Becker (1975), if the firm makes the investment and collects all the returns, the level of specific training it chooses will be efficient.

Where this result differs from Becker (1975) is over what happens when there is a possibility of labour turnover. To reduce quits, Becker suggests that the firm share some of the relationship specific rents with the worker. This would result in a rising wage/tenure profile. The studies by Altonji and Shakotko (1987) and Abraham and Farber (1987) claim, however, that tenure per se does not affect the wage once one corrects for worker characteristics and experience. That is what Proposition 4 implies, despite the presence of specific investments by the firm and endogenous turnover.

VII. Efficiency with Self Investment by Both Parties

In some cases efficiency requires both parties to make specific investments. Then the existence of outside options is, in contrast to the previous case, no longer a sufficient condition for efficient investment. In this section we consider the case in which each agent makes an investment that, for a given trading price, affect his or her own payoff only, what we have called a "self investment". In the case of employment this corresponds to the firm investing in specific training for the employee at the same time as the employee incurs transactions costs in moving to a home located close to the job.

Our results here are motivated by Joskow's (1987, 1988, 1989) observations concerning long term contracts for coal. Joskow observed that about 70% of the coal contracts in his data involved long term agreements ranging in duration from one year to fifty years, the duration being related to the level of relationship specific assets. In Joskow (1988), he studied the nature of the pricing agreement for contracts with duration longer than four years. He found that most contracts specified not a fixed price, but a price adjusted over time according to changes in certain external circumstances (in particular, the input prices, productivity and actual costs faced by the supplier) that kept the actual price paid from deviating too far from the spot market price.

If the parties can diversify enough to be risk neutral, such escalator clauses are not necessary for risk sharing purposes. Presumably they also increase the complexity of writing and administering contracts. Moreover, fixed price contracts have desirable incentive properties with specific self investments because they ensure each party gets the returns from his or her own self investments when trade takes place at that price. However, as Shavell (1980, 1984) and Rogerson (1984) have shown, fixed price contracts run into problems if there are conditions under which it is efficient for the relationship to end. A contract can allow for separation decisions to be made in either of two ways. It can allow each party to decide unilaterally to separate or it can require that they both agree before separation can occur. But both ways have adverse incentive effects. If both parties must agree to a separation (a specific performance requirement), separation will occur only if the gainer compensates the loser. But then the loser gets a private return on his or her specific investment even when there is no social return on it because the relationship ends. This corresponds to Rogerson's result that specific performance induces over investment. On the other hand, if either party can unilaterally decide to separate, there will in general be circumstances (a high value of the outside option ν or μ) in which one party would do better from separation than from continuing to trade at the fixed price even when it is efficient for the relationship to continue. Suppose it is the seller's outside option μ that is high. The buyer and the seller will of course renegotiate the contract so that the relationship continues but the seller will receive only her outside option payoff μ from the renegotiation. Thus the buyer will capture some of the return on the seller's self investment. Anticipation of this ex ante will have an adverse incentive effect on the level of investment. To ensure efficient investment, the parties need to design a contract such that (i) neither has a binding outside option except when it is efficient that they should separate, and (ii) neither can use the N option as a credible threat to renegotiate the trading price.

We show that, under appropriate conditions, it is possible for them to do that if the long term contract can be conditioned on ν and μ even when the investment levels themselves, and the random variable θ that determines the returns to the investments, are not contractible. This can, moreover, be done without the need for payments for breach of contract. The last property could be important in practice. Joskow suggests that large breach payments are difficult to enforce and, particularly in the case of public utilities, the authority to make advance commitment to them questionable.

Suppose θ can take on only two values, a "good" value θ_g and a "bad" value θ_b, such that in the good state trade between the buyer and the seller is always efficient, whereas in the bad state it is never efficient. The good state might be the normal state of affairs for the long term relationship, the bad state an unlikely event, such as war or a major accident at one of their facilities affecting their ability to carry out the contract. In the bad state the value of continuing the relationship is lower than that of choosing the outside option (which might, for example, be bankruptcy for one of the parties). This, along with the assumption that only self investment is efficient, is captured in the following assumption.

Assumption 4: The efficient investment levels satisfy $I^*_{sb} = I^*_{bs} = 0$ and I^*_{ss}, I^*_{bb} > 0. Moreover, $v(0, \theta_g) + u(0, \theta_g) \geq \nu + \mu$, for all $(\nu, \mu) \in A(\theta_g)$, and $v(I^*, \theta_b) + u(I^*, \theta_b) \leq \nu + \mu$, for all $(\nu, \mu) \in A(\theta_b)$, where $A(\theta) = \{(\nu, \mu) \mid (\theta, \nu, \mu) \in \text{supp}\ \chi\}$.

