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Self-Enforcing Union Contracts: Efficien Investment and Employment*

Baldwin (1983) asks whether a fir can credibly deter union opportunism that would lead to underinvestment. We show that the punishments Baldwin considers credible exclude tougher threats that only have the appearance of being self-destructive. If the firm' discount factor is sufficientl close to one, union opportunism can indeed be deterred. Moreover, we show that given the firm' discount factor, a shorter lifetime of capital does not necessarily promote effi ciency. Although, as Baldwin emphasizes, it does enhance the firm' ability to punish union opportunism, it also creates adverse incentives for the fir to engage in opportunistic employment cuts.

I. Introduction

Carliss Baldwin's ''Productivity and Labor Unions: An Application of the Theory of Self-Enforcing Contracts'' (1983), provides a rich set of strategies firm might employ to counter union opportunism in the context of long-lived relation-specifi capital. This work both anticipated and in an important (dynamic) sense outflanke the collective voice view of unionism (e.g., Freeman and Medoff 1984) and the ensuing slew of union productivity effects studies (e.g., Addison and Hirsch 1989). Our purpose here is to update Baldwin's influentia work, renewing it to incorporate advances in game theory that have taken hold since 1983.

Baldwin's work has had staying power because it is a leading-edge application of the idea that long-term interests can form the foundation for credible self-enforcement of contracts. Her core conclusion is that the union's temptation for opportunistic conduct is strongest if the life of sunk capital is long in relation to the union's horizon. Because unions represent current membership and property rights in the union are not transferable, these tendencies are likely to prevail.

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Baldwin provides a variety of ingenious remedies. These include the use of inefficien capacity to make substantial cuts in employment, a short-run profit-maximizin response to wage demands. Other proposed counterstrategies include a variety of measures designed to extend the union's horizon and thereby avoid the use of an inefficien defense by the firm

The debate over the efficienc of union contracts has long been dominated by a separate literature that takes capital to be exogenous and focuses on the temptation of the fir to make an opportunistic cut in employment. Espinosa and Rhee (1989) bridge the underlying monopoly-union and efficien contracts models in this literature by showing that in a repeated game setting efficien self-enforcing contracts are guaranteed to exist, provided the fir is sufficientl patient. There is some irony here. Although Baldwin neglects opportunism by the firm her application of repeated games to investment did predate their application to union employment.

Our update of Baldwin incorporates the potential for opportunistic behavior *from both sides* by extending the repeated game of Espinosa and Rhee (1989) to include sunk capital. We conclude that with suffi cient patience on the part of the fir self-enforcing contracts will exist that are efficien with respect to employment and investment. This bottom-line result is of course sharply at odds with Baldwin in that it holds irrespective of the union's horizon or the productive life of capital.

One key to this result lies in the natural order of play. The fir observes the wage demand before selecting the concurrent level of employment, thereby permitting immediate punishment of union opportunism. In Espinosa and Rhee (1989) retaliating to wage breaches simply by choosing employment to maximize profi will deter union opportunism in any of the set of efficient-contrac core of outcomes that are mutually acceptable relative to the monopoly union equilibrium. With exogenous capital this set is nonempty.

Even with endogenous capital, there are conditions under which an immediate one-period relocation to the labor demand curve is adequate to enforce an efficien contract acceptable to the firm Echoing Baldwin, there are also conditions in which they will not because the fir find it privately advantageous to cope with union opportunism up front by underinvesting. Further echoing Baldwin, the firm' ability to deter union malfeasance is strengthened if capital is finitel durable, provided the union places some weight on the future. Following an extortionate union wage demand, the fir can reduce investment and in so doing carry forward a deeper employment penalty into the future.

But capital flexibilit is a two-edged sword: there is also the possibility that the finit durability of capital will itself cause inefficiency Suppose that efficien employment and investment would obtain with perfect durability. With finit durability, the fir may lose the incentive to honor the contract if its discount factor is not sufficientl close to one. The cost to the fir of losing the union's trust is no longer so severe because the fir can counter by reducing investment.

Baldwin rightly requires that retaliation to union opportunism be credible. Relocating to the labor demand curve if the union cheats is a credible form of punishment by the firm Baldwin sees tougher punishment as self-destructive and thus not credible. However, the logic of the cost of future consequences applies not only to breach of contract but also to the credibility of enforcement mechanisms. If its discount factor is sufficientl close to one, the fir will defend a reputation for toughness, a reputation for immediate cuts in employment severe enough to remove the union's temptation to cheat.

This insight implies that even unions with no concern for future consequences can be deterred from cheating. Baldwin's remedies for effi cient deterrence of union opportunism all boil down to extending the union's concern for punishment into the future. On our analysis, these remedies are a substitute for a fir discount factor that is not suffi ciently close to one.

The one-shot game that forms the foundation of our analysis is set out in Section II. The focus of Section III is to establish a common metric for the subsequent discussion of repeated play. Section IV then examines Espinosa and Rhee's (1989) result in the context of repeated play of the one-shot game, while sections V*A* and V*B* consider on-the-demand punishment with perfectly durable and finitel durable capital, respectively. Section VI introduces the innovation of more severe fir punishment of opportunistic behavior on the part of the union. Section VII concludes.

II. The One-Shot Game

A one-period multistage game forms the foundation for the repeated game analysis to follow.[1] This one-period game extends the monopoly-union model of wage and employment determination by including capital as an additional endogenous variable. There are two players, the fir and the union. The firm' objective is to maximize profi

$$\pi(w, N, K; r) = R(N, K) - wN - rK,$$

where N = labor, K = capital, $R(N, K)$ = revenue, w = wage, and r = rental price of capital. Exogenous to the model, r appears after a

1. Similar one-period models have been considered by Anderson and Devereux (1988) and Hirsch and Prasad (1995).

semicolon to distinguish it from the endogenous variables. It is assumed that the firm’ revenue function $R(N, K)$ is strictly concave, that $R_N(N, K) > 0$ and $R_K(N, K) > 0$, and that $R_{NK}(N, K) > 0$.

The union’s objective is to maximize utility $U(w, N)$. To simplify matters, its utility function is assumed to take the familiar union-rent form

$$U(w, N) = (w - w_0)N,$$

where w_0 is the competitive market wage. The workers can and will leave the fir if wage falls below the competitive wage. In the relevant region $w \geq w_0$, the union-rent utility function is quasiconcave.

The order of play in the one-shot multistage game is

$$\text{fir chooses } K \rightarrow \text{union chooses } w \rightarrow \text{fir chooses } N.$$

That is, the fir moves first choosing K. Observing K and taking it as given, the union moves second and sets w. Finally, knowing K and w, the fir chooses N in the third stage. The last two moves follow the order of play in the monopoly-union model in which the union sets the wage unilaterally but the firm retaining the right to manage, determines employment. Appending the firm’ investment in K as the firs move of the extended model captures the notion that capital is relatively inflexible thereby possibly exposing the fir to subsequent holdup by the union.

