

OPTIMAL EFFORT IN MULTI-YEAR CONTRACTS: AN EMPIRICAL ANALYSIS

BY HARRY J. PAARSCH, ELENA PASTORINO, AND JOHN L. SOLOW

University of Melbourne, University of Iowa, and University of Iowa

We model a multi-period, principal-agent problem—in the presence of moral hazard—accounting for the possibility that the principal may prefer to replace the agent and that the agent may pursue alternative employment opportunities. To begin, we provide a recursive formulation of the contracting problem under full commitment and then compare the effect of variability in current and deferred compensation on the characteristics of the contract and the incentives of the agent. Subsequently, we contrast the properties of the optimal contract under full-commitment with those of the optimal contract under one-sided commitment (when only either the principal or the agent can commit long-term) and under uncertainty concerning principal- and agent-specific productivity (to capture the possibility of competition among principals). Finally, using uniquely-rich data and estimating the model structurally, we assess empirically the incentive power of long-term employment contracts offered to players in Major League Baseball, focusing on hitters.

1. Introduction. Three decades ago, [Fama \[1980\]](#) observed that time could have a beneficial effect in the provision of incentives to improve performance: repeated observation of performance admits better inference concerning unobserved actions, thus mitigating the moral-hazard problem. [Dewatripont and Tirole \[2005\]](#) have mentioned two other potential gains are often associated with long-term contracting under moral hazard. First, the agent may be willing to take more risk, as he can partially self-insure against a bad outcome by smoothing consumption over time. Second, an optimal long-term contract can improve over repeated one-period contracts by forcing the agent to consume more in earlier periods. Intuitively, by keeping the agent's continuation wealth low, the principal can ensure that the agent's marginal utility of money remains high and, thus, reduce the cost of providing the agent with monetary incentives for performance.

On the other hand, it is well-known that the possibility of contracting long-term may exacerbate incentive problems. For example, consider the standard model of moral hazard between one principal and one agent when no technological link exist across production periods. By allowing the agent greater flexibility when supplying effort over time—the agent gets to choose an entire action plan in a repeated relationship—the principal's ability to benefit from an enduring relationship with the agent is constrained. In a repeated relationship, the agent has more opportunities to shirk, to try his luck, and to recover from bad outcomes by working harder. Since the agent's action set is richer, the incentive problem, from the perspective of the principal, can get worse.

In many economic environments, long-term contracts governing the entire length of a relationship are unusual. Employment contracts are a good example. Nevertheless, a single contract may cover a substantial fraction of the total duration of the relationship between the principal and the agent. If either the principal or the agent can force the renegotiation of an existing contract, then an additional layer of complexity is added to the problem of providing incentives. When compared to the full commitment case, the gains from long-term contracting in this case depend on whether the prospect of renegotiation allows the principal to provide higher-powered incentives in other ways—for instance, by relying on the threat of dismissal—or whether, instead, such prospects reduces the level of effort that the principal may find optimal to induce in

JEL classification: C5, D2, J4, L8

Keywords and phrases: multi-period contracts, optimal effort, sports economics, baseball

the first place, given the smaller scope for risk-sharing.

In this paper, we model a multi-period, principal-agent problem in the presence of moral hazard. We estimate the effect time has on incentives, allowing for the possibility that the principal may prefer to replace the agent and that the agent may pursue alternative employment opportunities. To begin, under full commitment, we provide a recursive formulation of the contracting problem and compare the effect of variability in current and deferred compensation on the characteristics of the contract and the incentives of the agent. We then contrast the properties of the optimal contract under full-commitment with those of the optimal contract under one-sided commitment (when only either the principal or the agent can commit long-term) and under uncertainty concerning principal- and agent-specific productivity (to capture the possibility of competition among principals in the unmodelled market for agents). Finally, using uniquely-rich data and estimating the model structurally, we assess empirically the incentive power of long-term employment contracts offered to players in Major League Baseball (MLB). The data used in our empirical work contain detailed information concerning demographic characteristics as well as compensation (both yearly salary and bonus pay), performance, and contracts (duration as well as renegotiation possibilities) for all players who participated at some point in MLB between 1995 and 2008.

We have organized the remainder of the paper as follows: in section 2, we develop a theoretical model under alternative contracting assumptions, while in section 3, as a preamble to our structural econometric analysis, we demonstrate how to compute numerically the optimal contracts under the different specifications outlined in section 2. We discuss, in section 4, the data we have collected and organized, while in section 5, we present our empirical results, and in section 6, we summarize and conclude. We collect in an appendix any results too cumbersome to report in the text of the paper.

2. Model. In this section, we develop a model of a dynamic moral-hazard problem involving one principal and one agent.¹ We introduce alternative assumptions in order to contrast the implications for contract form as well as incentives under different contractual and competitive environments. Specifically, we first allow both the principal and the agent full commitment. In this case, we also consider situations in which compensation in any period cannot be made contingent on that period's output, to assess how providing incentives only through variation in future compensation affects the principal's cost of providing incentives and the variability of the agent's compensation over time. Next, we analyze the case in which, respectively, only the principal or the agent can contract long-term. Finally, we analyze an environment in which limited commitment exists, also allowing for exogenous principal- and agent-specific fluctuations in productivity, to capture the possibility of contract termination that may be relevant in our empirical application.

Below, we refer to a long-term contract as *renegotiation-proof* if, at every contracting date, the continuation contract is an optimal solution to the contracting problem for the remaining periods. We refer to commitment as *long-term* if both the principal and the agent are able to commit to contracts disciplining the entire duration of the relationship. On the other hand, we refer to commitment as *short-term* if it extends to some limited number of periods.

Where appropriate, we shall discuss how our formulation has been motivated by data considerations. For the benchmark environment, we have relied on the formulation of the dynamic moral-hazard problem described by Aseff [2005].

2.1. Environment. Consider a numéraire economy populated by one risk-neutral principal and one risk-averse agent. Let time be discrete and indexed by $t = 0, 1, 2, \dots$. When employed by the principal in period

¹For the moment, we abstract from output complementarities among agents, which may be relevant in our empirical application. Later, we shall argue, however, that the output measure we use in estimating the model captures closely the performance of individual players, at least at the measured task—hitting.

t , the agent provides effort e_t , which can be either high $\bar{e}$ or low $\underline{e}$. The agent's effort, which we assume to be unobserved by the principal, affects the output produced by the agent. We denote the probability of period- t output y_t , when the agent exerts effort $e_t \in \{\underline{e}, \bar{e}\}$, by $f(y_t; e_t)$. With a slight abuse of notation, we let $f(\cdot; \cdot)$ denote either a probability mass function or a probability density function. We assume that the output distribution satisfies the monotone-likelihood ratio property—viz., $f(y; \bar{e})/f(y; \underline{e})$ is increasing in y .

The agent's preferences over w_t , consumption in period t , are described by the utility function $\hat{u}(w_t, e_t)$, which is assumed to be separable in consumption and effort, so $\hat{u}(w_t, e_t) = v(w_t) - c(e_t)$, $w_t \in \mathbb{R}_+$. We also assume that $v(\cdot)$ is twice-continuously differentiable with $v'(\cdot) > 0$ and $v''(\cdot) < 0$. The principal and the agent are assumed to discount future payoffs according to a common discount factor, $\delta \in (0, 1)$. In each period, the agent has available an outside option of value $\bar{v}_t$, which can be interpreted as the highest expected present-discounted utility that the agent can guarantee himself when not employed by the principal. We denote by $\bar{\pi}_t$ the principal's reservation profit.

2.2. Two-Sided Commitment. Denote by h^t the observable history of output realizations up to, but not including, period $t \geq 1$, with $h^0 = \emptyset$. In period $t = 0$, the principal offers a contract to the agent which specifies a sequence of compensations, to be paid in each period after output has realized, and effort functions, $\sigma = \{w_t(h^t), e_t(h^{t-1})\}_{t=0}^\infty$. Denote by $d_0 \in \{0, 1\}$ an indicator function of the agent's acceptance decision in period $t = 0$, with $d_0 = 1$ if and only if the agent accepts the contract in period $t = 0$. We denote the continuation of the contract in each period $t \geq 1$ by $\sigma_{t+1}(h^{t+1}) = \{w_\tau(h^\tau), e_\tau(h^{\tau-1})\}_{\tau=t+1}^\infty$.