The next proposition is concerned with the case in which the ex ante contract can be made conditional on (ν, μ). In the case of coal, ν and μ depend on, for example, the spot market price for coal and the price of other factors of production, which may be readily verifiable. The levels of the specific investments and the value of θ, however, remain non–contractible.

Proposition 5: Let Assumption 4 be satisfied and let V* and U* be any pair of

numbers satisfying $V^* + U^* = S^*$, where S^* is the efficient ex ante surplus defined in (3.4). Then there exists a contract $P(\nu, \mu)$ which, agreed upon at Stage I, results in unique equilibrium payoffs in the limiting exchange game of V^* to the buyer and U^* to the seller. Furthermore, if side payments are permitted at Stage I, this contract does not require penalties for breach.

Proof: Define the contract $P(\nu, \mu) = \{p^T(\nu, \mu), p^N, p^O\}$ by $p^N = p^O = 0$ and $p^T(\nu, \mu)$ such that $u(0, \theta_g)+p^T(\nu, \mu) \geq \mu$, and $v(0, \theta_g)-p^T(\nu, \mu) \geq \nu$. This is always possible because of Assumption 4. Note that, in the good state, $v(\omega)+u(\omega) > \nu+\mu$ for all feasible investment levels and, since $\nu, \mu > 0$, case (ii) of Proposition 1 always applies under the contract $P(\nu, \mu)$. Moreover, $P(\nu, \mu)$ is defined in such a way that the outside options never bind in the good state so the payoff to the buyer in that state is given by the top line of (4.2). In the bad state, case (iii) of Proposition 1 applies and the payoff to the buyer from the renegotiation game is at the rate ν. The ex ante payoff to the buyer defined in (3.2a) will therefore be

$$\hat{V}[I, z(\cdot)] = -I_{bb} + r^{-1} \int_{\sigma \in \Sigma} \{\tau(\omega)[v(I_{bb}, \theta) - p^T(\nu, \mu)] + [1-\tau(\omega)]\nu\} d\chi(\sigma),$$

where $\tau(\omega)$ is 1 if trade is efficient and 0 otherwise. It is a straightforward exercise to check that the level of investment maximizing $\hat{V}[I, z(\cdot)]$ is efficient. A symmetric argument for the seller establishes that under $P(\nu, \mu)$ there will be efficient investment by both parties in equilibrium. To obtain the payoffs V^* and U^* one sets the side payments appropriately at the time of signing the contract $P(\nu, \mu)$ in Stage I. If up front payments are not permitted, then one need only modify each element of $P(\nu, \mu)$ by the same fixed amount to make the ex ante payoffs V^* and U^*. ▮

The intuition underlying this result is simply that in those states in which it is efficient for trade to occur, it is important that the trading price not depend on the levels of the specific investments. On the other hand, when separation is efficient, one of the parties needs actually to take up an outside option. A long term contract is necessary to ensure that the trading price is not influenced by the levels of the specific investments. If there were no contract in force, the payoffs in the renegotiation game would be those given in Proposition 2. When, for example, case 4 of that proposition occurs, the outside option for the seller is binding, the seller receives only the payoff μ/r and consequently receives no return on her investment. Indeed, there is always an inefficiency if the outside option is binding for either party in circumstances in which it is efficient for trade to occur. Assumption 4 ensures that it is possible to set breach conditions such that the outside option is binding if and only if separation is efficient.

What Proposition 5 highlights is the importance of designing a contract whose conditions do not depend on the relation specific investments and which in equilibrium is not renegotiated. Tying certain payments to easily observable exogenous factors can help reduce the incentives that an agent has to breach a contract and renegotiate. In contrast to the efficient contract in the previous case, where renegotiation was an important ingredient, here renegotiation never effectively occurs, even though the trading price itself changes. The analysis in this section provides a way to interpret Joskow's observations on long term contracts for coal.

VIII. Some Implications

We have shown that market contracting can, despite incompleteness, ensure efficient investment in relationship specific assets under much wider conditions than has been previously suggested. Moreover, at least in certain cases, this can be done with contracts that are not so complicated for it to be implausible that they could be written or enforced.

