Games and Economic Behavior **33,** 195–205 (2000)
doi:10.1006/game.1999.0782, available online at http://www.idealibrary.com on IDEAL®

Can a Contract Solve Hold-Up When Investments Have Externalities? A Comment on De Fraja (1999)

Yeon-Koo Che*

Department of Economics, University of Wisconsin, Madison, Wisconsin 53706

Received April 2, 1999

This comment finds an error in De Fraja (1999), the correction of which overturns its main result. In contrast to his claim, under a mild condition, the suggested contract is not only unable to solve the hold-up problem but it can provide almost no incentive for specific investments, when they exhibit sufficiently large direct externalities. His result holds primarily when the investments have no externalities. We remark on a related result in the literature and propose an alternative contract that achieves efficiency. *Journal of Economic Literature* Classification Numbers: C70, J41, K12, L22.

1. INTRODUCTION

De Fraja (1999) (henceforth DF) proposes a contract that he claims can solve the hold-up problem even when specific investments have direct externalities if: (1) the investments are made sequentially with one party investing after observing the other's investment choice; (2) the first-mover has the entire bargaining power initially (see Proposition 3, p. 30); and (3) the parties renegotiate their contract according to the Hart and Moore (1988) (henceforth HM) specification. As we show below, however, this claim does not hold when the investments have externalities. Specifically, under a plausible assumption (which is consistent with those of DF), not only is the suggested contract unable to solve the hold-up problem in the presence of investment externalities, but it generates almost no incentive for specific investments when the externalities are sufficiently important.

* I am grateful to József Sákovics and an Associate Editor for helpful comments. This research was conducted while I was visiting the Institut d'Anàlisi Econòmica, CSIC in Spain. I gratefully acknowledge the hospitality of the institute and its financial support (provided by the Spanish Ministry of Education) as well as the sabbatical grant provided by the University of Wisconsin. E-mail: yche@facstaff.wisc.edu.

0899-8256/00 $35.00

We find that DF's result holds primarily when the late mover's investment has no externalities.

The inefficiency results do not extend to all contracts, however. We propose an alternative contract that can achieve efficiency in the environment studied by DF. This latter contract specifies, much in the spirit of HM, a *menu* of contract terms that make, through renegotiation, the late mover a residual claimant at the margin.

The rest of this paper is organized as follows. In Section 2, we summarize the model and the main claim of DF, point out its error, and show how its result is overturned. Section 3 discusses the relationship of this latter finding to a recent article and offers a solution to the problem.

2. INEFFICIENCY RESULTS: FAILURE OF PROPOSITION 3 OF DE FRAJA (1999)

DF posits a buyer and a seller, both risk neutral, engaged in a long-term relationship for trade of a good. The sequence of events is as follows. At date 0, the buyer makes an investment of $\beta \geq 0$. At date 1, the buyer makes a take-it-or-leave-it offer of a contract that specifies the delivery, at a certain future date, of a given quantity of the good, $q_0 \geq 0$, by the seller in exchange for a payment from the buyer of $t_0 \in \Re$. At date 2, the seller makes its own investment of $\sigma \geq 0$. At date 3, the nature draws a random variable $\omega \in \Omega$, which determines the gains from trade between the two parties. At date 4, the parties may renegotiate the contract. Renegotiation proceeds as in HM, so each party can send a new proposed trade term and reveal in the court the proposal received from his partner (see Assumption 4 of DF).[1] Finally, the contract (a renegotiated one if there was renegotiation at date 4) is enforced at date 5.

Given (ω, σ, β), trade of quantity q generates (gross) value of $v(q, \omega, \sigma, \beta)$ to the buyer and incurs a cost of $c(q, \omega, \sigma, \beta)$ to the seller. These functions are assumed to satisfy standard technical conditions (see Assumptions 1 and 2 of DF for details). Given these conditions, the first-best efficient outcome is well defined and unique, and consists of an efficient trade level, $q^*(\omega, \sigma, \beta) \equiv \arg\max_{q \geq 0} v(q, \omega, \sigma, \beta) - c(q, \omega, \sigma, \beta)$