A strategy for a player is a complete set of instructions specifying what the player would do in each possible contingency. In the one-period model, a strategy for the union expresses the wage as a function of capital. For the fir in this one-period model, a strategy designates a level of capital and specifie employment as a function of capital and the wage. Nash subgame-perfect equilibrium is adopted as the solution concept both for this one-period model and in the subsequent repeated-game analysis. Under the Nash requirement, each player’s strategy must be a best response to the other’s strategy. Subgame perfection rules out strategies that embody incredible threats. Specifically a threat is credible only if the player would be prepared to carry it out if called on to do so. Credible mutual best responses can be thought of as forming a self-enforcing contract.

Before turning to the determination of the equilibrium, some preliminary results and notation regarding factor demand and efficienc will prove useful. First, contrary to the order of play given, suppose the fir chooses N and K taking the prices w and r as given. The firm’ choices will satisfy the profit-maximizin first-orde conditions of a competitive firm

$$R_N(N, K) = w \tag{1}$$

and

$$R_K(N,\ K) = r. \tag{2}$$

The long-run labor and capital demands, $LN(w;\ r)$ and $LK(w;\ r)$, solve the system (1) and (2). Each demand has the familiar property that the quantity of the factor demanded is decreasing in its own price. Solving equation (1) alone for employment yields the short-run labor demand function $N = SN(w;\ K)$, the semicolon signifying that K is given in the short run. It, too, has the property that employment and the wage are inversely related. Further, because $R_{NK}(N,\ K) > 0$, $SN(w;\ K)$ increases with an increase in K. In addition, it is well known that $SN[w;\ K(w';\ r)] = LN(w;\ r)$ evaluated at $w = w'$ and that at this point of coincidence the short-run demand for labor is less elastic than the long-run demand.

The efficien $(w,\ N)$ pairs for a *given* K lie on the contract curve of tangencies between the iso-profi and iso-utility curves. Specifically the tangency condition under the rent maximand is

$$-[R_N(N,\ K) - w]/N = -(w - w_0)/N, \tag{3}$$

where the left-hand side is the short-run iso-profi slope and the right-hand side is the iso-utility slope. As is easily confirme from (3), under the union-rent utility function, the contract curve is vertical at the competitive-equilibrium employment level $SN(w_0;\ K)$, the solution to (1) evaluated at $w = w_0$. Thus, the competitive employment level is the efficien level as well.

For a given level of capital, K_A, the relations among the short-run labor demand, the iso-profi contours, the iso-utility contours, and the contract curve are illustrated in figur 1. The function $SN(w;\ K_A)$ is the short-run labor demand curve. The quantity demanded at the competitive wage, $SN(w_0;\ K_A)$, then identifie the position of CC_A, the contract curve given K_A. Representative iso-profi and iso-utility contours have also been included.[2]

Since the union's payoff does not depend directly on capital, the efficien level of capital is simply the profit-maximizin choice as determined by equation (2). Thus, the efficien levels of labor and capital happen to be the competitive-equilibrium levels, the solution to (1) and (2) with w in (1) set equal to w_0. Denote these $N^* = LN(w_0;\ r)$ and $K^* = LK(w_0;\ r)$.

With these preliminaries completed, next consider the determination

2. As indicated by the arrow in fig 1 pointing toward the northeast, union utility is increasing in w and N (in the relevant region, $w \geq w_0$). Given N, the firm' profi increases with a fall in w. Given w, profi increases as employment moves toward the demand curve. Thus, the downward pointing arrow in fig 1 is a shorthand to indicate the firm' preference for moving toward inner–nested iso-profi contours. Further, each iso-profi curve has a slope of zero where it crosses the demand curve.

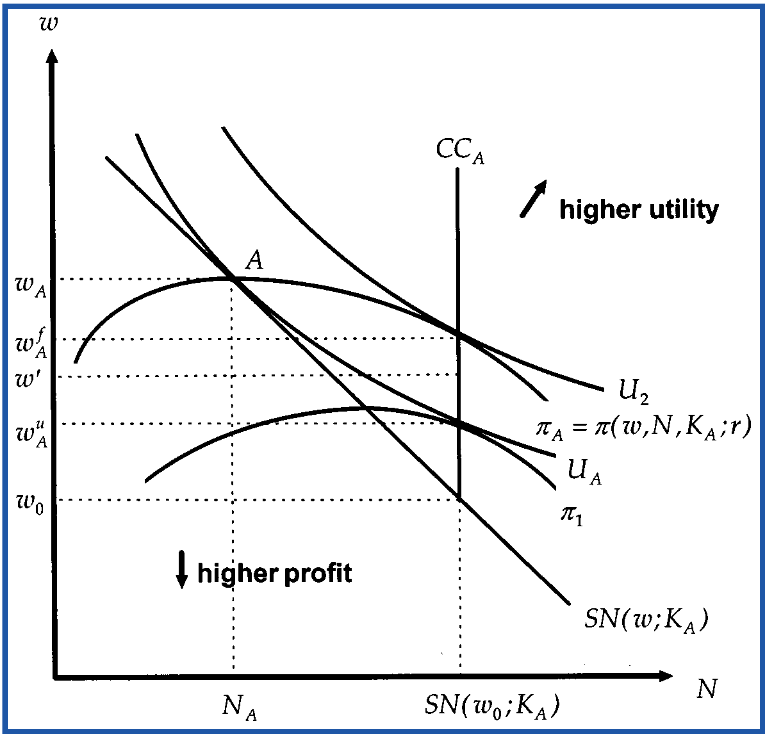

FIG. 1.—The monopoly-union equilibrium, *A,* and the contract curve showing efficien employment given K_A.

of a Nash subgame-perfect equilibrium of the one-period model. The credibility condition is implicit in the familiar solution given for the monopoly-union model of wage and employment determination. For a given $K = K_A$, and facing a price w, the firm’ only credible choice of employment is dictated by the first-orde profit-maximizin condition (1), the short-run labor demand $SN(w;\ K_A)$. As it is illustrated in figur 1, given K_A, the monopoly-union equilibrium (w_A, N_A) is characterized by the tangency at point A between the iso-utility curve U_A and the short-run labor demand curve $SN(w;\ K_A)$. Foreseeing that the fir will choose N to maximize profit the union chooses w in order to maximize utility subject to the constraint $N = SN(w;\ K_A)$.[3]

3. Not all Nash equilibria are subgame perfect. Consider the strategies $w = w_0$ and N solves $R_N(N, K) = w_0$ if $w = w_0$, and $N = 0$ otherwise. These are Nash best replies for the monopoly-union game, given capital. They also produce the competitive wage and employment outcome, the most desirable outcome the fir can attain given that labor can always quit to earn at least the competitive wage. However, despite what the fir desires, if it was faced with a wage other than w_0, its only credible reply would be to set employment according to $N = SN(w;\ K)$, not $N = 0$.