There are a number of implications of this. One is that, in the kind of circumstances we have discussed here, there should be no need for institutional structures to replace markets to economize on transactions costs. Indeed, our analysis suggests that, in the case of specific investments by one party only, it can be important for efficiency that the non-investing party be free to take up opportunities outside the relationship. Contractual arrangements, or ownership of one party by the other, that inhibit this could hamper the efficiency of specific investment. An obvious example is slavery. A slave is not in a position to make a choice to work with another slave owner – that is the prerogative of the slave owner. But the conclusion is not limited to that extreme example. The same arguments apply to vertical integration of two firms, which could induce inefficient specific investment by one of them when efficiency could be achieved by a market relationship.

Another implication concerns the question of who should undertake the specific investments when that is something that can be chosen. The robustness of the efficiency result for the case in which all specific investments are made by one party suggests that, wherever it is possible to choose which party will make those investments, efficiency may well be enhanced by having them all made by one party.

Our results also have implications for the design of legal remedies for breach of contract. A common view of such remedies is that the law should operate to fill in appropriate contract terms for contingencies that the contracting parties did not explicitly incorporate into their contract. One principle on which this can be done is that of compensating appropriately a party who makes a specific investment if the other party subsequently refuses to carry co-operate. Breach measures based on compensation make obvious sense if the only concern is with ex post fairness. But, as Shavell (1980) and Rogerson (1984) recognized, the form of breach measures affects the inducements to invest in specific assets. Compensation measures may provide appropriate inducements if courts can obtain enough information to assess (i) whether it was actually efficient that trade take place and (ii) what the payoffs to the parties both are without trade and would have been had trade taken place. Then the courts can ensure that the investing party is fully compensated only if trade would have been efficient and this provides the appropriate incentives for investment. But, in the absence of such information, compensation damages cannot in general induce efficient investment, as Shavell (1980) and Rogerson (1984) have shown.

For such circumstances, the analysis in the present paper suggests an alternative approach to designing breach measures that can be more effective at achieving efficient investment. That alternative is based not on the principle of compensation for an injured party but on the principle of preventing one party capturing the marginal returns to specific investments made by the other. At least in the case of investment by one party only, all that is required for this is to ensure that the non-investing party is never worse off quitting the relationship than staying in it under the terms of the original contract. The nature of outside options in bargaining then ensures that this party does not capture any of the marginal returns to the specific investment. Since to achieve efficient specific investment this approach requires only enough information to put a lower bound on the payoff to the non-investing party, it is much less demanding of information than the compensation approach.

There are still many cases that are not covered by our analysis. Obvious ones are those with risk averse parties and those with all the four types of specific investments that we have discussed. The question of whether market contracting can achieve efficient investment in these cases is one that needs further investigation.

Appendix

This appendix gives a proof of Proposition 1. We first characterize the payoffs for a Markov perfect equilibrium on the assumption that such an equilibrium exists. Then, with the use of this characterization, we show that a Markov perfect equilibrium does indeed exist. For notational convenience, we define $\delta = e^{-r\Delta}$. Also, since for the whole of the renegotiation game the state ω is fixed and known to both parties, we omit this argument from the notation where it causes no confusion. Note that an implication of the definition of a Markov perfect equilibrium is that the equilibrium payoffs for the renegotiation game from stage n.0 on can be written $\{V_n(P_{n-1}), U_n(P_{n-1})\}$, where P_{n-1} is the contract in force at the start of round n. In a similar way, the equilibrium payoffs from stage n.1 on if agent i ($i \in \{b, s\}$) has the opportunity to offer a new contract at n.1 can be denoted $\{V_n^i(P_{n-1}), U_n^i(P_{n-1})\}$.

For any contract $P_n = \{p_n^T, p_n^N, p_n^O\}$ in force at stages n.3 and n.4 of the game, the flow payoffs per unit of time during the period $[n\Delta, (n+1)\Delta]$ for the action choices at stages n.3 and n.4 are given by the matrix in Figure 3. (Note that the money values of the N option gross of payments are normalized at zero.)

		Seller	
		T	N
Buyer	T	$v(I_b,\theta)-p_n^T,\quad u(I_s,\theta)+p_n^T$	$-p_n^N,\quad p_n^N$
	N	$-p_n^N,\quad p_n^N$	$-p_n^N,\quad p_n^N$

FIGURE 3: PAYOFF MATRIX

Proposition A.1: For given $P_n = \{p_n^T, p_n^N, p_n^O\}$, the payoffs from stages n.3 and n.4 in any Markov perfect equilibrium are generically unique. The equilibrium flow payoffs from $n\Delta$ to $(n+1)\Delta$, denoted $v^O(P_n)$ for the buyer and $u^O(P_n)$ for the seller, are

$$[v^O(P_n),\ u^O(P_n)] = \begin{cases} [v(\omega)-p_n^T,\ u(\omega)+p_n^T], & \text{if } v(\omega)-p_n^T > -p_n^N \text{ and } u(\omega)+p_n^T > p_n^N; \\ [-p_n^N,\ p_n^N], & \text{if } v(\omega)-p_n^T < -p_n^N \text{ or } u(\omega)+p_n^T < p_n^N. \end{cases}$$