Consider the situation in which the principal's goal is to induce the same level of effort $e = (e_0, e_1, e_2, \dots) = (\bar{e}, \bar{e}, \bar{e}, \dots)$ at each point in time. In this case, σ reduces to $\sigma = \{w_t(h^t), \bar{e}\}_{t=0}^\infty$, and the principal's expected present-discounted profit from the contract is

$$d_1 \mathcal{E}_0 \left\{ \sum_{t=0}^\infty \delta^t [y_t - w(h^t)] \middle| e \right\} + (1 - d_1) \bar{\pi}_1 \quad (2.1)$$

where $\mathcal{E}_0$ denotes the expectation with respect to the probability distribution over outcomes induced by the effort sequence e . The agent accepts the principal's offer if

$$\mathcal{E}_0 \left\{ \sum_{t=0}^\infty \delta^t (v[w(h^t)] - c(\bar{e})) \middle| e \right\} \geq \bar{v}_0,$$

which represents the agent's participation (IR) constraint. Let $e' = (e'_0, e'_1, e'_2, \dots)$ denote an effort profile different from e . The agent finds it optimal to follow the effort recommendation of the principal if

$$\mathcal{E}_0 \left\{ \sum_{t=0}^\infty \delta^t (v[w(h^t)] - c(\bar{e})) \middle| e \right\} \geq \mathcal{E}_0 \left\{ \sum_{t=0}^\infty \delta^t (v[w(h^t)] - c(e'_t)) \middle| e' \right\},$$

which defines the agent's incentive-compatibility (IC) constraint. The principal's problem consists in maximizing (2.1) subject to the agent's (IR) and (IC) constraints. Although not crucial, for the moment, we assume that the cost of effort is linear, so $c(e) = e$. Also, for the time being, we focus on cases in which both $\bar{v}_t$ and $\bar{\pi}_t$ are constant over time, denoting them by $\bar{v}$ and $\bar{\pi}$, respectively.

2.2.1. Recursive Formulation. Now, let $v_t(h^t) = v[w_t(h^t)]$ denote the agent's period t base utility when offered the compensation $w_t(h^t)$ after history h^t . Denote the inverse of $v(\cdot)$ by $\mu(\cdot)$, so $w_t(h^t) = \mu[v_t(h^t)]$.

Given this change of variables, the principal's problem can be expressed equivalently in utility space as the problem of providing the agent with utility levels which minimize

$$\mathcal{E}_0 \left\{ \sum_{t=0}^{\infty} \delta^t w(h^t) \middle| e \right\} = \mathcal{E}_0 \left\{ \sum_{t=0}^{\infty} \delta^t \mu[v_t(h^t)] \middle| e \right\}$$

subject to the above (IR) and (IC) constraints. Note that the objective function is concave, and defined over a convex set. Thus, we can substitute $w_t(h^t)$ for $v_t(h^t)$ in σ and focus on minimizing the cost of compensation for given effort level.

Since only “temporary” incentive-compatibility need be satisfied, it can be shown that the following reformulation of the contracting problem obtains. Let $V \subset \mathbb{R}$ be an interval containing the values of all feasible continuation values and reservation utilities for the agent. Also, let $u^{\text{FC}} : Y \times V \rightarrow \mathbb{R}$ and $v^{\text{FC}} : Y \times V \rightarrow V$ be defined by $u^{\text{FC}}(y, \omega) = v(y) - e$ and $v^{\text{FC}}(y, \omega)$ —the superscript FC denoting full commitment. Denote the agent's current and continuation utilities, following realization y , when the agent's reservation utility is ω , by $u^{\text{FC}}(\cdot)$ and $v^{\text{FC}}(\cdot, \cdot)$, respectively. Therefore, the agent will accept the contract and exert high effort in each period if

$$\mathcal{E}[u^{\text{FC}}(y, \omega) + \delta v^{\text{FC}}(y, \omega) | \bar{e}] - \bar{e} = \omega \quad (2.2)$$

$$\mathcal{E}[u^{\text{FC}}(y, \omega) + \delta v^{\text{FC}}(y, \omega) | \bar{e}] - \bar{e} \geq \mathcal{E}[u^{\text{FC}}(y, \omega) + \delta v^{\text{FC}}(y, \omega) | \underline{e}] - \underline{e}. \quad (2.3)$$

The solution to the principal's problem can be calculated by solving the following functional equation:

$$C^{\text{FC}}(\omega) = \min_{(u^{\text{FC}}, v^{\text{FC}}) \in \Gamma^{\text{FC}}(\omega)} \mathcal{E} \left\{ \mu[u^{\text{FC}}(y, \omega)] + \delta C^{\text{FC}}[v^{\text{FC}}(y, \omega)] \middle| \bar{e} \right\}$$

where $\Gamma^{\text{FC}}(\omega) = \{(u^{\text{FC}}, v^{\text{FC}}) : (2.2), (2.3), \text{ and } v^{\text{FC}}(y, \omega) \in V \text{ hold}\}$.

2.2.2. State Space. To compute the domain of the value function $C^{\text{FC}}(\cdot)$, following Aseff [2005], we numerically implemented the algorithm proposed by Abreu et al. [1990], henceforth APS. To do this, we explicitly relied on the linearity of the constraints of the dynamic programming problem. The APS algorithm allows us to calculate, in a straightforward manner, the state space V as the fixed point of a set-valued operator. Namely, because V is the fixed point of the APS self-generating operator $B(\cdot)$, it can be calculated iteratively beginning with any initial interval W_0 ; convergence to V is guaranteed by APS. Each time $B(\cdot)$ is applied to an interval W , given reservation utility $\omega \in W$, we check the existence of a feasible pair $(u^{\text{FC}}, v^{\text{FC}})$ in $\Gamma^{\text{FC}}(\omega)$.

2.2.3. Constant Current Compensation. A large number of observed contracts are based on constant annual salaries, adjustable from period to period, depending on last period's performance; this is true, in general, but particularly relevant in MLB. By focusing on policy functions for current compensation that exhibit no variability in performance in given period, all variability needed to satisfy the agent's incentive compatibility constraint must necessarily arise from deferred compensation. We now turn to this case.

In this case, the current state will determine current compensation next period, so the dynamic programming problem solved by the principal is given by the following functional equation:

$$C^{\text{CC}}(\omega) = \min_{(u^{\text{CC}}, v^{\text{CC}}) \in \Gamma^{\text{CC}}(\omega)} \mathcal{E} \{ \mu[u^{\text{CC}}(y, \omega)] + \delta C^{\text{CC}}[v^{\text{CC}}(y, \omega)] \}$$

subject to the agent's (IR) and (IC) constraints, where Γ^{CC} denotes the feasible correspondence when one restricts attention to policy functions $u^{\text{CC}} : V \rightarrow \mathbb{R}$ and $v^{\text{CC}} : Y \times V \rightarrow V$.