[1]The use of the HM renegotiation game distinguishes the current model (in addition to the sequential investment) from some models of incomplete contracting: Che and Hausch (1999), Edlin and Reichelstein (1996), Hart and Moore (1999), and Segal (1999), who assume the split-the-surplus negotiation game. In particular, Che and Hausch (1999) derive inefficiency results in the presence of investment externalities, much in contrast to what Proposition 3 of DF claims. We show below that Proposition 3 of DF is false, but this difference remains important as we argue in Section 3.

and an efficient investment pair,

$$(\beta^*, \sigma^*) = \arg \max_{\beta, \sigma \in \Re_+^2} \int [v(q^*(\omega, \sigma, \beta), \omega, \sigma, \beta) \\ - c(q^*(\omega, \sigma, \beta), \omega, \sigma, \beta)] dF(\omega) - h_b(\beta) - h_s(\sigma).$$

DF makes the usual information assumption that the investment-related information is unverifiable yet observable to the buyer and the seller, which makes the complete contract approach infeasible. Given this model with the aforementioned assumptions, Proposition 3 of DF claims that the first-best efficiency can be attained in a subgame perfect equilibrium for some contract term (q_0, t_0). The validity of this proposition is the central focus of this comment.

Since the buyer has the entire bargaining power in his contract offering, he extracts the entire trade surplus (via the adjustment of t_0). Hence, the buyer internalizes the social return from his investment, which leads to the efficient investment choice on his part (given any anticipated level of investment by the seller). The crucial part of the proof thus lies in the seller's (second mover's) investment incentive. To understand the latter, first note that the buyer has the incentive to choose a contract term (q_0, t_0) that maximizes the expected social gains from trade (again because of his internalizing the social surplus from trade). In particular, if there exists (q_0, t_0) that induces the seller to choose the first-best investment level σ^*, given the buyer's investment β^*, then he will choose that contract term. The key question is therefore whether such a contract term exists. DF answers this question in the affirmative: formally, he claims that there exists (q_0, t_0) such that $\sigma(q_0, \beta^*) = \sigma^*$, where $\sigma(\cdot, \cdot)$ denotes the induced investment choice by the seller. We find this claim to be false.[2]

To prove this point, we make the following assumptions (in addition to Assumptions 1 and 2 of DF):

ASSUMPTION 1′. $\int v_\sigma(q^*(\omega, \sigma^*, \beta^*), \omega, \sigma^*, \beta^*) dF(\omega) > 0.$

ASSUMPTION 2′. $\sigma^* > 0$ and the seller's investment cost, $h_s(\cdot)$, is differentiable.

ASSUMPTION 3′. $v_{q\sigma}(\cdot) \geq 0$ and $-c_{q\sigma}(\cdot) \geq 0.$

ASSUMPTION 4′ $\sup |c_\sigma(q^*(\cdot), \cdot)| < \epsilon$ *for some* $\epsilon > 0.$

[2]The proof of the claim, the author argues, follows an argument by Chung (1991) (see DF p. 37). This latter argument does not work, however, when the seller's specific investment has external effects.

Assumption $1'$ says that the seller's investment has strictly positive externalities at the first-best investment choices. This is the minimal condition for the presence of the direct externalities highlighted in DF. Assumption $2'$ rules out corner-solution/kink cases, for which the incentive problem is uninteresting. Assumption $3'$ says that a higher (anticipated) volume of trade increases the marginal (social) value of investments. This assumption is not only plausible but it is made commonly in the hold-up literature.[3] Finally, Assumption $4'$ is not necessary to overturn Proposition 3 of DF but is rather used to consider a case in which the investment externalities are sufficiently important: the smaller ϵ is the more important (relatively) than the (seller's) investment externalities. Note that all these assumptions do not contradict DF's assumptions.

We prove below that Proposition 3 of DF cannot hold, given the first three assumptions. Before proceeding, it is useful to provide some intuition behind the proof. To this end, note first that the HM renegotiation has the following two implications. First, the first-best trade decision emerges from the renegotiation. Second, roughly speaking, the original contract term serves as an *outside option* for each party in renegotiation, so the renegotiation makes a party who would otherwise do worse than the outside option position indifferent to it (see Proposition 1 of DF). At first glance, it may appear from the second fact that the seller will become a residual claimant if the buyer's outside option is binding. This is not the case, however. A contract term that makes the buyer's outside option binding will indeed ensure that the seller will become a residual claimant at the margin, *but only relative to the payoff the buyer would have received had the contract not been renegotiated*. It can be demonstrated (as it is done below in the proof) that the latter payoff varies more sensitively to the seller's investment than the social surplus, so any additional incentive this residual claimant position gives to the seller (in addition to the own effect) can only be a *disincentive*. The result is now formally presented.