Proof: For a Markov perfect equilibrium, the payoffs from the beginning of round n+1 do not depend on the strategies chosen at stages n.3 and n.4. It then follows directly from the payoff matrix in Fig. 3 that, for $v(\omega)-p_n^T \neq -p_n^N$ and $u(\omega)+p_n^T \neq p_n^N$, the best responses are unique and give the flow payoffs stated. The cases $v(\omega)-p_n^T = -p_n^N$ and $u(\omega)+p_n^T = p_n^N$ are non-generic. ∎

In fact, if both $v(\omega)-p_n^T = -p_n^N$ and $u(\omega)+p_n^T = p_n^N$, the equilibrium payoffs are unique even though the equilibrium actions are not. In the case $v(\omega)-p_n^T > -p_n^N$ and $u(\omega)+p_n^T = p_n^N$ and the case $v(\omega)-p_n^T = -p_n^N$ and $u(\omega)+p_n^T > p_n^N$, the equilibrium payoffs are not unique because one party prefers to trade but the other is indifferent. In those cases, the player who is indifferent between the two actions would always wish the other to believe he or she would choose the action that would hurt his or her opponent most. For concreteness in what follows, therefore, we adopt as a convention that no trade takes place under these circumstances.

Proposition A.2: Let U* and V* be any two numbers corresponding to a division

of the ex post surplus, that is $U^* + V^* = S(\omega)/r$, for any given $\omega \in \Omega$. Then there exists a contract $P^*(\omega)$ which, if offered by one agent at stage 0.1 and accepted by the other at stage 0.2, results in a unique outcome $z^*(\omega)$ and payoffs $V[\omega, z^*(\omega)] = V^*$ and $U[\omega, z^*(\omega)] = U^*$ from stage 0.3 on for every <u>Markov perfect equilibrium</u>.

Proof: We consider the two cases $v(\omega)+u(\omega) > \nu+\mu$ (trade is efficient) and $v(\omega)+u(\omega) \leq \nu+\mu$ (trade is not efficient) separately.

Case (i): $v(\omega)+u(\omega) > \nu+\mu$. Define the contract $P^*(\omega) = \{p^T, p^N, p^O\}$ by

(A.1) $$[v(\omega) - p^T]/r = V^*;$$

(A.2) $$-rV^* < p^N < rU^*;$$

(A.3) $$\nu - rV^* < p^O < rU^* - \mu.$$

From the definition of $S(\omega)$ in (3.3), $U^*+ V^* > \nu+\mu$ so this is always possible. It also follows from (A.1) and the definition of $S(\omega)$ in (3.3) that

(A.4) $$[u(\omega)+p^T]/r = U^*.$$

Suppose $P^*(\omega)$ is in force. If renegotiation of $P^*(\omega)$ is rejected, then from Proposition A.1 the unique outcome of stages n.3 and n.4 is (T, T). Let $\underline{U}$, (resp. $\underline{V}$) be the lowest payoff of the seller (resp. buyer) from any Markov perfect equilibrium conditional on $P^*(\omega)$ being currently in force. A feasible strategy for the seller is to reject all offers of renegotiation made by the buyer and to offer $P^*(\omega)$ when given the opportunity to make an offer. Since from (A.3) and (A.4) $u(\omega)+p^T > \mu+p^O$, this strategy results in a payoff greater than $(\mu+p^O)/r$ and it must therefore be that $\underline{U} > (\mu+p^O)/r$. Thus, if $P^*(\omega)$ is in force, the seller is better off choosing R in the current period and O in the next period than choosing O in the current period. But then, if the buyer follows the strategy of offering $P^*(\omega)$ whenever given the opportunity to do so and rejecting all offers of renegotiation, the seller will never respond by choosing O and the buyer can ensure that, for the period $[n\Delta, (n+1)\Delta]$, he gets a payoff at the rate of at least $[v(\omega)-p^T]$. For the period from $(n+1)\Delta$ on, he gets at least $\underline{V}$. It must therefore be that

$$\underline{V} \geq \frac{1}{r}(1-\delta)[v(\omega) - p^T] + \delta\underline{V}.$$