2.3. *One-Sided Commitment by the Principal.* Now suppose that, at the beginning of each period, the agent can decide whether to participate in the relationship with the principal, while the principal can commit long-term.² In this case, the principal's problem is given by

$$C^{\text{PC}}(\omega) = \min_{(u^{\text{PC}}, v^{\text{PC}}) \in \Gamma^{\text{PC}}(\omega)} \mathcal{E} \left\{ \mu[u^{\text{PC}}(y, \omega)] + \delta C^{\text{PC}}[v^{\text{PC}}(y, \omega)] \middle| \bar{e} \right\}$$

subject to

$$\mathcal{E}\{u^{\text{PC}}(y, \omega) + \delta v^{\text{PC}}(y, \omega) | \bar{e}\} - \bar{e} = \omega \quad (2.4)$$

$$\mathcal{E}\{u^{\text{PC}}(y, \omega) + \delta v^{\text{PC}}(y, \omega) | \bar{e}\} - \bar{e} \geq \mathcal{E}\{u^{\text{PC}}(y, \omega) + \delta v^{\text{PC}}(y, \omega) | \underline{e}\} - \underline{e} \quad (2.5)$$

$$v^{\text{PC}}(y, \omega) \geq \omega, \text{ for all } y \in Y \quad (2.6)$$

where the additional enforceability constraint states that the agent will continue the relationship with the principal if guaranteed a utility higher than the one associated with the best alternative employment/unemployment option. Observe that, since we are introducing an additional constraint to the minimization problem, naturally $C^{\text{PC}}(\omega) \geq C^{\text{FC}}(\omega)$. Moreover, since for higher values of ω , the principal must offer the agent a higher minimum discounted utility, the higher cost of providing incentives may translate in both higher present and deferred compensation.

2.4. *One-Sided Commitment by the Agent.* In our data, only the agent (player) typically has the ability to commit to long-term contracts (a common feature of contracts in MLB), so we consider here an extension of the benchmark model which allows for the possibility of agent termination. To keep the problem tractable, we focus on pure-strategy termination rules; for more on this, see [Spear and Wang \[2005\]](#). Under this assumption, a fully dynamic contract can be expressed recursively as follows. Denote the principal's cost, when she does not trade with the agent, by $C_f^{\text{AC}}(\omega)$. We can interpret $C_f^{\text{AC}}(\omega)$ as the payoff associated with hiring another agent and inducing him to exert effort. For simplicity, we assume that if the agent is terminated, then he cannot be rehired by the principal in any future period. We shall relax this assumption later on. Let $r \in \{0, 1\}$ denote the principal's retention decision in the current period and $r' \in \{0, 1\}$ the principal's retention decision next period, where $r = 1$ (respectively, $r' = 1$) if and only if the agent is retained in the current (respectively, next) period. In general, prime on variables denote their future values.

If the principal can decide whether to offer a contract to the agent at the beginning of each period, then the principal's problem is given by

$$C^{\text{AC}}(\omega) = \max [C_r^{\text{AC}}(\omega), C_f^{\text{AC}}(\omega)]$$

where

$$C_r^{\text{AC}}(\omega) = \min_{(u^{\text{AC}}, v^{\text{AC}}) \in \Gamma^{\text{AC}}(\omega)} \mathcal{E} \left\{ \mu[u^{\text{AC}}(y, \omega)] + \delta \mathcal{E} \max (C_r^{\text{AC}}[v^{\text{AC}}(y, \omega)], C_f^{\text{AC}}[v^{\text{AC}}(y, \omega)]) \middle| \bar{e} \right\} \quad (2.7)$$

subject to

$$\mathcal{E}\{u^{\text{AC}}(y, \omega) + \delta \mathbb{I}(r' = 1) v^{\text{AC}}(y, \omega) + \delta \mathbb{I}(r' = 0) \bar{v} | \bar{e}\} - \bar{e} = \omega$$

$$\mathcal{E}\{u^{\text{AC}}(y, \omega) + \delta \mathbb{I}(r' = 1) v^{\text{AC}}(y, \omega) + \delta \mathbb{I}(r' = 0) \bar{v} | \bar{e}\} - \bar{e} \geq$$

$$\mathcal{E}[u^{\text{AC}}(y, \omega) + \delta \mathbb{I}(r' = 1) v^{\text{AC}}(y, \omega) + \delta \mathbb{I}(r' = 0) \bar{v} | \underline{e}] - \underline{e}.$$

²In our data, a minimum wage binds in each year, so this case also captures the impact on contracting outcomes of such a constraint on compensation.

The optimal contract solves the Bellman equation in (2.7) subject to the agent's (IR) and (IC) constraints. We assume that, if the principal is indifferent between firing and retaining the agent, then he retains the agent.

An alternative formulation obtains by considering the possibility of severance pay. Let $V = V_r \cup V_f$ be the set of utilities promised to the agent that can be supported—recall that V is endogenously determined—such that if $\omega \in V_r$ the agent continues to be employed, and if $\omega \in V_f$, then he is terminated. Therefore, if the agent's expected utility from next period on is $v^{\text{AC}}(y, \omega) \in V_r$, then he is retained; otherwise, he is dismissed. In this case, it follows that the principal's problem can be expressed as

$$C^{\text{AC}}(\omega) = \max [C_r^{\text{AC}}(\omega), C_f^{\text{AC}}(\omega)]$$

where

$$C_r^{\text{AC}}(\omega) = \min_{(u^{\text{AC}}, v^{\text{AC}}) \in \Gamma^{\text{AC}}(\omega)} \mathcal{E} \{ \mu[u^{\text{AC}}(y, \omega)] + \delta C^{\text{AC}}[v^{\text{AC}}(y, \omega)] | \bar{e} \}$$

subject to

$$\mathcal{E} \left\{ u^{\text{AC}}(y, \omega) + \delta v^{\text{AC}}(y, \omega) \middle| \bar{e} \right\} - \bar{e} = \omega \quad (2.8)$$

$$\mathcal{E} \left\{ u^{\text{AC}}(y, \omega) + \delta v^{\text{AC}}(y, \omega) \middle| \bar{e} \right\} - \bar{e} \geq \mathcal{E} \left\{ u^{\text{AC}}(y, \omega) + \delta v^{\text{AC}}(y, \omega) \middle| \underline{e} \right\} - \underline{e} \quad (2.9)$$

$$V = V_r \cup V_f = \{v^{\text{AC}}(y, \omega) \in V : C_r^{\text{AC}}(\omega) \geq C_f^{\text{AC}}(\omega)\} \cup \{v^{\text{AC}}(y, \omega) \in V : C_r^{\text{AC}}(\omega) < C_f^{\text{AC}}(\omega)\}. \quad (2.10)$$

Notice that equation (2.10) captures the possibility that the principal compensates the agent on termination.

2.5. Environment with Productivity Shocks. To account for the fact that, in the data, we observe players who sign multiple (mostly consecutive) contracts with the *same* team—an outcome that cannot obtain in the environment as outlined so far—we assume that a public team- and player-specific revenue shock is realized at the beginning of each period, which affects the cost to the principal of providing incentives to the agent she is currently employing or to alternative agents she may sample from the outside market. These shocks can be interpreted as idiosyncratic fluctuations in a player's productivity from year to year or as fluctuations in unobserved (to us) market factors affecting the value of a player to a team. Examples of the former case are situations in which players get injured or a team decides to rotate a player because other players have been injured. The market can affect a team's incentive to retain a particular player when, for example, better players from other teams are available. As before, let $r \in \{0, 1\}$ denote the principal's retention decision in the current period and $r' \in \{0, 1\}$ the principal's retention decision next period, where $r = 1$ (or $r' = 1$) if and only if the agent is retained.