In figur 1 the iso-profi contour $\pi_A = \pi(w, N, K_A; r)$ has a slope of zero at point A on the demand curve. So it must cross the iso-utility curve that is tangent to labor demand at point A, demonstrating that relative to any given K the monopoly-union equilibrium employment will be inefficientl low. Conditional on K_A, there exists a nonempty subset of efficien allocations that is mutually preferred to A. In figur 1, these mutually preferred efficien allocations, or core, lie on the contract curve CC_A at wages between w_A^f and w_A^u on the wage axis. Using A as the comparator, moving along the isoprofi contour $\pi_A = \pi(w, N, K_A; r)$ to its intersection with CC_A determines w_A^f, the highest wage the fir is willing to pay at the efficien level of employment. Likewise, again using A as the comparator, moving the iso-utility curve U_A to its intersection with CC_A determines w_A^u, the lowest wage the union would accept at the efficien level of employment. To anticipate later results, efficien employment at wages between these *reservation wages* w_A^f and w_A^u cannot be achieved under a monopoly-union equilibrium, but these allocations are certainly candidates for support in a repeated-game equilibrium.

As seen above, each choice of capital will yield a monopoly-union wage and employment pair. That is, each K will imply its own short-run labor demand, and each such labor demand will have an associated, tangent iso-utility curve. In figur 2, the locus of these equilibria is labeled *MUE,* for monopoly-union equilibria. Two such equilibria are illustrated: point A from figur 1, and another point T, the monopoly-union equilibrium associated with $K = K_T$. Note that because $SN(w; K_A)$ lies below $SN(w; K_T)$ in figur 2, it follows from assumptions that $K_A < K_T$.

Now the slope of *MUE* cannot be signed. It will be assumed its slope is positive, implying (as is plausible) that the greater is capital, the higher will be employment and wages.[4]

By its choice of K the fir determines which monopoly-union equilibrium along *MUE* will obtain. Anderson and Devereux (1988) provide a clever way of geometrically illustrating the equilibrium of the full one-shot game as a tangency between *MUE* and an appropriately constructed iso-profi contour. The trick is to recognize that first-orde condition (1) for the profit-maximizin employment of labor is always true in equilibrium and then to use it to determine *K, not N,* as a function of N and w. (Whatever values of N and w emerge in equilibrium, (1) must hold and K can be inferred.) Label this function $K^1(w, N)$ to signify that K solves equation (1). Profi can then be determined from the

4. The slope of *MUE* is

$$\frac{-R_{LK}(R_{LL} + LR_{LLL}) + LR_{LL}R_{LLK}}{R_{LK} + LR_{LLK}}.$$

The ambiguity of its sign corresponds exactly to the ambiguous effect a shift in demand

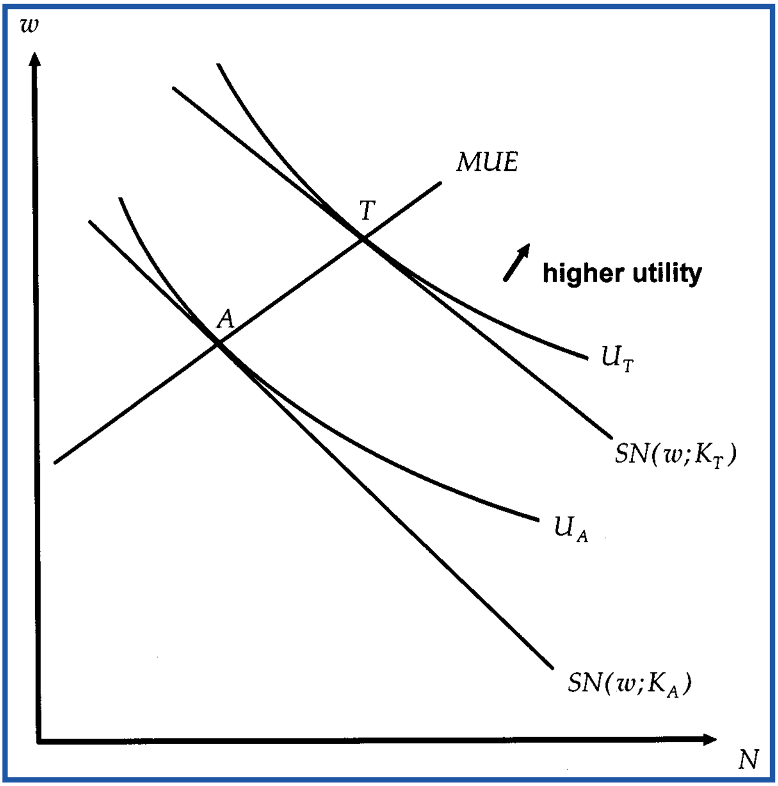

FIG. 2.—The locus of monopoly union equilibria, *MUE,* generated by varying capital.

composite function, $\pi[w, N, K^1(w, N); r]$, from which iso-profi contours in (w, N) space can be defined These contours will of course differ from the short-run iso-profi curve family for which K is given.

The equilibrium of the one-shot game can thus be determined graphically in figur 3 in which the *MUE* locus is carried over from figur 2. Long-run labor demand $LN(w; r)$ and two key short-run labor demands are included. As mentioned earlier, at a point of intersection of a short-run demand curve with long-run demand, short-run demand is less elastic—and so the schedules cross only once. The curves π_E and π_F are representative iso-profi contours for the profi function $\pi[w, N, K^1(w, N); r]$. These iso-profi contours display the same features with respect to the long-run demand for labor as do capital-fixe iso-profi

(in this case a change in capital shifts short-run labor demand) will have on the price (wage) set by a monopoly.