It follows that $\underline{V} \geq [v(\omega)-p^T]/r = V^*$ by (A.1). By a similar argument, by (A.4) $\underline{U} \geq [u(\omega)+p^T]/r = U^*$. Let $V_n(P^*)$ and $U_n(P^*)$ denote the payoffs under $P^*(\omega)$ from any Markov perfect equilibrium. From the definition of $S(\omega)$ in (3.3), $V_n(P^*)+U_n(P^*) \leq S(\omega)$. By definition of $\underline{V}$ and $\underline{U}$, $[V_n(P^*), U_n(P^*)] \geq (\underline{V}, \underline{U}) = (V^*, U^*)$. But $V^*+U^* = S(\omega)$. Together these imply $[V_n(P^*), U_n(P^*)] = (V^*, U^*)$. Thus every Markov perfect equilibrium has the same payoffs V^* and U^* as stated in the proposition.

Case (ii): $v(\omega)+u(\omega) \leq \nu+\mu$. In this case, immediate separation is efficient. Thus to obtain the payoffs (U^*, V^*), each agent must select the outside option in period $n = 0$ if given the opportunity to do so. Define the contract $P^*(\omega) = \{p^T, p^N, p^O\}$ by

(A.5) $$(\nu - p^O) = rV^*;$$

(A.6) $$-\nu + p^O < p^N < \mu + p^O;$$

(A.7) $$v(\omega) - \nu + p^O < p^T < \mu + p^O - u(\omega).$$

This is always possible since $\nu, \mu > 0$.

First, we show that the equilibrium payoffs $V_0(P^*)$ and $U_0(P^*)$ cannot be such that $V_0(P^*) < V^*$ and $U_0(P^*) < U^*$. To see this, note first that, since (V^*, U^*) is efficient, it must always be that either $U_1(P^*) \leq U^*$ or $V_1(P^*) \leq V^*$. Suppose $U_1(P^*) \leq U^*$. Note also that, under $P^*(\omega)$, $u^o(P^*) < \mu+p^O$. Thus the payoff to the seller of continuing with $P^*(\omega)$ at $n = 0$ is strictly less than choosing O if she gets the opportunity to do so. Then, if the buyer gets to offer a new contract at stage 0.1, the seller will respond by choosing O unless the buyer offers a new contract giving the seller at least U^*. That will result in payoffs V^* and U^* and, since the buyer can never get more than V^* because the seller will choose O rather than accept a contract giving her less than U^*, the buyer will always offer a contract that induces the seller to choose O. Thus, $V_0^b(P^*) = V^*$ and $U_0^b(P^*) = U^*$. If, on the other hand, it is the seller who has the opportunity to offer a new contract at stage 0.1, the buyer can always guarantee V^* by responding to any offer by rejecting it and choosing O. Thus, $V_0^s(P^*) \geq V^*$. Since $V_0(P^*) = \pi V_0^b(P^*)+(1-\pi)V_0^s(P^*)$, it follows that $V_0(P^*) \geq V^*$. If, alternatively, $V_1(P^*) \leq V^*$, a similar argument ensures that $U_0(P^*) \geq U^*$. Thus either $V_0(P^*) \geq V^*$ or $U_0(P^*) \geq U^*$.

Consider therefore the possibility that $V_0(P^*) < V^*$ and $U_0(P^*) > U^*$. Since $V_0^s(P^*) \geq V^*$ (the buyer can always respond to any offer of the seller by rejecting it and choosing O), it must be that $V_0^b(P^*) < V^*$ and hence $U_0^b(P^*) > U^*$. Moreover, since $u^o(P^*) < \mu + p^O$, it must also be the case that $V_1(P^*) < V^*$ and $U_1(P^*) > U^*$ because otherwise the seller would choose the outside option at time 0, resulting in $V_0(P^*) = V^*$. But, by a similar argument, $V_1(P^*) < V^*$ and $U_1(P^*) > U^*$ implies that $V_n(P^*) < V^*$ and $U_n(P^*) > U^*$ for all n. Since $v^o(P^*) < \nu - p^O$, this means that the buyer will always choose the outside option under the contract P* whenever he gets a chance to do so and therefore $U_n^s(P^*) = U^*$, and thus $U_n^b(P^*) > U^*$, for all n. For $V_0(P^*) < V^*$ and $U_0(P^*) > U^*$ to be an equilibrium there must exist a sequence of numbers $U_n^b(P^*) > U^*$ such that the seller rejects any contract offered by the buyer that results in a payoff less that $U_n^b(P^*)$ and accepts any contract yielding $U_n^b(P^*)$. $U_n^b(P^*) > U^*$ can only be attained by continuing the relationship and so $U_n^b(P^*)$ must satisfy