Denote by S_r the cost shock that the principal experiences when employing the agent in any period t and S_f the cost shock that the principal experiences when, say, replacing the agent she is currently employing with a new one. Now, let the principal's flow cost from not employing the agent be denoted by $c(\omega, s_r, s_f, 0) = \hat{c}_f(\omega)$ and the principal's flow cost associated with employing the agent by $c(\omega, s_r, s_f, \bar{e}) = \mathcal{E}_Y [u(Y, \omega) | \bar{e}]$. Compactly,

$$c(\omega, s_r, s_f, r) = \mathbb{I}(r = 1) \mathcal{E}_Y \left\{ \mu[u^{\text{PS}}(y, \omega)] \middle| \bar{e} \right\} + \mathbb{I}(r = 0) \hat{c}_f(\omega).$$

The principal's problem can now be expressed as

$$\begin{aligned}
C^{\text{PS}}(\omega, s_r, s_f) = & \\
\max \left(\min_{(u^{\text{PS}}, v^{\text{PS}}) \in \Gamma^{\text{PS}}(\omega, s_r, s_f)} \mathcal{E}_Y \{ \mu[u^{\text{PS}}(Y, \omega)] | \bar{e} \} + s_r + \right. & \\
& \delta \mathcal{E}_{Y, S'_r, S'_f} \left\{ \max (C_r^{\text{PS}}[v^{\text{PS}}(Y, \omega), S'_r, S'_f], C_f^{\text{PS}}[v^{\text{PS}}(Y, \omega), S'_r, S'_f]) \mid \bar{e}, s_r, s_f, r = 1 \right\}, \\
& c_f(\omega, s_r, s_f) + s_f + \\
& \left. \delta \mathcal{E}_{Y, S'_r, S'_f} \left\{ \max (C_r^{\text{PS}}[v^{\text{PS}}(Y, \omega), S'_r, S'_f], C_f^{\text{PS}}[v^{\text{PS}}(Y, \omega), S'_r, S'_f]) \mid \bar{e}, s_r, s_f, r = 0 \right\} \right)
\end{aligned}$$

subject to

$$\begin{aligned}
\mathcal{E}[u^{\text{PS}}(Y, \omega, S_r, S_f) | \bar{e}] + \delta \mathcal{E}[I(r' = 1) v^{\text{PS}}(Y, \omega, S_r, S_f) + I(r' = 0) \bar{v} | \bar{e}] - \bar{e} &= \omega \\
\mathcal{E}[u^{\text{PS}}(Y, \omega, S_r, S_f) | \bar{e}] + \delta \mathcal{E}[I(r' = 1) v^{\text{PS}}(Y, \omega, S_r, S_f) + I(r' = 0) \bar{v} | \bar{e}] - \bar{e} &\geq \\
\mathcal{E}[u^{\text{PS}}(Y, \omega, S_r, S_f) | \underline{e}] + \delta \mathcal{E}[I(r' = 1) v^{\text{PS}}(Y, \omega, S_r, S_f) + I(r' = 0) \bar{v} | \underline{e}] - \underline{e}. &
\end{aligned}$$

Note that when S_r and S_f are extreme-value (Gumbel) distributed, independently over time and of each other, in each period the probability that a contract is signed has closed form, as in the standard multinomial logit problem; see [Rust \[1987\]](#). Specifically, assume that the disturbances have cumulative distribution function

$$F_a(s_a) = \exp(-\exp[-\mu_S(s_a - \eta_S)]) \quad a = r, f$$

with $\mu_S > 0$ and mean $\eta_S + \gamma/\mu_S$ and variance $\pi^2/6\mu_S^2$ where γ is Euler's constant. Suppose, for simplicity, that they have mean zero. Then, the probability that a agent is retained ($r = 1$) or replaced ($r = 0$) in any period t is given by

$$\frac{\exp \mu_S \left\{ c(\omega, s_r, s_f, r) + \delta \mathcal{E}_{Y, S'_r, S'_f} \max \left[\hat{C}(v^{\text{PS}}(Y, \omega, S'_r, S'_f)) | \bar{e}, s_r, s_f, r = 1 \right] \right\}}{\sum_{r=0}^1 \exp \mu_S \left\{ c(\omega, s_r, s_f, r) + \delta \mathcal{E}_{Y, S'_r, S'_f} \max \left[\hat{C}(v^{\text{PS}}(Y, \omega, S'_r, S'_f)) | \bar{e}, s_r, s_f, r \right] \right\}}$$

or, equivalently,

$$\frac{\exp \mu_S \left\{ \mathcal{E}_Y [\mu(u^{\text{PS}}(Y, \omega)) | \bar{e}] + \delta \int_Y \log \left[\sum_{a=r}^f \exp \left\{ \hat{C}_a(v^{\text{PS}}(Y, \omega)) | \bar{e}, r = 1 \right\} \right] \right\} df(y | \bar{e})}{\exp \mu_S \left\{ \mathcal{E}_Y [\mu(u^{\text{PS}}(Y, \omega)) | \bar{e}] + \delta \int_Y \log \left[\sum_{a=r}^f \exp \left\{ \hat{C}_a(v^{\text{PS}}(Y, \omega)) | \bar{e}, r = 1 \right\} \right] df(y | \bar{e}) \right\} + \exp \mu_S \left\{ \hat{c}_f(\omega) + \delta \log \left[\sum_{a=r}^f \exp \left\{ \hat{C}_a(v^{\text{PS}}(Y, \omega)) | \bar{e}, r = 0 \right\} \right] \right\}}$$

where $\hat{C}(\cdot)$ solves

$$\hat{C}(\omega) = \max \left\{ \min_{(u^{\text{PS}}, v^{\text{PS}}) \in \Gamma^{\text{PS}}(\omega)} \mathcal{E}_Y [\mu(u^{\text{PS}}(Y, \omega)) | \bar{e}] + \delta \int_Y \log \left[\sum_{a=r}^f \exp \left\{ \hat{C}_a(v^{\text{PS}}(y, \omega)) | \bar{e}, r = 1 \right\} \right] df(y | \bar{e}), \dots \right\}$$

(2.12)

subject to the agent's (IR) and (IC) constraints. Analogously to the above, in the presence of severance pay, additional constraints are

$$\begin{aligned} V = V_r \cup V_f = & \{v^{\text{PS}}(y, \omega, s_r, s_f) \in V : C_r^{\text{PS}}(\omega, s_r, s_f) \geq C_f^{\text{PS}}(\omega, s_r, s_f)\} \\ & \cup \{v^{\text{PS}}(y, \omega, s_r, s_f) \in V : C_r^{\text{PS}}(\omega, s_r, s_f) < C_f^{\text{PS}}(\omega, s_r, s_f)\}. \end{aligned}$$

In the following, we shall also consider situations in which the parameter μ_S is agent-specific. In this case, we shall denote it by $\mu_S(x)$, where x is a vector of individual- and team-specific characteristics, possibly time-varying. The above expressions modify accordingly. To produce situations in which the principal strictly benefits *ex ante* from offering multi-period contracts, we consider below cases in which the agent can improve his productivity while employed by the principal.

3. Numerical Experiments. As a preamble to our structural econometric work, we have performed a number of numerical experiments. For specific functions and parameters, we can compute the optimal contract under the alternative assumptions described in the previous section. Following Aseff [2005], in the computations to follow, we assumed that $\hat{u}(w, e) = v(w) - c(e) = \sqrt{w} - e$ and $e \in \{0.1253, 0.1469\}$. We also maintain that the observable outcome measure Y is drawn from the time-invariant interval $\mathcal{Y} = [0.55, 1.70]$ according to a normal distribution with mean 1.04 and standard deviation 0.261 for the case $e = \underline{e}$, and according to a normal distribution with mean 1.08 and standard deviation 0.274 for the case $e = \bar{e}$. We discretize $\mathcal{Y}$ to a set of N points ($N = 5$, from smallest to largest). The values of Y , $\underline{e}$ and $\bar{e}$ are borrowed from the calibration exercise presented by Aseff and Santos [2005], where the effort levels satisfy the estimates of Margiotta and Miller [2000]—viz., $\bar{e}/\underline{e} = 1.17$.

In both the full-commitment and the limited-commitment cases, the first step involved determining the state space of future promised utilities for which the (IR) and (IC) constraints are simultaneously satisfied. We relied on the FORTRAN subroutine DDLPRS to verify that each state point satisfies both (IR) and (IC) constraints. Specifically, the subroutine returns the solution to a linear programming problem using a revised simplex algorithm. The smallest W_0 we considered was the interval $[-\bar{e}/(1-\delta), (y(N) - \underline{e})/(1-\delta)]$, ranging from highest effort and no consumption every period to lowest effort and highest consumption every period. Next, we determined $u^j(\cdot)$ and $v^j(\cdot, \cdot)$ in each case $j = \text{FC, CC, PC, AC, PS}$ as solution to the corresponding functional-equation problem. For each candidate value function, we performed the constrained optimization step in FORTRAN using the constrained optimization routine DLCONF, which minimizes a general objective function subject to linear equality/inequality constraints. The result for these experiments are reported at the end of the paper.