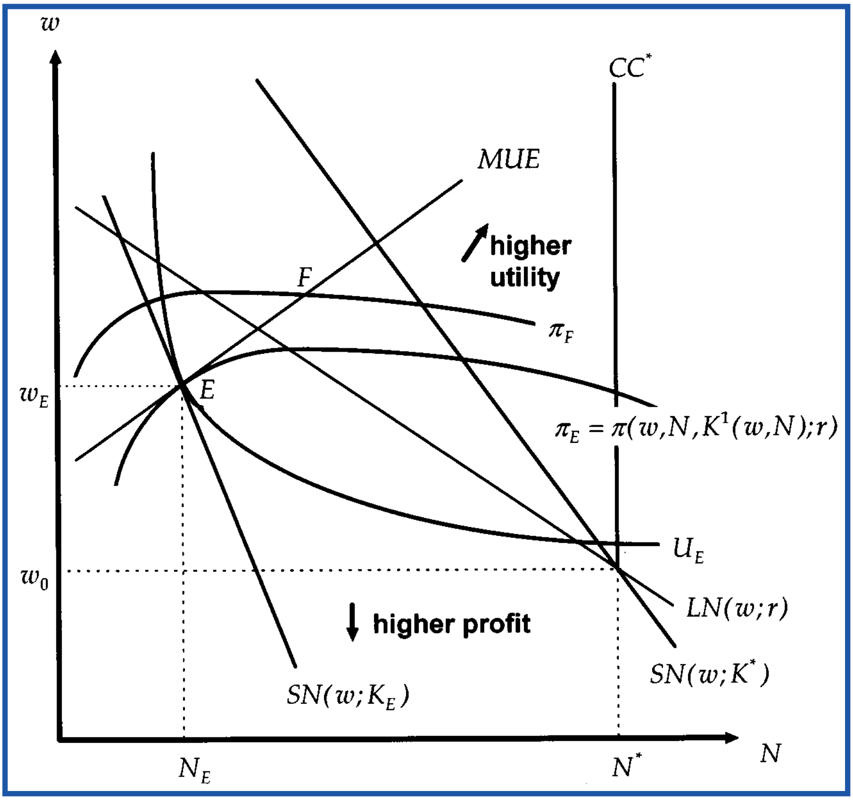

FIG. 3.—The inefficienc of the one-shot capital-firs equilibrium *E*

contours with respect to the short-run demand.[5] In deciding how much to invest, the fir moves along *MUE* until it reaches tangency *E* between π_E and *MUE,* with the implication that equilibrium capital is $K_E = K^1(w_E, N_E)$. Higher levels of profi cannot be attained within the constraint of the model of union wage and employment determination.[6]

5. That is, they have positive (negative) slope to the left (right) of long-run demand, and zero slope where they cross that demand. As before, the firm' profi increases as it moves to lower iso-profi contours.

6. The interpretation due to Hirsch and Prasad (1995) is instructive, and for some readers perhaps more intuitive. Express the locus *MUE* in parametric form $[w(K), N(K)]$. The firm' problem reduces to the maximization of $\pi(w(K), N(K), K; r))$. The first-orde condition for this problem is

$$[R_N - w(K)]dN/dK + [R_K - r - (dw/dK)N] = 0.$$

From (1) the firs term is zero, leaving $R_K = r + (dw/dK)N$. With a positively sloped *MUE*, $dw/dK > 0$: the fir faces an effective price of *capital,* $r + (dw/dK)N$, greater than the market rate r. At this effective price, the long-run demand for *labor* passes through *E* and lies below the long-run demand at a price of capital of r. The monopoly union, in essence, not only drives up the price of labor but also that of capital.

Finally, now that the full equilibrium has been determined, what of the efficienc of capital? As was established earlier, the unique efficien combination of labor and capital (N^*, K^*) is determined by first-orde conditions (1) and (2) with the wage set equal to the competitive level w_0. Along long-run demand $LN(w; r)$ in figur 3 the first-orde conditions (1) and (2) hold simultaneously. Thus, at the competitive wage w_0 the long-run demand curve determines N^*. The contract curve CC^* is accordingly positioned vertically at N^* in figur 3, while the identity $SN[w; K(w; r)] = LN(w; r)$ is used to establish the position of $SN(w; K^*)$ relative to the long-run demand. Note also that, because short-run demand is less elastic than long-run demand, $SN(w; K_E)$ lies below $SN(w; K^*)$. Thus, because short-run demand follows the marginal revenue product of labor R_N, and $R_{NK} > 0$, the implication is $K_E < K^*$. By the standard of efficiency both capital and labor are underutilized in the equilibrium of the one-shot game. The extent to which the efficien outcome (N^*, K^*) can be sustained in a repeated-game context is the subject of the balance of the article.

III. Repeated Play: Preliminaries

In subsequent sections, three alternative repeated games are considered. The firs of these is repeated play of the monopoly-union model taking capital to be exogenous. This is the repeated game considered by Espinosa and Rhee (1989). The second variant extends the firs by appending at the outset a once-and-for-all choice of capital by the firm Here, the natural interpretation is that capital is perfectly durable and irreversible. Also an extension of the first the third variant is, strictly speaking, the repeated game of the one-shot game of Section II. Capital lasts one period and is chosen by the fir at the outset of each period.

To maintain comparability among the one-shot game and the two variants of repeated play with endogenous capital, the price of capital is expressed in terms of its rental price r per period. As a consequence, the efficien mix of labor and capital remains (N^*, K^*), the same as in the one-shot game. In particular, by holding constant the rental price of capital r, the firm' discount factor δ will have no effect on the efficien level of capital. The roles that the discount factor of the fir and the lifetime capital play *strategically* in sustaining an efficien equilibrium can thereby be addressed without ambiguity. It is well known that, for a given price of capital of a given lifetime, a decrease in the discount factor decreases the present value of the stream of capital services, thereby reducing the level of capital preferred by the firm The analysis here instead takes the rental price for the services of capital as given, and therefore the efficien level of capital is the same throughout the analysis. The price of capital is not independent but is inferred from the exogenously given rental price and discount factor.

The firm' objective at date t is to maximize the discounted sum of profits $\sum_{s=t}^{T} \delta^s \pi(w_s, N_s, K_s; r)$, where $\delta < 1$ is the aforementioned discount factor of the fir and T is the firm' time horizon.[7]

For the union objective at date t, two alternative specification are considered. One is to assume the union has its own discount factor $\delta_u < 1$ and a horizon T matching that of the firm Then, its objective is $\sum_{s=t}^{T} \delta_u^s U(w_s, N_s)$. In the second specification the union has a horizon of just one period so that the objective of the union is simply $U(w_t, N_t)$. Equivalently, the second specificatio is a specialization of the firs in which the union's discount factor is zero.

As in the one-shot game, the equilibrium concept of subgame perfection will also be applied to the repeated games. Note that subgame perfection means that the fir and the union are constrained by their own future objectives even if their discount factors are not zero. This is the reason for specifying the objectives not just at the start of the game but at every date.

In what follows, the horizon T is replaced with infinity For a finit horizon it is well known that if the equilibrium of the one-shot game is unique, as it is here, then the repeated game equilibrium outcome will in each period duplicate this one-shot equilibrium (e.g., Telser 1980). The reason is that the last period of play is identical to a one-shot game. Recognizing that the last period of play has a unique equilibrium that is not influence by earlier moves, the penultimate period also is equivalent to the one-shot game. Continuing back in this way, every period is identical to a one-shot game. In the monopoly-union context this precludes the possibility of an efficien outcome. Our subsequent analysis will, therefore, focus exclusively on infinitel repeated play.

Finally, only stationary equilibria will be considered—that is, for all t, $(w_t, N_t, K_t) = (w, N, K)$. Note that the assumptions of the model imply efficien equilibria are stationary in employment and capital.