$$U_n^b(P^*) = (1-\delta)u^o(P^*)/r + \delta U_{n+1}(P^*),$$

where $U_n(P^*) = \pi U_n^b(P^*) + (1-\pi)U_n^s(P^*)$. This implies

$$U_n(P^*) = \pi[(1-\delta)u^o(P^*)/r + \delta U_{n+1}(P^*)] + (1-\pi)U^*.$$

By solving this difference equation it is straightforward to show that, since $u^o(P^*) \leq \mu + p^O < rU_0$, the sequence $U_n(P^*)$ increases without bound. But by rejecting every new contract and taking up the outside option whenever possible, the buyer can guarantee himself an amount $\underline{V} > -\infty$. Since $U_n(P^*) \leq S(\omega) - V(P^*) \leq S(\omega) - V$, then $U_n(P^*)$ cannot increase without bound, which is a contradiction. Together with the preceding result, this establishes that $U_0(P^*) = U^*$ and $V_0(P^*) = V^*$. A symmetric argument establishes that a Markov perfect equilibrium cannot have $V_0(P^*) > V^*$ and $U_0(P^*) < U^*$, which in turn establishes the proposition. ∎

This proposition establishes that any division of the ex post surplus between the buyer and the seller can be supported as unique equilibrium payoffs in the renegotiation game for some contract. Thus, in each period the party with the opportunity to offer a new contract may offer one with unique equilibrium payoffs corresponding to any division of the surplus. The importance of this is that it implies that every equilibrium of the renegotiation game is equivalent to a game in which agents offer a division of the surplus and there is no further renegotiation. Thus, in what follows we need only be concerned with renegotiation over the division of the surplus at $t = 0$. We make extensive use of this.

Proposition A.3: Suppose $\delta[v(\omega)+u(\omega)] > \nu+\mu$. For any contract $P = \{p^T, p^N, p^O\}$ in force at the beginning of round n for which $[v^O(P), u^O(P)] = (-p^N, p^N)$, the payoffs to the buyer and the seller in any Markov perfect equilibrium of the renegotiation game are uniquely given by $V(\omega, P)$ and $U(\omega, P)$ defined by

$$(A.8)\qquad rV(\omega, P) = \begin{cases} (1-\delta\pi)^{-1}\cdot\{\pi(1-\delta)[S(\omega)-p^N] + (1-\pi)(\nu-p^0)\}, \\ \qquad\qquad \text{if } \delta\pi S(\omega)-p^N \le \nu-p^0; \\ [1-\delta(1-\pi)]^{-1}\cdot\{\pi[S(\omega)-\mu-p^0] - (1-\pi)(1-\delta)p^N\}, \\ \qquad\qquad \text{if } \delta(1-\pi)S(\omega)+p^N \le \mu+p^0; \\ \pi S(\omega)-p^N, \text{ otherwise;} \end{cases}$$

$$(A.9)\qquad U(\omega, P) = \frac{S(\omega)}{r} - V(\omega, P).$$

Proof: Consider stage n.1 of a Markov perfect equilibrium with payoffs $\{V_n(P), U_n(P)\}$ to the buyer and seller respectively, where P is the contract in force at the start of n.1 and satisfies the conditions required in the proposition. Suppose that the buyer has been chosen by nature to make an offer. If the seller rejects the offer made by the buyer, the payoff to the seller will be given by:

$$(A.10)\qquad \tilde{U} = \max\{\frac{\mu+p^O}{r}, (1-\delta)\frac{u^O(P)}{r} + \delta U_{n+1}(P)\}$$
$$= \max\{\frac{\mu+p^O}{r}, (1-\delta)\frac{p^N}{r} + \delta U_{n+1}(P)\}.$$

This expression states that the seller gets the maximum of the value of the outside option or the value of $u^O(P)$ over the period n to n+1 and then the equilibrium payoff from n+1 on. By Proposition A.1, no trade takes place during round n unless the contract is first renegotiated, so the seller receives payoff at the rate $u^O(P) = p^N$ in round n if any revised contract is rejected and the outside option not taken up. Note that we have used the property of Markov perfection when we write the payoff from round n+1 on as independent of the offer made by the buyer in round n.