3.1. Results of Numerical Experiments. The results of the numerical experiments conducted for each case considered in section 2 are depicted in figures 1 through 4.

3.1.1. Full Intertemporal Commitment Case. In this case, observe that, as in Aseff [2005],

- a) the value function is convex;
- b) the value function increases in the state variable;
- c) as the state variable increases, so too does the variability of current compensation;
- d) as the state variable increases, the per period variability of future utility decreases, so agents with high reservation utility are induced to exert high effort through contracts with higher variability in current compensation—utility.

That current compensation becomes a more prominent incentive tool as the state variable increase has also been reported by Wang [1997]. Moreover, when compensation is constrained to be independent of the output realized in the period, the variability in current and deferred compensation increases. In the unconstrained full-commitment case, the variance of compensation ranges from 0.090 to 0.218 (respectively, after $y(2)$ and $y(5)$), whereas the variance of future continuation utility ranges from 1.156, after $y(5)$, to 14.306, after $y(3)$. In the case in which both parties can commit to contract over the entire duration of the relationship, but performance-based pay is not feasible, the variance of future continuation utility ranges from 1.671 to 16.567, respectively, after $y(1)$ and $y(4)$.

3.1.2. Case of Limited Intertemporal Commitment. Not surprisingly, in all instances we considered in which the parties' contracting abilities are constrained, the cost of the contract to the principal increases. We examine the cost of the contract for the principal and the agent's compensation in some more detail in each case.

One-Sided Commitment by the Principal

In terms of the optimal contract, note that the enforceability constraint truncates expected discounted utility, and thus it bounds the ability of deferred compensation to provide incentives for effort—recall we obtained the opposite result when performance-based pay is ruled out. Consequently, current compensation becomes steeper than under full commitment at higher states. The per-period participation constraint, and the fact that the variability needed to satisfy the agent's (IC) constraint is attained by compensating the agent more at higher values of y , imply an increase in the cost of the contract to the principal.

One-Sided Commitment by the Agent

As expected, in an environment in which termination is possible, the trade-off between incentives and insurance is solved by granting a smaller premium for high output at all states and motivating the agent through the threat of termination. It also conforms to intuition the fact that, compared to the full-commitment case in which compensation cannot vary in the output realized in a period, the variation in continuation utilities across output realizations is smaller. However, in contrast to Spear and Wang [2005], termination only occurs at the highest states, when it is too expensive for the principal to motivate the agent to exert effort.

4. Data.

4.1. Institutional Detail. For several reasons, MLB provides an excellent laboratory to study these issues. First, much data concerning individual players' personal characteristics, performance records, and contracts. Second, major league baseball contracts are relatively simple and unconditional. Finally, a player's offensive performance, while subject to a great deal of randomness, is individualistic and does not depend on the complementary skills or efforts of other players. The question of incentive effects in long-term contracts in baseball has been examined extensively, with some studies finding evidence suggesting that players do engage in opportunistic behavior (e.g., Lehn [1982], Scoggins [1993], Stiroh [2007]), and others not (e.g., Krautmann [1990], Maxcy [1997], Maxcy et al. [2002]). These researchers typically have focused on the change in performance immediately following the signing of a multi-year contract, and ignore the dynamic contracting problem facing management and the player. Krautmann and Solow [2009] have provided a reduced-form analysis of the dynamics of player performance over the length of multi-year contracts, finding that the incentive to shirk, while significant, is largely offset by the incentive to perform in order to receive a subsequent contract; see also Hakes and Turner [2008].