PROPOSITION 1. *Given Assumptions* $1', 2'$, *and* $3'$ (*in addition to the Assumptions* 1 *and* 2 *of DF*), *the first-best investments can never be attained under any* (q_0, t_0).

Proof. It suffices to show that there does not exist any (q_0, t_0) such that $\sigma(q_0, \beta^*) = \sigma^*$. To this end, first write the seller's ex post payoff

[3]The assumptions will hold, for example, if $v(q, \omega, \sigma, \beta) = A(\omega, \sigma, \beta)B(q, \omega, \beta)$ and $c(q, \omega, \sigma, \beta) = C(\omega, \sigma, \beta)D(q, \omega, \beta)$, for some functions A, B, C and D, so the investments affect the marginal value and marginal cost. Chung (1991) assumes this precisely for the purpose of proving the disputed claim.

(after renegotiation and excluding her investment cost) as:

$$u_S(q_0, \sigma, \beta) \equiv \max\{\Delta c(q_0, \omega, \sigma, \beta), 0\} + \min\{\Delta v(q_0, \omega, \sigma, \beta), 0\} \\ + t_0 - c(q_0, \omega, \sigma, \beta),$$

where

$$\Delta v(q_0, \omega, \sigma, \beta) \equiv v(q^*, \omega, \sigma, \beta) - v(q_0, \omega, \sigma, \beta) \text{ and} \\ \Delta c(q_0, \omega, \sigma, \beta) \equiv c(q_0, \omega, \sigma, \beta) - c(q^*, \omega, \sigma, \beta).$$

(See Lemma 1 of DF, p. 35 for derivation; and from now on, the arguments of q^* are suppressed for notational simplicity.) The payoff can be rewritten as:

$$u_S(q_0, t_0, \omega, \sigma, \beta) = t_0 - c(q^*, \omega, \sigma, \beta) - \Delta c(q_0, \omega, \sigma, \beta)1_{\{q^*>q_0\}} \\ + \Delta v(q_0, \omega, \sigma, \beta)1_{\{q^*<q_0\}},$$

where $1_{\{\cdot\}}$ is a characteristic function which takes the value of one in the set $\{\cdot\}$ and zero outside the set. Notice that when $q^* > q_0$, the seller's outside option is binding, so she receives the same payoff as if there were no renegotiation. When $q^* < q_0$, the buyer's outside option is binding, which makes the seller a residual claimant at the margin *relative to* the buyer's no renegotiation payoff.

To see how the seller's investment affects her payoff, differentiate it with respect to σ (using the envelope theorem[4]), which yields

$$\begin{aligned} \frac{\partial u_S(q_0, t_0, \omega, \sigma, \beta)}{\partial \sigma} &= -c_\sigma(q^*, \omega, \sigma, \beta) - 1_{\{q^*>q_0\}} \frac{\partial \Delta c(q_0, \omega, \sigma, \beta)}{\partial \sigma} \\ &\quad + 1_{\{q^*<q_0\}} \frac{\partial \Delta v(q_0, \omega, \sigma, \beta)}{\partial \sigma} \\ &\le -c_\sigma(q^*, \omega, \sigma, \beta), \end{aligned} \tag{1}$$

where the inequality holds since $\Delta c(q_0, \omega, \sigma, \beta)$ is nondecreasing in σ whenever $q^* > q_0$ (by Assumption 3′) and $\Delta v(q_0, \omega, \sigma, \beta)$ is nonincreasing in σ whenever $q^* < q_0$ (again by Assumption 3′).

Consider now the seller's (gross) ex ante expected payoff, assuming that the buyer has chosen β^*:

$$\mathcal{U}_S(q_0, t_0, \sigma, \beta^*) = \int u_S(q_0, t_0, \omega, \sigma, \beta^*) dF(\omega).$$

[4]That is, $(v_q(q^*, \omega, \sigma, \beta) - c_q(q^*, \omega, \sigma, \beta))[\partial q^*/\partial \sigma]1_{\{q^*<q_0\}} \equiv 0$.