7. The discount factor corresponds in continuous time to $\delta = \exp(-\rho D)$, where D is the length of the period and ρ is the firm' rate of time preference. It is plausible to suppose that the rate of time preference of the fir equals the market rate of interest. References below to the feasibility of cooperative outcomes "for a discount factor sufficientl close to one" can be interpreted to mean "for rates of time preference or length of period suffi ciently close to zero." Game theorists typically regard the length of the period and the rate of time preference as beyond the scope of their analysis. Nevertheless, as a referee has pointed out, the results derived below do suggest two intriguing possibilities. First, if the length of the period is interpreted as the wage-contract length, then there are mutual benefit to *negotiating* a *shorter* contract length. Second, if the market rate of interest determines the rate of time preference, then the larger the market rate, the less likely is an efficien outcome.

IV. Exogenous Capital

In Espinosa and Rhee (1989), the one-shot monopoly-union game is infinitel repeated. Although capital is exogenous, their results provide a useful stepping stone to the analysis of endogenous capital.

Let capital take any arbitrary value K_A. Refer to figur 1. What Espinosa and Rhee show is that, for any efficien allocation on the contract curve CC_A between w^u_A and w^f_A, the efficien allocations mutually preferred to the one-shot equilibrium A can be supported in equilibrium provided the firm' discount factor is close enough to one.

To review their results, consider the following strategies:

$$
\begin{aligned}
N_t &= SN(w_0;\, K_A) \quad \text{if } w_t = w' \text{ and the action } N_s = SN(w_0;\, K_A) \text{ has} \\
&\qquad\qquad\qquad\quad \text{been taken each time that } w_s = w' \text{ for } s < t, \\
N_t &= SN(w_t;\, K_A) \quad \text{otherwise;}
\end{aligned}
$$

and

$$
\begin{aligned}
w_t &= w' \quad \text{if the fir has always adhered to its strategy,} \\
w_t &= w_A \quad \text{otherwise.}
\end{aligned}
$$

If these strategies are used, then $[w', SN(w_0;\, K_A)]$ will be the outcome in each period. Also, let w' belong to the necessarily nonempty interval (w^u_A, w^f_A) as indicated in figur 1 so that the fir achieves greater profi and the union achieves greater utility than at point A, the one-shot equilibrium.

Under these strategies, any deviation by the union triggers on-the-demand punishment by the firm specifically a move back onto the firm' labor demand curve for that period only. A deviation by the fir triggers a permanent move to the monopoly-union equilibrium.

As long as the firm' discount factor is sufficientl close to one, these strategies will constitute an equilibrium. The sequencing of moves within a period permits the fir to condition employment on the contemporaneous wage, thereby enabling immediate retribution. At the wage $w' \geq w^u_A$, the simple threat to leave the contract curve CC_A in figur 1 and go to the demand curve for one period is adequate to deter the union—if it fails to choose w' in a period, the best it can achieve is its utility at A, which is no better than if it had not deviated. Importantly, irrespective of the union's horizon or its discount factor, the union's strategy is a best reply to the firm' strategy. And the firm' threat is credible. As can be seen in figur 1, beginning on CC_A at a given wage of w, the firm' profi is increasing as its employment declines until the short-run demand $SN(w;\, K_A)$ is reached. The fir can never do better in the current period than move to its demand curve, and under the strategies specifie above there are no future consequences if that move is triggered by a deviation by the union.[8]

And what of the firm' promise to choose $SN(w_0; K_A)$ if it faces the wage demand w'? Unlike punishment of the union, any punishment of the fir by the union (or unions) must rely on future, rather than immediate, consequences. Under the strategies specified if the fir ever chooses an employment level other than $SN(w_0; K_A)$ after the union has chosen w', then the union will react by demanding w_A in each subsequent period. This reaction can be interpreted as a permanent loss of trust in the firm The players all revert to playing their one-shot strategies, yielding outcome A in figur 1. These one-shot strategies are mutual best replies in the infinitel repeated game regardless of the history of play and are thus available to the players as a credible punishment. In short, the loss of trust in the fir is a self-fulfillin prophecy.

Having seen that the union will punish the firm it is left to check that this punishment will deter the fir from cheating. If the fir does cheat, its highest immediate payoff will be

$$\begin{aligned}\pi[w', SN(w'; K_A), K_A; r] &> \pi[w', SN(w_0; K_A), K_A; r]\\ &> \pi[w_A, SN(w_A; K_A), K_A; r],\end{aligned}$$

which is achieved by moving to the short-run demand curve. The effects of cheating can be traced using figur 1; the fir receives an immediate one-period gain by moving from CC_A to $SN(w'; K_A)$, albeit at the cost of a permanent reduction in the future stream of profi when the union duly reacts by raising the wage to w_A. For any $w' < w_A^f$, there exists a discount factor δ sufficientl close to one such that the punishment will exceed the gain. Specifically δ must satisfy

$$\begin{aligned}\frac{\pi[w', SN(w_0; K_A), K_A; r]}{1-\delta} &\geq \pi(w', SN(w'; K_A), K_A; r)\\ &\quad + \delta\left\{\frac{\pi[w_A, SN(w_A; K_A), K_A; r]}{1-\delta}\right\}\end{aligned} \tag{4}$$

or, rearranging,

$$\delta \geq \frac{\pi[w', SN(w'; K_A), K_A; r] - \pi[w', SN(w_0; K_A), K_A; r]}{\pi[w', SN(w'; K_A), K_A; r] - \pi[w_A, SN(w_A; K_A), K_A; r]}. \tag{5}$$

For any w' satisfying $w_A^u \leq w' \leq w_A^f$, therefore, there exists a δ such that an efficien outcome can be achieved as a self-enforcing equilibrium.