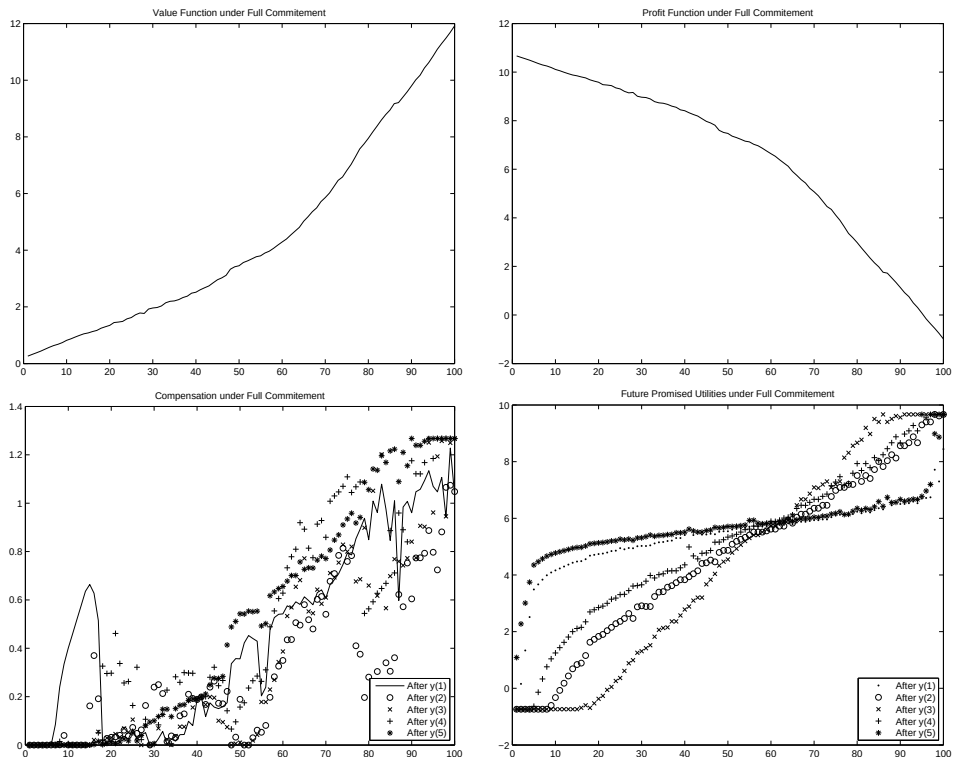


FIG 1. Outcomes Under Full Commitment

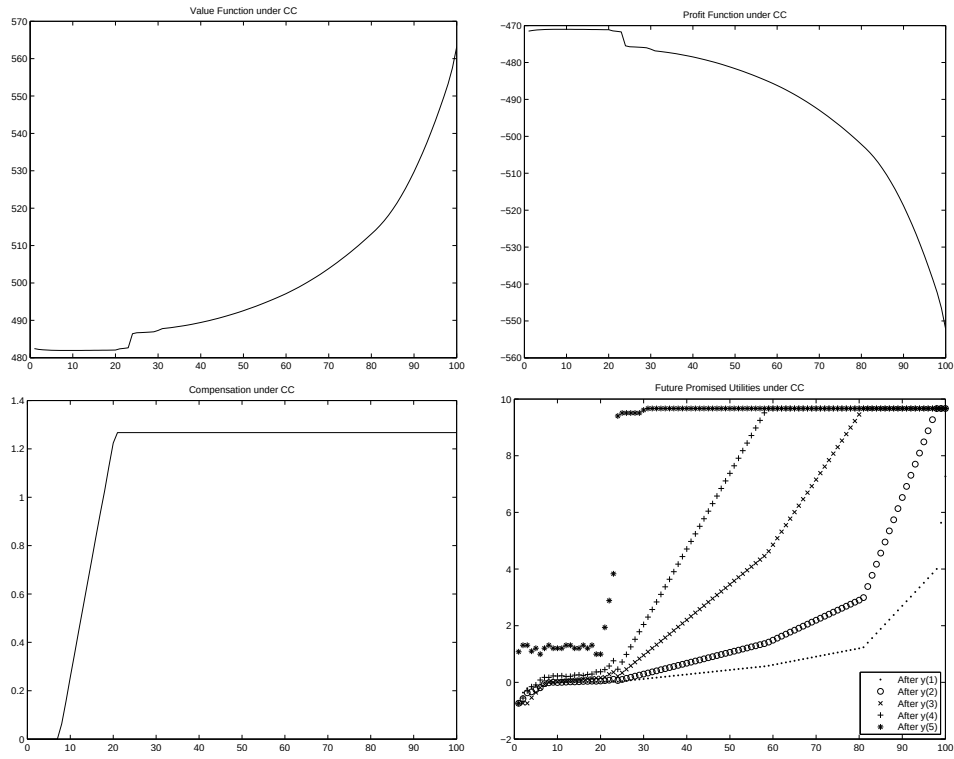


FIG 2. Outcomes Under Long-Term Commitment and Constant Compensation

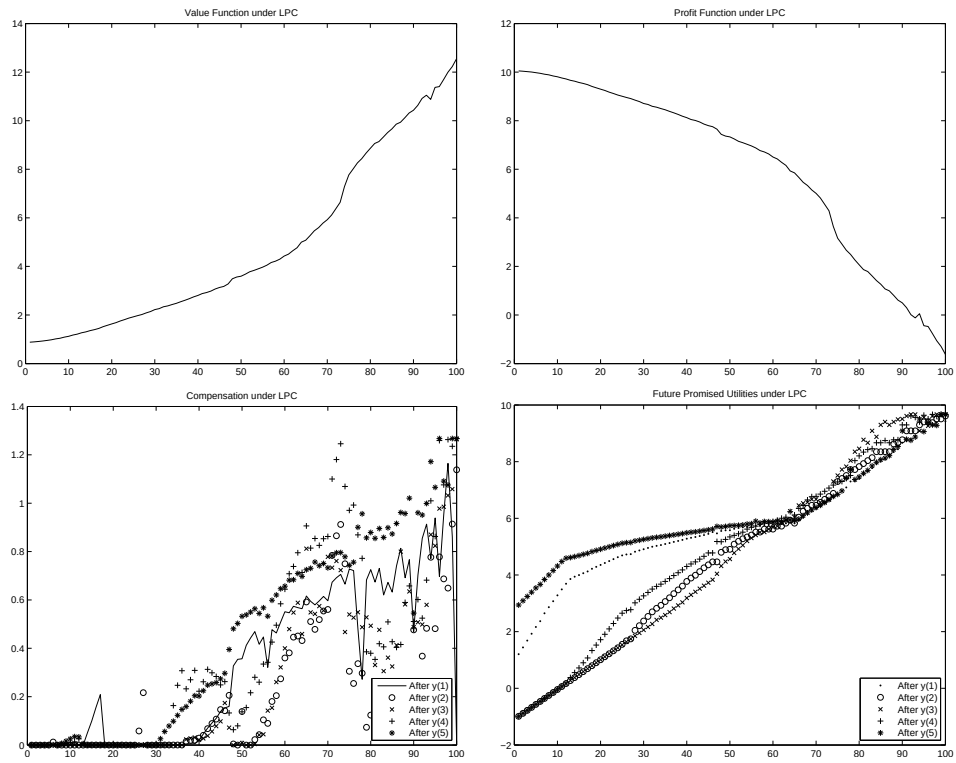


FIG 3. Outcomes Under Limited Commitment by the Principal

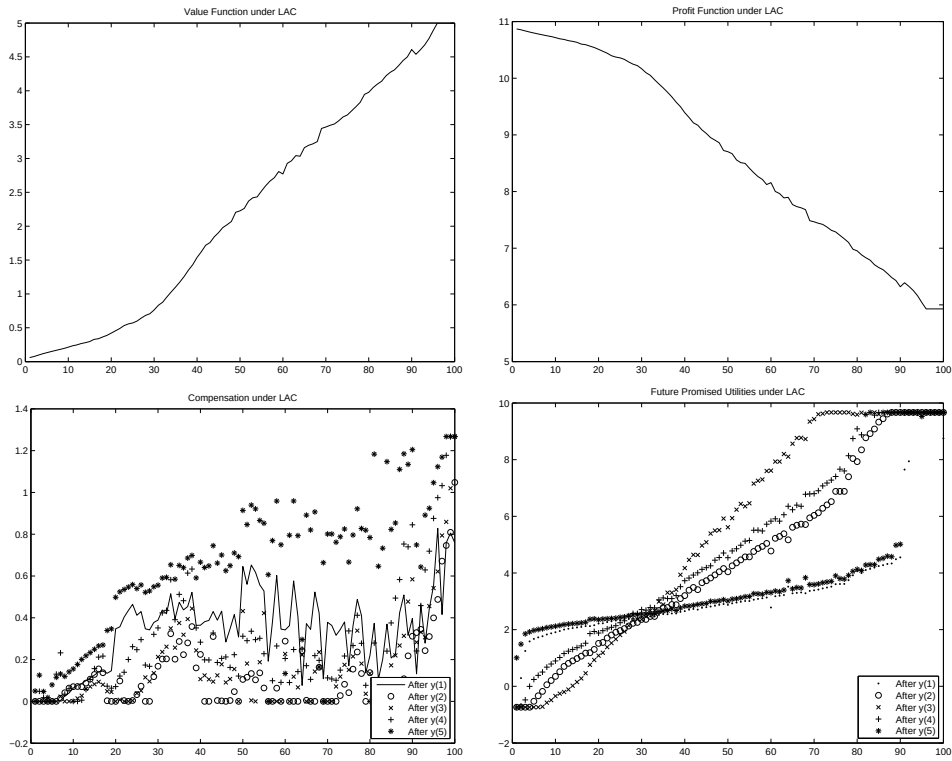


FIG 4. Outcomes Under Limited Commitment by the Agent

Professional baseball clubs in the United States (and Canada) have two levels of competition, the major league team and a number of minor league teams at different levels of skill. The latter are developmental in nature, employing young players who are acquiring and improving skills with the goal of being hired by the major league team. Minor league players are occasionally brought up to the major league team in the middle of a season to replace an injured major league player. Also, toward the end of the season, major league teams often add minor league players to their rosters in order to evaluate their talents and give them experience at an higher level competition. Players usually start their major league careers in their early 20s; the oldest active players are in their early 40s, although many careers end much sooner.

We can distinguish three groups of players by their accumulated major league experience, based on the rules governing player contracts under the Collective Bargaining Agreement (CBA) between the players' union and the team owners. Under the CBA, players are ineligible to bargain with other teams for the first three seasons of major league experience. They are typically offered one-year contracts which are subject to a minimum salary set forth in the CBA; salaries typically do not deviate much from the minimum. If a player in this group is unable to reach agreement with his team on salary, then the team is allowed to unilaterally renew the player's previous contract. Once a player has accumulated three seasons of major league experience, he cannot be returned to his team's minor league system, although he can be released and signed by other minor league teams.

A player who has accumulated three seasons of major league service and who does not have a multi-year contract is eligible for final-offer arbitration. If arbitration actually occurs, then the team and the player each present a proposed salary to a three-person arbitration panel, which then decides for either the player or the team based on comparable salaries. The resulting contract is for one year. Often, the threat of arbitration leads to a salary agreement between an arbitration-eligible player and his teams, before arbitration actually takes place.

A player with six or more years of major-league service who is not under contract for the following season is eligible to file for free agency. He is free to negotiate with any team for the best contract he can find, subject to the constraints on contracts imposed by the CBA.

MLB contracts share certain basic characteristics. They are of fixed-length terms, with options to extend at a specified salary at the team's (or, more rarely, the player's) discretion. Very rarely, a player negotiates the option to end his contract at a fixed time prior to the contract's final year at the player's discretion. When a team negotiates an option to extend a contract another year, it sometimes agrees to pay a "buy-out" if it chooses not to exercise that option. Contracts specify a sequence of annual salaries that are guaranteed; even if an injury ends a player's career in the middle of the contract, the team must pay the player's contracted salary. Salaries cannot be conditioned on performance, although minor bonuses (on the order of \$100,000 when salaries are in the millions of dollars) are sometimes offered for winning post-season awards such as being named the league's Most Valuable Player. A lump-sum "signing bonus" is sometimes negotiated.