For any $\sigma \geq \sigma^*$, its derivative with respect to σ is

$$\begin{aligned}
\frac{\partial \mathcal{U}_S(q_0, t_0, \sigma, \beta^*)}{\partial \sigma} &= \int \left[\frac{\partial u_S(q_0, t_0, \omega, \sigma, \beta)}{\partial \sigma} \right] dF(\omega) \\
&\leq \int [-c_\sigma(q^*, \omega, \sigma, \beta^*)] dF(\omega) \\
&\leq \int [-c_\sigma(q^*, \omega, \sigma^*, \beta^*)] dF(\omega) \\
&< \int [v_\sigma(q^*, \omega, \sigma^*, \beta^*) - c_\sigma(q^*, \omega, \sigma^*, \beta^*)] dF(\omega) \\
&= h_s'(\sigma^*), \\
&\leq h_s'(\sigma),
\end{aligned}$$

where the first inequality follows from (1), the second and last inequalities follow from the fact that $\sigma \geq \sigma^*$ (and $c_{\sigma\sigma}(\cdot) \geq 0$, $h_s''(\cdot) \geq 0$), and the strict inequality follows from Assumption 1′ (investment externalities).

The above string of inequalities implies that, when the buyer chooses β^*, the seller will strictly underinvest for any (q_0, t_0). Therefore, the first-best outcome can never arise for any (q_0, t_0). Q.E.D.

This result shows that the suggested noncontingent contract cannot solve the hold-up problem, thus serving as a counter-example of DF's Proposition 3. Admittedly, this counter-example covers only a subset of the circumstances DF considered (in that Assumptions 1′, 2′, and 3′ are used additionally), but the subset constitutes a economically meaningful and plausible set of circumstances, as argued above. Moreover, the way the result is overturned is remarkable: efficiency fails whenever the seller's investment has externalities, *no matter how small they are*. From this point follows the next result which says that, if the externalities are sufficiently important, not only is the contract unable to induce the first-best choice, it generates virtually no incentive for the seller.

PROPOSITION 2. *Given Assumptions* 1′ *through* 4′,

$$\sup_{q_0, \beta} \sigma(q_0, \beta) \to 0 \textit{ as } \epsilon \to 0.$$

Proof. This result follows since, by (1),

$$\begin{aligned}
\frac{\partial \mathcal{U}_S(q_0, t_0, \sigma, \beta)}{\partial \sigma} &\leq \int [-c_\sigma(q^*, \omega, \sigma, \beta)] dF(\omega) \\
&< \epsilon,
\end{aligned}$$

where the last inequality follows from Assumption 4′. Q.E.D.

Can Proposition 3 of DF ever hold? We next address this issue by finding its sufficient conditions. These conditions say that either the seller's investment must have no external effects or else Assumption 3′ must be violated in a drastic fashion: i.e., either the seller's investment *lowers* the marginal value or *increases* the marginal cost of production sufficiently rapidly for some quantity level.

PROPOSITION 3. *There exists a contract term that yields the first-best outcome, if (i) $v_\sigma(\cdot) = 0$, or (ii) there exists $q' \geq \sup_{\omega,\sigma} q^*(\omega, \sigma, \beta^*)$ such that $\int v_\sigma(q', \omega, \sigma, \beta^*)dF(\omega) = 0$ for all $\sigma \leq \sigma^*$ or (iii) there exists $q'' < \sup_{\omega,\sigma\leq\sigma^*} q^*(\omega, \sigma, \beta^*)$ such that $-E[c_\sigma(q'', \omega, \sigma, \beta^*)|q^* > q''] > M$ for a sufficiently high $M > -E[c_\sigma(q^*, \omega, \sigma, \beta^*)|q^* > q'']$, for all $\sigma \leq \sigma^*$.*

Proof. We show that $\sigma(q_0, \beta^*) = \sigma^*$ for some q_0 under each sufficient condition.

(*i*) $v_\sigma(\cdot) = 0$:
In this case, the third term of (1) vanishes. Now choose any $q_0 \geq \sup_{\omega,\sigma} q^*(\omega, \sigma, \beta^*)$. Since then $q_0 \geq q^*(\omega, \sigma, \beta^*)$ for all (ω, σ), the second term of (1) also vanishes. Hence,

$$\frac{\partial \mathcal{U}_S(q_0, t_0, \sigma, \beta^*)}{\partial \sigma} = -\int c_\sigma(q^*, \omega, \sigma, \beta^*)dF(\omega),$$

which is the correct social marginal return to the investment when $v_\sigma(\cdot) = 0$. Hence, $\sigma(q_0, \beta^*) = \sigma^*$.