8. For more on efficien play between long-run and short-run players, a useful starting point is Kreps (1990).

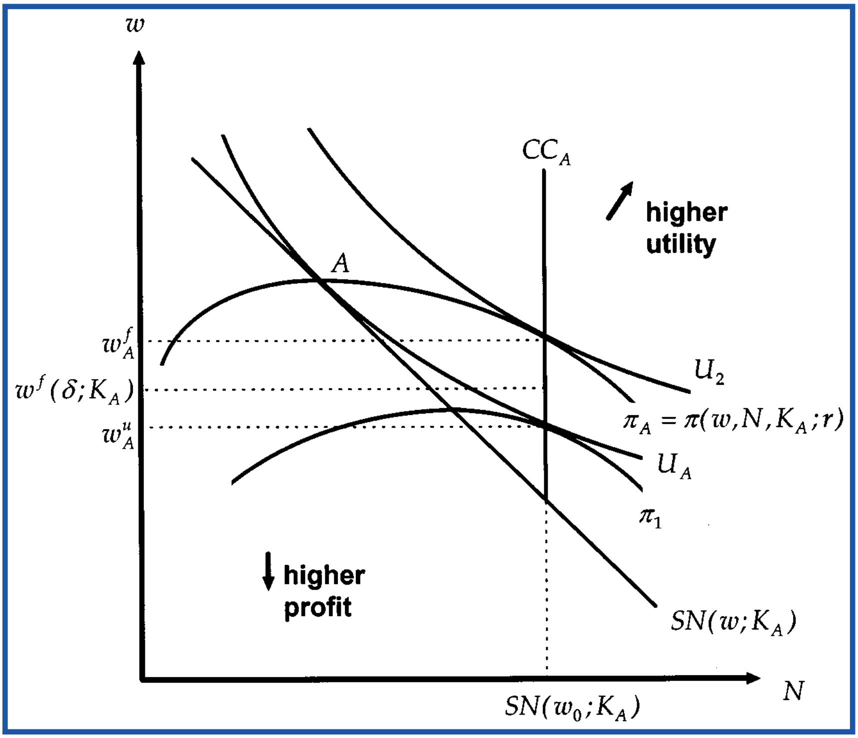

FIG. 4.—The sustainable set of efficien equilibria given K_A and δ

Alternatively, for a given δ, is there a *sustaining wage set,* a set of wages that will sustain efficien outcomes? Now, for $\delta = 0$, the sustaining wage set is empty. Under $\delta = 0$, condition (5) implies that the fir pays $w' = w_0$, which is in turn less than w_A^u, the lowest wage the union would accept at the efficien level of employment. It follows that a discount factor of zero is incompatible with efficiency Rather, there exists a critical value δ_c, such that for all δ in the interval $\delta_c \leq \delta < 1$ there is a nonempty sustaining wage set, a proper subset of the interval $w_A^u \leq w' \leq w_A^f$. Replacing the inequality in (5) with an equality and solving for w' define a function $w^f(\delta; K_A)$.[9] Values w_A^u and $w^f(\delta; K_A)$ are then the lower and upper bounds of the sustaining wage set. Figure 4 illustrates for the case $\delta \geq \delta_c$. The sustaining wage set is that portion of CC_A covering wages between w_A^u and $w^f(\delta; K_A)$. Note that if $\delta < \delta_c$, then the sustaining set is empty.[10]

9. Here it is assumed the right-hand side of (5) is monotonically increasing in w'.

10. Espinosa and Rhee (1989, p. 571) go on to show that a positive discount factor allows mutually beneficia improvements on the one-shot outcome, even if the discount

V. Endogenous Capital

A. Perfect Durability

The key insight in Espinosa and Rhee (1989) is that, because of the natural order of play, efficien outcomes can be achieved in equilibrium, even if only the fir has a long-run horizon. To what extent does this insight carry over once capital is endogenized?

Take Espinosa and Rhee's game tree and graft on to it an opening once-and-for-all choice of capital by the firm The natural interpretation is that capital is perfectly durable and irreversible. The fir commits to a perpetual lease at a per period rental price of r for each unit of capital. As discussed in Section III, expressing the cost of capital in terms of its rental price achieves comparability of the perfect durability case with the earlier one-shot model and with the later case of finitel durable capital.

For each value of capital, there follows a subgame that is the repeated game of the exogenous capital model just considered. Subgame perfection implies that play from that point must itself be a Nash subgame-perfect equilibrium.

If an equilibrium is to be efficient play subsequent to the installation of K must be efficien if the efficien level of capital K^* is chosen. Once K^* has been sunk, the preceding analysis of exogenous capital can be applied. Given a w', there is a minimal δ required to achieve efficien employment. Or, alternatively, δ must exceed a critical value in order for the sustainable set of efficien equilibria to be nonempty.

However, the fir must also fin it attractive to choose K^* over any other K. Suppose that if K^* is not chosen the players go permanently to the one-shot monopoly-union equilibrium associated with the chosen K. (Again, this is always one equilibrium of such a subgame.) The best outcome for the fir amongst these alternatives ($K \neq K^*$) is the one-shot endogenous capital outcome, namely, point E in figur 5, which carries over from figur 3.

As can be seen from figur 5, the fir can guarantee itself more profi at E than it can achieve at point T, the one-shot equilibrium associated with K^*. As a result, some of the efficien outcomes that can be supported in the repeated game *given* K^* might not be achievable when capital is endogenous. To induce the fir to select K^* adds a further limitation: the fir must earn at least $\pi_E = \pi(w_E, N_E, K^1(w_E, N_E); r)$, not just $\pi_T = \pi(w_T, N_T, K^*; r)$.

factor is not sufficientl large to support an efficien outcome. As pointed out earlier, the discount factor depends on the rate of time preference and the length of a period (which can be interpreted as the contract length). If the rate of time preference equals the market rate of interest, then the discount factor can be computed from observable variables. But in order to quantify the effect these variables have on the sustainable set, the entire model would have to be parameterized.

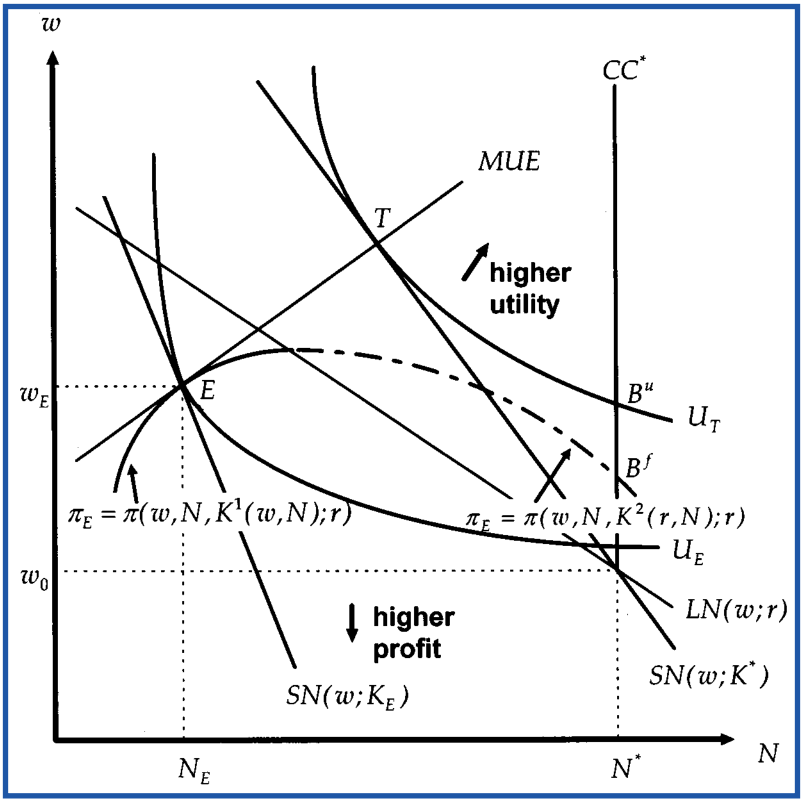

FIG. 5.—Efficiency durability, and the repeated game

Figure 5 illustrates. The iso-profi contour π_E is a hybrid. Below $LN(w;\ r)$, it is drawn for K satisfying equation (1). Recall that this is done in order to fin the one-shot endogenous capital equilibrium point E. But above the long-run demand, the continuation of π_E is drawn for K satisfying equation (2). (Along $LN(w;\ r)$, both (1) and (2) hold, so the contour π_E is continuous where it intersects long-run demand.) Let $K^2(r,\ N)$ be the function that solves equation (2) for K. At point B^f, the intersection of π_E with the contract curve CC^*, $N = N^*$ and, because $K^* = K^2(r,\ N^*)$, $K = K^*$. The wage coordinate of B^f establishes the highest wage the fir would be willing to pay to enter into an efficien contract.