A team may trade any player it controls to another team and, generally, the player has no right to refuse the trade (although players with ten years of major-league service and five years with their current team can veto any trade and players can, of course, quit the game altogether). In the event that a player is traded to another team, the acquiring team must fulfill the terms of the player's current contract for the remainder of its duration.

Major league seasons take place within the span of a calendar year, beginning in April and ending in October, so it makes sense to speak of a season or a year interchangeably.

We summarize our data in the following point form:

First Group. The first three years of a player's career (players begin at ages 20/21/22). Characteristics: (a) the wage is determined according to a contractual minimum (\$400,000 a year) and rarely exceeds it;

- (b) no performance based pay;
- (c) contract length: any length but we predominantly observe one-year contracts which can be renewed; the team can trade a player, but the player cannot refuse to be traded; the player can retire but he can be recalled;
- (d) a player can be sent to a minor league at most three times, but he can be recalled to the major league afterwards; the pay is substantially lower (\$400 dollars a week as opposed to \$400,000 a year); for injured players (on the fourteen days or sixty days disabled list), a replacement player from either the team's minor league or from another team can be employed as a substitute;

Second Group. The next three years of a player's career:

- (a) the wage is determined according to a contractual minimum (\$500,000 a year) and rarely exceeds it;
- (b) no performance-based pay;
- (c) contract length: any length but we observe predominantly one-year contracts where the team can trade a player but the player cannot refuse to be traded; the player can retire but he can be recalled;
- (d) a player can be sent to a minor league at most three times, but he can be recalled to the major league afterwards; the pay is substantially lower (\$400 dollars a week as opposed to \$400,000 a year); for injured players (on the disabled list), a replacement player from either the team's minor league or from another team can be employed as a substitute;

The major difference with respect to the previous group: at the beginning of the fourth period (or end of the third), a player can request "arbitration," the possibility to have his salary modified through a process in which the team and the player simultaneously submit an offer. The arbitrator chooses one, his decision is final. The threat of arbitration can trigger bargaining.

In principle, the arbitrator could select an offer that is below the player's original salary as long as his salary strictly exceeds the minimum wage. However, since virtually no player is paid any salary above the minimum wage, no player can experience a salary decrease as a consequence of arbitration.

Third Group. It is composed of "free agents" (until a player is in his early 40s):

- (a) the wage is determined according to a contractual minimum (\$500,000 a year) and rarely exceeds it;
- (b) no performance-based pay;
- (c) contract length: a player can be employed under a contract of any length by any team;
- (d) severance pay: it is possible, and in some cases it is a penalty agreed at the beginning of a t -period contract that the team pays at the end of period t in case the worker is not retained in the $(t + 1)$ -period.

Note that in no group a player can separate from the team unless he retires.

As part of the compensation package, each player receives health insurance which, however, corresponds to a negligible fraction of annual pay. All players are also entitled to a defined-benefit pension plan which is determined according to the number of years the player has spent in the league.

4.2. Estimation Sample. The sample consists of 4,474 observations concerning 783 players who participated in MLB between 1991 and 2008. The sample contains information concerning a player's name, team, year of entry in MLB, salary, bonus (amount in million of dollars to be paid to the player in addition to his salary), and the following contract data: whether the player has signed a new major league contract in a particular year, the number of years a contract has been in place and the remaining years over which the contract is valid, the availability of the option for the player to "opt-out" of a team before the expiration of the current contract and whether such option has been exercised, the availability of the option for a team to extend an outstanding contract—usually by one year—at a pre-negotiated salary established at the time the

outstanding contract has been signed and whether such option has been exercised, the amount of the team buy-out, the transfer due by a team to the player in case the team option is available but is not exercised and, finally, direct measures of individual performance (see the Appendix for details).³ Note that the data record all the major characteristics of all contracts under which a player has been employed by a major league team.

The average age of players in our dataset is 26.868 years with a standard deviation of 3.297, from a minimum of 19 to a maximum of 39 years; the age distribution of players has remained approximately constant over the sample years. All contracts we observe last between 1 to 10 years, even though contracts of short durations are predominant.

4.2.1. Preliminary Analysis. As for the determinants of a player's salary under a major league contract, it emerges from Table 1 that a player's physical attributes are important and significant.

TABLE 1
Regression Results on Salary I

Variable	Coefficient	(Std. Err.)
age	316866.530	(11139.993)
height	80037.148	(12174.732)
intercept	-13027264.789	(947185.116)

Observe, too, that the positive coefficient on age may capture experience. However, adding an age-squared term did not significantly affect the above results and the coefficient resulted insignificant. However, not all physical characteristics are important as measure of productivity—assuming that a player's productivity affects his salary. For instance, we excluded a player's weight from all specifications as it proved always insignificant. Regressing a player's salary on the player's age, height, and hitting performance (*ops_plus*), we obtain that all the regressors we previously considered, still significant, diminish in importance.⁴ Note that this dependence of compensation on performance is compatible with an incentive rationale for pay.

TABLE 2
Regression Results on Salary II

Variable	Coefficient	(Std. Err.)
age	309132.938	(10925.953)
height	62513.908	(11992.582)
ops_plus	9321.253	(675.937)
intercept	-12297411.081	(929270.120)

Observe also the importance of the contract life-cycle effect, measured either as the number of years a player has already been employed under a particular contract ('*contract_year*'), or the remaining years of guaranteed employment under a contract ('*yrs_remain*').

Finally, as for bonus payments, both the effect of age and performance seem modest. We shall investigate this further in the structural analysis to follow.

The contracts we observe in the data are of predetermined length and largely unconditional on performance. A combination of a binding minimum wage and the incentive effect of variation in future rather than in current compensation may be responsible for this.

³Note that these two variables allow us to identify whether observations concerning the *same* player also pertain to a *same* contract.

⁴The measure of performance we chose combines two aspects of hitting performance (consistency and power) and adjusts for the difference in home field.

TABLE 3
Regression Results on Salary III

Variable	Coefficient	(Std. Err.)
age	255608.786	(9222.286)
height	42216.733	(10043.984)
yrs_remain	1588845.815	(36286.137)
ops_plus	5219.099	(573.213)
intercept	-9451032.838	(780162.630)

TABLE 4
Regression Results on Salary IV

Variable	Coefficient	(Std. Err.)
age	194539.525	(9139.938)
height	48464.325	(9698.383)
contract_year	1673180.802	(34354.755)
ops_plus	4776.028	(554.301)
intercept	-9133379.706	(753970.924)

TABLE 5
Regression Results on Bonus I

Variable	Coefficient	(Std. Err.)
age	0.012	(0.003)
height	0.003	(0.004)
intercept	-0.511	(0.280)

TABLE 6
Regression Results on Bonus II

Variable	Coefficient	(Std. Err.)
age	0.012	(0.003)
height	0.002	(0.004)
ops_plus	0.001	(0.000)
intercept	-0.458	(0.281)

5. Model Estimation. In order to illustrate the feasibility of a structural estimation of the model, we present here the results of an estimation exercise performed on synthetic data simulated from the solution to the contracting problem under limited agent commitment.