(*ii*) *There exists $q' \geq \sup_{\omega,\sigma} q^*(\omega, \sigma, \beta^*)$ such that $\int v_\sigma(q', \omega, \sigma, \beta^*) dF(\omega) = 0$ for all $\sigma \leq \sigma^*$:*
In this case, choose $q_0 = q'$. It then follows from (1) that

$$\begin{aligned}
&\frac{\partial \mathcal{U}_S(q_0, t_0, \sigma, \beta^*)}{\partial \sigma} \\
&\quad = \int [v_\sigma(q^*, \omega, \sigma, \beta^*) - v_\sigma(q', \omega, \sigma, \beta^*) - c_\sigma(q^*, \omega, \sigma, \beta^*)]dF(\omega) \\
&\quad \begin{cases} = \int [v_\sigma(q^*, \omega, \sigma, \beta^*) - c_\sigma(q^*, \omega, \sigma, \beta^*)]dF(\omega) & \text{for } \sigma \leq \sigma^*, \\ \leq \int [v_\sigma(q^*, \omega, \sigma, \beta^*) - c_\sigma(q^*, \omega, \sigma, \beta^*)]dF(\omega) & \text{for } \sigma \geq \sigma^*. \end{cases}
\end{aligned}$$

From this the result follows.

(*iii*) *There exists* $q'' < \sup_{\omega,\sigma\le\sigma^*} q^*(\omega,\sigma,\beta^*)$ *such that* $-E[c_\sigma(q'',\omega,\sigma,\beta^*)|q^* > q''] > M$ *for a sufficiently high* $M > -E[c_\sigma(q^*,\omega,\sigma,\beta^*)|q^* > q'']$, *for all* $\sigma \le \sigma^*$:

In this case, choose $q_0 = q''$. Then, for any $\sigma \le \sigma^*$,

$$\begin{aligned}
&\frac{\partial \mathcal{U}_S(q_0,\sigma,\beta^*)}{\partial\sigma}\\
&\quad = \int_{\{q^*<q''\}} [v_\sigma(q^*,\omega,\sigma,\beta^*) - v_\sigma(q'',\omega,\sigma,\beta^*) - c_\sigma(q^*,\omega,\sigma,\beta^*)]dF(\omega)\\
&\qquad\qquad - \int_{\{q^*\ge q''\}} c_\sigma(q'',\omega,\sigma,\beta^*)dF(\omega)\\
&\quad > \int_{\{q^*<q''\}} [v_\sigma(q^*,\omega,\sigma,\beta^*) - v_\sigma(q'',\omega,\sigma,\beta^*) - c_\sigma(q^*,\omega,\sigma,\beta^*)]dF(\omega)\\
&\qquad + M\text{Prob}\{q^* \ge q''\}.
\end{aligned}$$

Since $\text{Prob}\{q^* \ge q''\} > 0$ by construction, for sufficiently large M, $\sigma(q'',\beta^*) \ge \sigma^*$. Since $\sigma(\cdot,\beta^*)$ is continuous (by the Berge's theorem of maxima) and $\sigma(0,\beta^*) \le \sigma^*$, there exists $q_0 \in [0,q'']$ such that $\sigma(q_0,\beta^*) = \sigma^*$ for such M. Q.E.D.

This result shows that DF's result holds primarily when the late mover's investment has no externalities. While the second and third conditions, (*ii*) and (*iii*), allow some externalities to exist, the investment must have either no external effect for some high level of q or a very large own effect for some low level of q.

3. DISCUSSION

The results in the preceding section cast doubt on the value of contracting in solving the hold-up problem when the specific investments have externalities. In this sense, these results are similar to those of Che and Hausch (1999), who also find contracting to be ineffective, and completely worthless in some extreme cases, when investment externalities are important (what they term "cooperativeness" of the investment). There are two differences in these findings, though. First, Che and Hausch (1999) assume the split-the-surplus renegotiation game while the current model adopts the HM specification. Second, while the inefficiency result (or the ineffectiveness of contracting) is shown in Che and Hausch (1999) for all feasible contracts (e.g., including the ones involving ex post message games), the negative results in the preceding section are shown for a fixed-quantity contract.[5] These two points beg the question: Is there any other contract arrangement, different from the one suggested by DF, that achieves efficiency?