The wage coordinate of B^u establishes the lowest wage the union would accept once K^* is installed, assuming for now that the firm' strategy is to deploy Espinosa and Rhee's (1989) on-the-demand punishment if the union cheats on the wage. In figur 5, B^u lies above B^f on the wage scale, although the reverse can also occur. In the case illustrated, no efficien contract that utilizes on-the-demand punishment is self-enforcing—irrespective of the firm’ discount factor. The reason such a case can arise is that, unlike the exogenous capital model, the parties do not compare the proposed efficien outcome with the same monopoly-union equilibrium (point A in figur 1). Rather, the fir compares the proposed efficien outcome with point E in figur 5, while the union compares the proposed efficien outcome with point T in figur 5. Clearly, the comparators are different.

If, instead, B^u lies below B^f on the wage scale, then for each wage in that interval an efficien outcome is self-enforcing for δ sufficientl close to one. Alternatively, given δ there is a set of sustainable effi cient equilibria *given* K^*, which define one upper bound on the wage. Endogenizing capital adds an additional constraint on the set of sustainable efficien equilibria, a constraint that is binding if the upper bound on wages given K^* lies above B^f on the wage scale.

B. *Finite Durability*

Assume that rather than being perfectly durable, capital can be costlessly adjusted at the start of each period. From the standpoint of achieving an efficien outcome, the advantage is that a harsher punishment can be imposed on the union that cheats. This is an effect along the lines suggested by Baldwin. But there is also a downside risk. Flexible capital weakens the union’s punishment of the fir that cheats.

To simplify the explanation of the latter effect, suppose that the union discounts the future entirely ($\delta_u = 0$). Further suppose that with perfectly durable capital an efficien outcome is possible. For any such equilibrium there is a minimum fir discount factor necessary to achieve that result. Now consider flexibl capital. If the fir cheats on employment, then its per period payoff in the punishment phase is its one-shot equilibrium payoff, not the smaller *MUE* payoff at the effi cient level of capital. This in turn raises the minimum fir discount factor necessary to achieve the same efficien result. As a consequence, efficien outcomes that could be achieved if capital were rigid become less likely with flexibl capital.

The more familiar effect, working to expand the possible efficien outcomes, requires that the union’s horizon extend beyond the present period. In comparison with perfect durability, the ability to choose capital each period enables the fir to respond to union misbehavior by reducing the union’s future payoffs. Provided the discount factors of both the fir and the union are sufficientl close to one, there will exist efficien allocations that can be achieved in equilibrium that did not exist under rigid capital.[11] The reason is that the union can now be made to effect a comparison with the same alternative outcome as the

11. Similarly, there will exist values of δ for which flexibilit is necessary to achieve an efficien equilibrium.

firm To understand this, consider the one-shot monopoly-union equilibrium outcome (w_E, N_E, K_E), corresponding to point E in figur 5. Choose an efficien allocation (w', N^*, K^*) from the core of allocations that is mutually preferred by both the fir and the union to (w_E, N_E, K_E). For discount factors sufficientl close to one, such an allocation can be achieved in equilibrium by an appropriate mutually reinforcing credible deterrent. Specifically if the outcome in a round ever differs for any reason from (w', N^*, K^*), play in subsequent rounds switches to the strategies used in the one-shot capital-firs equilibrium.

VI. Reputation for Toughness

The foregoing discussion of endogenous capital limited the fir to using on-the-demand punishment for union malfeasance. However, harsher short-term cuts in employment can also be credible. The idea is to obtain more leverage from the firm' regard for the future. The fir has an interest in maintaining not only a reputation for honesty but also a reputation for toughness.[12]

Regarding the union horizon, let us focus on the most challenging case for achieving efficiency namely, a union with a one-period horizon. Thus, attention will be duly restricted to one-period punishment in response to a union holdup.

Consider the following strategies:

1. For the firm at each round t,
   a) if it has always adhered to its strategy,
      i) install $K_t = K^*$.
      ii) If $w_t = w'$, choose $N_t = N^*$. Otherwise, maximize profi subject to the constraint $U(w_t, N_t) \leq U(w', N^*)$.
   b) If it has ever failed to adhere to its strategy prior to round t, then henceforth play according to its one-shot capital-firs equilibrium strategy.
   c) If $K_t \neq K^*$, choose N_t according to its monopoly-union equilibrium strategy given K_t.[13]
2. For the union, at each round t,
   a) if the fir has never deviated from its strategy (including capital choice in round t), choose $w_t = w'$.
   b) Otherwise, choose w_t to maximize $U(w_t, N_t)$ subject to $N_t = SN(w_t, K_t)$.

12. This notion could also be applied to expand the set of efficien equilibria in Espinosa and Rhee's setting with exogenous capital.

13. Note that the firm' strategy here applies to the setting where capital has a one-period life. With small modification it can be adapted to the infinitel durable case, and the equilibrium analysis will go through with little change.

Finally, (w', N^*, K^*) is an allocation located on the contract curve CC^* which gives the union at least $U(w_0, N^*)$ and gives the fir at least as much as the one-shot-capital-firs equilibrium. It will be shown that these strategies constitute a Nash subgame-perfect equilibrium.

Note that the fir in 1*a* ii utilizes the least-cost ‘‘punishment schedule’’ for employment, namely, the employment schedule that maximizes profi in the current period subject to the condition that the union not gain from demanding a wage different from the contract wage w'. The intersection of $SN(w, K^*)$ and the locus given by $U(w, N) = U(w', N^*)$ define a critical wage. Below that critical wage this schedule follows $SN(w, K^*)$, that is, on-the-demand punishment. Above that critical wage, the punishment schedule instead follows the locus $U(w, N) = U(w', N^*)$, namely, off-the-demand punishment.

If strategies 1 and 2 are deployed, the outcome is (w', N^*, K^*), which is a member of the set of efficien outcomes. Are 1 and 2 equilibrium strategies? Consider the union. It is enough to sort subgames according to whether the fir has deviated. First, consider the case where the fir has never deviated. The union cannot gain from departing from 2*a,* thereby initiating a deviation. If the union did deviate, the firm’ response would be to implement the punishment in 1*a*ii, which, by construction, does not allow the union to gain from cheating. Second, consider histories where the fir has cheated. Because the firm’ strategy says that once it cheats it will henceforth play as if engaged in a one-shot game, the union can do no better than choose a wage as if it were playing a one-shot game. The union will adhere to 2*b*.