5.1. *Simulation.* We simulate the model by generating a random sample of size I of individuals with initial states drawn from the interval V of promised utilities. For each of the I individuals, we then draw a T -period sequence of performance outcomes $y_i = (y_{i1}, \dots, y_{iT})$ to obtain a sequence of individual s -specific states $(\omega_{i1}, \dots, \omega_{iT})$ conditional on the individual's performance realized in each period. For each individual, we solve the principal's problem at each such state. Concretely, we proceed according to the following steps:

(1) we draw I states from V using a standard random number generation algorithm, the routine DRNUN in FORTRAN. Specifically, we draw a vector of pseudorandom numbers $(\omega'_{it}, \dots, \omega'_{It})$ from a uniform $(0, 1)$ distribution, which we rescale to the interval V to obtain $(\omega_{it}, \dots, \omega_{It})$ according to $\omega_{it} = \omega'_{it}(\bar{V} - \underline{V}) + \underline{V}$, the vector of initial states for the S individuals;

(2) for each $i \in I$ we draw a length- T sequence of pseudo-random numbers from a standard normal distribution based on an inverse CDF method. We relied on the routine DRNNOR in FORTRAN. Recall that we assumed performance is normally distributed with mean $\mu_y = 1.08$ and standard deviation $\sigma_y = 0.274$. We then rescaled each draw so that, if x_{it} is the univariate standard normal draw in period t for individual i ,

then his realized performance in period t is $x'_{it} = x_{it}\sigma_y + \mu$. We then employed a nearest-neighbour procedure to ensure all draws are one of the five realizations we admit;

(3) from the solution of the agent-commitment problem, we obtain the sequence of states $(\omega_{i1}, \dots, \omega_{iT})$ for each individual i . Recall that $u : Y \times V \rightarrow R$ and $v : Y \times V \rightarrow V$ (we omit the superscript ‘AC’ for simplicity), that is, in each period at each state the policy function optimally selects current payments and future promised utilities, where the latter define the next-period states;

(4) based on the computed policy function at each state, we record whether individual i in period t is retained or terminated, to obtain a sample IT of (contract) durations.

5.2. Estimation. Consider the subvector of model parameters $\psi^* = (c, \delta)$, where c denotes the disutility of effort and δ the principal’s and agent’s common discount factor. We focussed on M moments on contract duration derived from the above simulated data given ψ^* . In general, for given ψ , denote these moments by $\mu(\psi) = (\mu_1(\psi), \dots, \mu_M(\psi))$, where $\mu_t(\cdot)$ represents the (simulated) sample fraction of individuals who have been retained for at least t consecutive periods by the principal. We chose $M = t = 3$. Let $\mu^i(\psi') = (\mu_1^i(\psi'), \dots, \mu_M^i(\psi'))$ be the vector of moments simulated from the model, as described in the previous subsection, at the trial parameter vector ψ' . We can then provide an estimate of ψ^* based on an iterative procedure that:

- (a) repeatedly solves the model to compute $\mu^i(\psi')$ at each trial parameter vector ψ' ;
- (b) selects the vector $\hat{\psi}$ which minimizes the following (simulated method of moments) criterion function,

$$\hat{\psi} = \arg \min_{\psi'} \left\{ \sum_{j=1}^M [\mu_j^i(\psi') - \mu_j(\psi')]^2 \right\}. \quad (5.1)$$

Note that we have assumed, for simplicity, that the variance and covariance matrix is the identity matrix.

We performed the optimization in (5.1) using the downhill simplex routine DUMPOL in FORTRAN, which minimizes a function of N variables using a direct search polytope algorithm. Estimating the model on data simulated from the model, when $\psi^* = (0.1469, 0.90)$ and for $S = 1,000$, we obtain the reasonably accurate estimate $\hat{\psi} = (0.16317768, 0.89845898)$.

5.3. Performance. As noted, the contracts we observe in the data are mostly uncontingent on performance (see the description in Section 4). In presence of externalities across players at the team level, a player’s contribution to the team’s output may be different from his performance as recorded in our dataset. For this reason, we also experimented with a noise-dampening error specification for performance that makes the theoretical performance of each player possible less informative about effort than the recorded one, to measure how much noisier performance must be for the contract to be non-contingent on it.

6. Conclusion. In this paper, we have presented a flexible model of a dynamic moral-hazard problem, in which we accounted for endogenous agent-termination, productivity shocks, and human-capital accumulation. Under alternative contracting assumptions, we have simulated the cost of contracting as well as the strength of incentives provided through current performance-based pay and deferred compensation, contract duration, and the variability of compensation over time. Preliminary results suggest that the proposed framework qualifies as a promising structure to estimate the incentive power of multi-period employment contracts in MLB and to recover primitive preference and technological parameters of interest.

Appendix.

Sample Construction. In constructing individual players' histories we encountered three main problems: (a) record of players who primarily played in the minor league and experienced short spells (that is, few games in a year) in a major league team; (b) record of players whose initial history of play in the major league is missing; and (c) players whose contract data was unavailable.

Bonuses paid to players are pro-rated over the years of employment guaranteed by the contract.

The minimum salary was of 109,000 dollars between 1994 and 1996, of 150,000 dollars in 1997, 170,000 in 1998, 200,000 dollars between 1999 and 2002, of 300,000 dollars in 2003 and 2004, of 316,000 dollars in 2005, of 327,000 dollars in 2006, of 380,000 dollars in 2007 and of 390,000 dollars in 2008.

Acknowledgements. We thank Sean Forman of Sports Reference, LLC who generously provided us the information we requested from the relational database that is used to create www.Baseball-Reference.com. We are also grateful to Alberto M. Segre who provided invaluable advice with incorporating the contract data into a relational database.

References.

- Dilip Abreu, David Pearce, and Ennio Stacchetti. Toward a theory of discounted repeated games with imperfect monitoring. *Econometrica*, 58:1041–1063, 1990.
- Jorge G. Aseff. A numerical analysis of a dynamic model of agency, Arizona State University, Department of Economics, typescript, 2005.
- Jorge G. Aseff and Manuel S. Santos. Stock options and managerial optimal contracts. *Economic Theory*, 26:813–837, 2005.
- Mathias Dewatripont and Jean Tirole. Modes of communication. *Journal of Political Economy*, 113:1217–1238, 2005.
- Eugene F. Fama. Agency problems and the theory of the firm. *Journal of Political Economy*, 88:288–307, 1980.
- Jahn K. Hakes and Chad Turner. Long term contracts in Major League Baseball. Available at SSRN: <http://ssrn.com/abstract=1309944>, 2008.
- Anthony C. Krautmann. Shirking or stochastic productivity in Major League Baseball? *Southern Economic Journal*, 56:961–968, 1990.
- Anthony C. Krautmann and John L. Solow. The dynamics of performance over the duration of Major League Baseball long-term contracts. *Journal of Sports Economics*, 10:6–22, 2009.
- Kenneth Lehn. Property rights, risk sharing, and player disability in Major League Baseball. *Journal of Law and Economics*, 25: 343–366, 1982.
- Mary M. Margiotta and Robert A. Miller. Managerial compensation and the cost of moral hazard. *International Economic Review*, 41: 669–719, 2000.
- Joel G. Maxcy. Do long-term contracts influence performance in Major League Baseball? In Wallace Hendricks, editor, *Advances in the Economics of Sports*, pages 157–176. Greenwich, Connecticut: JAI Press, 1997.
- Joel G. Maxcy, Anthony C. Krautmann, and Rodney Fort. The effectiveness of incentive mechanisms in Major League Baseball. *Journal of Sports Economics*, 3:246–255, 2002.
- John Rust. Optimal replacement of GMC bus engines: An empirical model of Harold Zurcher. *Econometrica*, 55:999–1033, 1987.
- John F. Scoggins. Shirking or stochastic productivity in Major League Baseball: Comment. *Southern Economic Journal*, 60:239–240, 1993.
- Steven E. Spear and Cheng Wang. When to fire a CEO: Optimal termination in dynamic contracts. *Journal of Economic Theory*, 120: 239–256, 2005.
- Stiroh. Playing for keeps: Pay and performance in the NBA. *Economic Inquiry*, 45:145–161, 2007.
- Cheng Wang. Incentives, CEO compensation, and shareholder wealth in a dynamic agency model. *Journal of Economic Theory*, 76: 72–105, 1997.

DEPARTMENT OF ECONOMICS, UNIVERSITY OF MELBOURNE, PARKVILLE, VIC, 3010, AUSTRALIA
 DEPARTMENT OF ECONOMICS, UNIVERSITY OF IOWA, IOWA CITY, IA, 52242, USA
 DEPARTMENT OF ECONOMICS, UNIVERSITY OF IOWA, IOWA CITY, IA, 52242, USA
 E-MAIL: HPaarsch@UniMelb.edu.au
Elena-Pastorino@UIowa.edu
John-Solow@UIowa.edu