We show below that there is indeed such a contract. Suppose that the buyer offers at date 1 a contract that specifies a menu of two prices (which can be negative)

$$p(q) = \begin{cases} p_1 & \text{if } q > 0, \\ p_0 & \text{if } q = 0 \end{cases}$$

to be paid by the buyer to the seller when they trade q. That is, it specifies a trade price of p_1 and a no-trade price of p_0. As in DF, these prices can be renegotiated (according to the HM specification) at date 4.[6] Choose (p_0, p_1) so that

$$v(q^*(\omega, \sigma, \beta^*), \omega, \sigma, \beta^*) < p_1 - p_0 \quad \forall(\omega, \sigma) \tag{2}$$

For any p_0, there exists p_1 that satisfies (2) since its left-hand side is finite for all (ω, σ). Enforcement of this contract requires the court to verify only whether the parties have traded or not, which is clearly feasible since q is verifiable.

Intuitively, condition (2) means that the buyer would prefer no trade to the efficient trade for all $(\omega, \sigma, \beta^*)$, if there were no renegotiation. Given this, the HM renegotiation specification implies that the efficient trade level $q^*(\omega, \sigma, \beta^*)$ arises ex post and that the renegotiated price level, $p^r(\omega, \sigma, \beta^*)$, makes the buyer indifferent to no trade, i.e.,

$$v(q^*(\omega, \sigma, \beta^*), \omega, \sigma, \beta^*) - p^r(\omega, \sigma, \beta^*) = -p_0 \quad \forall(\omega, \sigma). \tag{3}$$

(This argument, just like Proposition 1 of DF, is obtained as a simple extension of Proposition 1 of HM.[7]) Hence, if the buyer chose β^* and offered the contract satisfying (2), then the seller's gross expected payoff at the time of her investment is given by

$$\begin{aligned} U_S(\sigma, p_0) &\equiv \int [p^r(\omega, \sigma, \beta^*) - c(q^*, \omega, \sigma, \beta^*)] d\omega \\ &= \int [v(q^*, \omega, \sigma, \beta^*) - c(q^*, \omega, \sigma, \beta^*)] d\omega + p_0, \end{aligned}$$

where the equality follows from (3). The seller becomes a residual claimant at the margin (now relative to a fixed payoff), so it immediately follows that,

[5]The sequential investment feature in DF does not constitute a critical difference in comparison with Che and Hausch (1999), as argued below.

[6]This contract is very similar to the one considered by HM. The difference is that the current contract does not specify the trade level, whereas this issue is moot in HM because of their binary trade structure.

[7]The presence of multiple trade levels means that there may exist other, Pareto-dominated, renegotiation equilibria. See Lülfesmann (1998) (Proposition 1) for a renegotiation analysis for a similar situation.

as long as p_0 satisfies $U_S(\sigma^*, p_0) \geq h_s(\sigma^*)$, the seller will choose σ^*. Now choose p_0^* so that $U_S(\sigma^*, p_0^*) = h_s(\sigma^*)$ and choose $p_1 = p_1^*$ so that (2) holds given $p_0 = p_0^*$. By choosing β^* and offering a menu of (p_0^*, p_1^*), then the buyer obtains the net expected payoff of $\int[v(q^*, \omega, \sigma^*, \beta^*) - c(q^*, \omega, \sigma^*, \beta^*)]dF(\omega) - h_b(\beta^*) - h_s(\sigma^*)$. Since the latter payoff constitutes an upper bound for the buyer's payoff, any deviation on his part (in terms of his investment or contract offering or both) can only lower his payoff. We thus conclude the following result.

PROPOSITION 4. *Given Assumptions* 1, 2, 3, *and* 4 (*of DF*), *the first-best outcome can be attained by a subgame perfect equilibrium involving a menu contract specifying* (p_0^*, p_1^*); *i.e., it is a subgame perfect equilibrium for the buyer to choose* β^* *and offer a menu* (p_0^*, p_1^*) *and for the seller to choose* σ^* *and trade* $q^*(\omega, \beta^*, \sigma^*)$.