And what of 1, the firm’ strategy? To start, suppose the fir at some time fails to utilize strategy 1. The union’s reaction according to 2*b* would be to play as if engaged in a one-shot game. The union in essence forms an unshakeable belief about the fir that deviates from its strategy. If the fir cheats on employment, the union concludes the fir is untrustworthy—just as in Espinosa and Rhee’s (1989) analysis, the fir would lose its reputation for honesty. The firm’ reputation for toughness is at stake in a subgame where the union has cheated. If the fir fails to carry out its off-the-demand punishment, the union concludes the fir is weak and will never carry out off-the-demand punishment. Once the union has been triggered to behave according to its one-shot strategy—that is, once it has formed an unshakeable belief the fir is untrustworthy or weak—the fir can do no better than to confir those beliefs and play as specifie in 1*b* and 1*c*.

So will the fir ever deviate? First, it will not cheat on capital. Given the union’s immediate response, the fir can do no better from cheating than the one-shot capital-firs equilibrium. But it prefers (w', N^*, K^*). Second, failure to be tough with a union that cheats yields a saving in the current period but at the price of permanently lower profitability It follows that the fir will choose to carry out its threats, thereby maintaining its reputation for toughness, as long as its discount factor is sufficientl close to one. Finally, what of the firm' temptation to cheat on the employment agreement? The analysis is familiar. Compared with the constant stream of profi $\pi(w', N^*, K^*; r)$ along the equilibrium path of play, it obtains a one-time gain at the expense of a permanently lower stream of profi in the future. For a discount factor sufficientl close to one, cheating on the labor agreement does not pay.

VII. Conclusion

This article has sought to modify Baldwin's (1983) influentia study of the efficienc of investment under self-enforcing union contracts in two major respects. First, it recasts her treatment by locating it in the context of the monopoly-union and efficient-contrac models. Second, it adheres throughout to a formal game-theoretic approach. If the focus is narrowly on on-the-demand punishment, our game-theoretic results reaffir Baldwin's prescription for deterring union malfeasance, namely, lengthen the union's time horizon or shorten the replacement cycle of capital. That said, much of our analysis has suggested that union malfeasance does not necessarily underpin suboptimal investment.

Moreover, the effect on efficienc of a shorter economic life of capital is itself not unambiguous. In particular, we identifie the potential for malfeasance on the part of the fir and not just the union. This approach allowed us to obtain the more exotic result that, where capital has a short lifetime, the ability of the union to punish the fir for opportunistic behavior is reduced—a result that clearly turns one Baldwin prescription on its head.

It was also argued that the fir can credibly impose punishment that is harsher than the conventional on-the-demand form, buttressing the broad conclusion of the article that the union's horizon and the durability of capital are not necessarily crucial to efficiency Specifically sufficien patience by the fir will suffic to make credible retribution that has the superficia appearance of a self-destructive threat. Stated another way, underinvestment may stem from an insufficien fir discount factor.

In the world of efficien equilibria as constructed here, no punishment is ever meted out for the obvious reason that no one breaks the agreement. But the real world admits of such things as lockouts, walkouts, and slowdowns. Repeated-game models of oligopolistic collusion have dealt with a similar discrepancy by showing that incomplete information regarding market demand can produce alternating phases of collusion and price wars brought on by the suspicion of cheating. This suggests a promising development of the model would be to incorporate the effects of incomplete information on the efficienc of union contracts. Prior to that, however, a more important task is to further parameterize the model so as to gauge the likelihood of observing inefficien contracts and the relative contribution of their proximate causes.

Finally, we have not up to this point addressed the small but growing empirical literature dealing with union effect on investments in physical and intangible capital. That literature points unequivocally to lower investment in the presence of unions (see, e.g., Hirsch 1991; Bronars and Deere 1993; Bronars, Deere, and Tracy 1994; Cavanaugh 1996; Fallick and Hassett 1996). Whether this association is merely an artifact of selection or is underinvestment stemming from unionization has not been resolved empirically. Even if there is underinvestment, one should be more than usually careful in attributing blame. Without a union there can of course be no conflic over the division of the surplus. However, this conflic in and of itself does not lead to suboptimal investment. Other factors must be present as well. It has been shown here that these must encompass not just union myopia but also the firm' patience and the durability of its capital. The task for the empirical literature—abstracting from selection issues—is now to determine the contribution of each of these factors to the lower levels of investment observed in union settings.

References

Addison, J. T., and Hirsch, B. T. 1989. Union effects of productivity, profits and growth: Has the long run arrived? *Journal of Labor Economics* 7 (January): 72–105.

Anderson, S. P., and Devereux, M. 1988. Trade unions and the choice of capital stock. *Scandinavian Journal of Economics* 90(1):27–44.

Baldwin, C. Y. 1983. Productivity and labor unions: An application of the theory of self-enforcing contracts. *Journal of Business* 56 (April): 155–85.

Bronars, S. G., and Deere, D. R. 1993. Unionization, incomplete contracting, and capital investment. *Journal of Business* 66 (January): 117–32.

Bronars, S. G.; Deere, D. R.; and Tracy, J. S. 1994. The effects of unions on fir behavior: An empirical analysis using firm-leve data. *Industrial Relations* 29 (October): 426–51.

Cavanaugh, J. K. 1996. Asset specifi investment and unionized labor. Unpublished manuscript. Dayton, Ohio: Wright State University.

Espinosa, M. P., and Rhee, C. 1989. Efficien wage bargaining as a repeated game. *Quarterly Journal of Economics* 104 (August): 565–88.

Fallick, B. C., and Hassett, K. A. 1996. Investment and union certification Federal Reserve Board, Finance and Economics Discussion Series No. 1996–43. Washington, D.C.: Board of Governors of the Federal Reserve System, November.

Freeman, R. P., and Medoff, J. L. 1984. *What Do Unions Do?* New York: Basic Books.

Hirsch, B. T. 1991. *Labor Unions and the Economic Performance of Firms*. Kalamazoo, Mich.: W. E. Upjohn Institute for Employment Research.

Hirsch, B. T., and Prasad, K. 1995. Wage-employment determination and a union tax on capital: Can theory and evidence be reconciled? *Economics Letters* 48 (April): 61–71.

Kreps, D. 1990. Corporate culture and economic theory. In J. E. Alt and K. A. Shepsle (eds.), *Perspectives on Positive Political Economy*. New York: Cambridge University Press.

Telser, L. G. 1980. A theory of self-enforcing agreements. *Journal of Business* 54 (January): 27–44.