If the seller is to accept the offer of the buyer in any equilibrium, she must therefore get at least $\bar{U}$ from the new contract. From Proposition A.2 we know that the buyer can offer the seller a new contract that will have a unique Markov perfect equilibrium outcome that splits the surplus in any way desired. This has two implications. First, it can never be the case that $U_n^b(P) = U' > \bar{U}$ because the buyer could offer an efficient contract that provides the seller with utility $\bar{U} + (U' - \bar{U})/2$ that would be accepted with probability one by the seller and yield a higher payoff to the buyer. Second, by a similar argument, the buyer will offer only an efficient contract. Precisely symmetric arguments apply to the case in which the seller makes the offer. Therefore the contract offered at stage n.1 will always be efficient, so $U_n(P) = S(\omega)/r - V_n(P)$ for all n. This implies (A.9).

It also implies that, to define the payoffs of the game, we need only define the payoff to the buyer, $V^i(P)$, $i \in \{b, s\}$. Efficiency implies

$$V_n^b(P) = \frac{S(\omega)}{r} - U_n^b(P), \text{ for all n,}$$

and

$$U_{n+1}(P) = \frac{S(\omega)}{r} - V_{n+1}(P), \text{ for all n.}$$

Since $U_n^b(P) = \tilde{U}$ defined by (A.10), it follows that

$$\text{(A.11)} \qquad rV_n^b(P) = S(\omega) - \max\{(\mu + p^O), (1-\delta)p^N + \delta[S(\omega) - rV_{n+1}(P)]\}.$$

Moreover, by reasoning analogous to that giving (A.10)

$$\text{(A.12)} \qquad rV_n^s(P) = \max\{(\nu - p^O), -(1-\delta)p^N + \delta rV_{n+1}(P)\}.$$

The payoff in period n.0 is

$$\text{(A.13)} \qquad V_n(P) = \pi V_n^b(P) + (1-\pi)V_n^s(P).$$

In view of this, we may write $V_n(P) = F[V_{n+1}(P)]$, where $F(\cdot)$ is continuous and also increasing because, with $\delta[v(\omega)+u(\omega)] > \nu+\mu$, the maximal term in either (A.11) or (A.12) must involve $V_{n+1}(P)$. Since the game is stationary with respect to time the supremum of all the Markov perfect equilibrium payoffs possible from round n on must be the same as at from round n+1 on. Thus we may define

$$\bar{V}(P) = \sup\{V_n(P) \mid V_n(P) \text{ is a payoff consistent with some Markov perfect equilibrium with history P in round n}\}.$$

Note that $\bar{V}(P)$ is bounded. Since $F(\cdot)$ is continuous and increasing, $\bar{V}(P) = F[\bar{V}(P)]$. But the solution to this is unique and, for the case $\delta[v(\omega)+u(\omega)] > \nu+\mu$, is given by (A.8). Since the infimum over the payoffs must satisfy the same relation, the payoffs for any Markov perfect equilibrium are unique and satisfy the proposition. ∎

In fact, the equilibrium payoffs are unique for $v(\omega)+u(\omega) > \nu+\mu$ provided the other assumptions of Proposition A.3 are satisfied but the formula corresponding to (A.8) is much more complicated. The reason is that, if δ is not sufficiently close to 1 that $\delta[v(\omega)+u(\omega)] > \nu+\mu$, both outside options may bind for some parameter values. For δ sufficienctly close to 1, at most one of the outside options binds in any period, yielding the formulae in the proposition. Since in the text we use only limiting results as $\Delta \to 0$ (so that $\delta \to 1$), we omit details of the more complicated case.

Proposition A.4: Suppose $v(\omega)+u(\omega) > \nu+\mu$. For any contract $P = \{p^T, p^N, p^O\}$ in force at the beginning of round n for which $\{v^O(P), u^O(P)\} = [v(\omega)-p^T, u(\omega)+p^T]$, the payoffs to the buyer and seller in any Markov perfect equilibrium of the renegotiation game are uniquely given by $V(\omega, P)$ and $U(\omega, P)$ defined by

$$\text{(A.14)}\qquad rV(\omega, P) = \begin{cases} (1-\delta\pi)^{-1}\cdot\{\pi(1-\delta)[S(\omega)-u(\omega)-p^T] + (1-\pi)(\nu-p^0)\}, \\ \qquad\qquad \text{if } v(\omega)-p^T \le \nu-p^0; \\ [1-\delta(1-\pi)]^{-1}\cdot\{\pi[S(\omega)-\mu-p^0] + (1-\pi)(1-\delta)[v(\omega)-p^T]\}, \\ \qquad\qquad \text{if } u(\omega)+p^T \le \mu+p^0; \\ v(\omega) - p^T, \text{ otherwise;} \end{cases}$$

$$\text{(A.15)}\qquad U(\omega, P) = S(\omega)/r - V(\omega, P).$$

Proof: Note that at most one outside option can be binding because trade is efficient and, by Proposition A.1, will actually take place whether or not the contract is renegotiated. Thus, exactly the same proof as for Proposition A.3 applies, except that now one uses the fact that $v^O(\omega)+u^O(\omega) = S(\omega)$ and replaces p^N by $u(\omega)+p^T$ in (A.11) and $-p^N$ by $v(\omega)-p^T$ in (A.12). ∎