One can easily confirm that $p_0^* < 0$ and $p_1^* > 0$, which can be interpreted in practical terms as the seller paying damages of $-p_0^*$ in the event of no trade ("breach by the seller") and the buyer paying price of p_1^* in the event of trade ("contract honoring"), absent renegotiation. In other words, this new contract can be implemented by a liquidated damage clause.[8]

Finally, some remark on the implication of this efficiency result seems warranted. Proposition 4 joins authors such as Chung (1991), Rogerson (1992), Hermalin and Katz (1993), MacLeod and Malcomson (1993), Aghion, et al. (1994), Nöldeke and Schmidt (1995), Edlin and Reichelstein (1996), and Maskin and Tirole (1999) in showing that contracts can solve the hold-up problem under certain circumstances. Its added scope—that is, the fact that it allows for investment externalities—is noteworthy.[9] It is important, however, to note that the current efficiency result requires all three behavioral assumptions (1) sequential investment, (2) the full-bargaining power of the first mover, and (3) the HM renegotiation specification, as necessary ingredients. In particular, since the combination of (1) and (2) trivially solves the first mover's investment problem, the crucial assumption is the renegotiation specification. If the parties were to renegotiate according to the split-the-surplus specification instead, then inefficiency persists under any contract, in the presence of large investment externalities.[10]

[8]In fact, liquidated damages clauses are much more common than a specific performance clause which the contract suggested by DF would have required.

[9]An exception is MacLeod and Malcomson (1993) who considered a similar contract that exploits switching to a third party as an outside option.

[10]Given (1) and (2), the subgame starting at date 1 is precisely the same, except for the renegotiation specification, as the game considered by Che and Hausch (1999) in which the seller alone invests. See Corollary 3 of Che and Hausch (1999) for an inefficiency result with the split-the-surplus specification in this case.

REFERENCES

Aghion, P., Dewatripont, M., and Rey, P. (1994). "Renegotiation Design with Unverifiable Information," *Econometrica* **62**, 257–282.

Che, Y.-K., and Hausch, D. B. (1999). "Cooperative Investments and the Value of Contracting," *Amer. Econom. Rev.* 125–147.

Chung, T.-Y. (1991). "Incomplete Contracts, Specific Investments, and Risk Sharing," *Rev. Econom. Stud.* **58**, 1031–1042.

De Fraja, G. (1999). "After You Sir, Hold-Up, Direct Externalities, and Sequential Investment," *Games Econom. Behav.* **26**, 22–39.

Edlin, A. S., and Reichelstein, S. (1996) "Holdups, Standard Breach Remedies, and Optimal Investment," *Amer. Econom. Rev.* **86**, 478–501.

Hart, O. D., and Moore, J. (1988). "Incomplete Contracts and Renegotiation," *Econometrica* **56**, 755–785.

Hart, O. D., and Moore, J. (1999). "Foundations of Incomplete Contracts," *Rev. Econom. Stud.* **66**, 115–138.

Hermalin, B. E. and Katz, M. L. (1993). "Judicial Modification of Contracts between Sophisticated Parties: A More Complete View of Incomplete Contracts and Their Breach," *J. Law, Econom. Org.* **9**, 230–255.

Lülfesmann, C. (1998). "Incomplete Contracts, Non-Verifiable Quality and Renegotiation," mimeo, University of Bonn.

Maskin, E., and Tirole, J. (1999). "Unforeseen Contingencies and Incomplete Contracts," *Rev. Econom. Stud.* **66**, 83–114.

MacLeod, B., and Malcomson, J. (1993). "Investments, Holdup and the Form of Market Contracts," *Amer. Econom. Rev.* **83**, 811–837.

Nöldeke, G., and Schmidt, K. M. (1995). "Option Contracts and Renegotiation: A Solution to the Hold-Up Problem," *RAND J. Econom.* **26**, 163–179.

Rogerson, W. P. (1992). "Contractual Solutions to the Hold-Up Problem," *Rev. Econom. Stud.* **59**, 777–793.

Segal, I. (1999). "Complexity and Renegotiation: A Foundation for Incomplete Contracts," *Rev. Econom. Stud.* **66**, 57–82.