Proposition A.5: **Suppose $v(\omega)+u(\omega) \le \nu+\mu$. For any contract $P = \{p^T, p^N, p^O\}$ in force at the beginning of round n for which $\{v^o(P), u^o(P)\} = [v(\omega)-p^T, u(\omega)+p^T]$, the payoffs to the buyer and seller in any Markov perfect equilibrium of the renegotiation game are uniquely given by $V(\omega, P)$ and $U(\omega, P)$ defined by**

$$\text{(A.16)}\qquad rV(\omega, P) = \begin{cases} (1-\delta\pi)^{-1}\cdot\{\pi(1-\delta)[S(\omega)-u(\omega)-p^T] + (1-\pi)(\nu-p^0)\}, \\ \qquad\qquad \text{if } u(\omega)+p^T > \mu+p^0; \\ [1-\delta(1-\pi)]^{-1}\cdot\{\pi(\nu-p^0) + (1-\pi)(1-\delta)[v(\omega)-p^T]\}, \\ \qquad\qquad \text{if } v(\omega)-p^T > \nu-p^0; \\ \nu - p^0, \text{ otherwise;} \end{cases}$$

$$\text{(A.17)}\qquad U(\omega, P) = S(\omega)/r - V(\omega, P).$$

Proof: In this case efficiency requires separation, and therefore $S(\omega) = \nu + \mu$. Hence at least one of the outside options must be binding in every period. The result follows from these observations and from replacing p^N by $u(\omega)+p^T$ in (A.11) and $-p^N$ by $v(\omega)-p^T$ in (A.12). ∎

Propositions A.1 to A.5 characterize the unique payoffs associated with any Markov perfect equilibrium if one exists. Thus, for any contract P, the payoffs in any Markov perfect equilibrium are uniquely defined by the functions {V(P), U(P)} at the beginning of any period, and by $\{V^i(P), U^i(P)\}$ if agent $i \in \{s,b\}$ is choosen to make an offer. These functions can be used to define strategies that will constitute a Markov perfect equilibrium yielding these payoffs as the outcome, thus ensuring existence.

Proposition A.6: A Markov perfect equilibrium for the renegotiation game exists.

Proof: Consider the following strategies for round n conditional on P_{n-1} being the contract currently in force:

Stages n.1 and n.2: If the buyer has the opportunity to offer a new contract, he offers a contract P that, if accepted, results in a payoff of $V^b(P_{n-1})$. Such a contract exists by Proposition A.2. The seller accepts (A or AO) all contracts P giving her a payoff $U^b(P) \geq U^b(P_{n-1})$ and rejects (R or RO) all others. She chooses between A and AO, and between R and RO, by choosing the outside option if and only if $\mu+p_n^0 > u^o(P_n)+r\delta U(P_n)$ when trade is strictly efficient and choosing that option if and only if $\mu+p_n^0 \geq u^o(P_n)+r\delta U(P_n)$ when trade is strictly or weakly inefficient. Symmetric strategies are played if the roles are reversed.

Stages n.3 and n.4: Agents play the equilibrium strategies given by Proposition A.1 and receive the associated flow payoffs $u^o(P_n)$ and $v^o(P_n)$.

Since the only relevant history at the beginning of each period is the contract in force, these strategies define agents' actions in all possible subgames. Given the way the payoffs have been defined, they constitute a Markov perfect equilibrium. ∎

From these results it is straightforward to prove Proposition 1 in the main text.

Proof of Proposition 1: Existence of a Markov perfect equilibrium follows from Proposition A.6. For the case $v(\omega)+u(\omega) > \nu+\mu$, it is also the case that $\delta[v(\omega)+u(\omega)] > \nu+\mu$ for Δ sufficiently small because $\delta \to 1$ as $\Delta \to 0$, so Propositions A.3-A.5 cover all limiting cases. Taking limits of the payoffs in (A.8) as $\delta \to 1$ gives the result for case (i) of Proposition 1. Taking limits of the payoffs in (A.14) and (A.16) as $\delta \to 1$ similarly give the results for cases (ii) and (iii) of Proposition 1. ∎

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