Productivity over the Life Cycle: Evidence from Professional Baseball

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This paper examines whether effort and productivity are optimally allocated over the life cycle, in response to anticipated changes in the rewards for performance. A simple model is presented in which effort is found to be positively related to the marginal returns to effort and the marginal utility of lifetime income. Major league baseball provides an ideal setting in which to test the predictions of this model, because the nature of the salary bargaining system means that the pay-performance gradient increases suddenly and substantially at predetermined points in a player's career. The expected pay-performance gradient facing each player is estimated, using annual data for 2005-2010. As expected, this is found to have a significant positive effect on performance, both for pitchers and non-pitchers. Accumulated forecast errors in lifetime income are not found to have a significant effect on performance.

'And he's a fool to himself too,' she burst out again. 'Cramping his own trade! He cheats us out of ninepence and stops us from earnings pounds more for him. Who's going to bring out any ideas when he treats you like that? It doesn't pay to have ideas here.'

High Wages, Dorothy Whipple

1. Introduction

Lifetime utility maximization implies that individuals should optimally allocate their labor supply over time in response to expected changes in wages. Despite this, previous empirical studies have found only mixed evidence of an intertemporal labor supply function. One explanation is that many workers are constrained in terms of the hours they must work each week. In contrast, workers are almost always to adjust the level of effort they put into their work. If the returns to effort (or penalties for lack of effort) vary over the life cycle, utility maximization implies that productivity should follow a similar pattern to that of labor supply – people should put more effort into their work during periods in which they think this will be most rewarded in the labor market.

U.S. professional baseball provides an ideal setting in which to study whether

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changes in the rewards for effort influence a person's productivity. Not only is accurate and comprehensive productivity data available at the individual level, in the form of performance statistics, but the salary bargaining system provides an exogenous source of variation in the relationship between pay and performance. Newly-signed players are tied to a single team and are typically paid the league minimum salary. However, since 1977, players with at least 3 years of experience may choose to have an independent arbitrator settle salary disputes and players with at least 6 years of experience have the right to become "free agents" once they are out of contract, meaning they can sign for any team they like. Salary arbitration has resulted in the salaries of eligible players being much more closely related to their past performance than is the case for less experienced players. Eligibility for free agency magnifies this effect further. Since the free agency system induces extremely large and sudden changes in the pay-performance gradient at predetermined points in a player's career, it provides an exogenous source of income growth, unrelated to a player's past performance.

This paper presents a model of lifetime utility maximization among players in the face of a predictable pattern of returns to performance. Effort is costly but results in higher future salaries. The model predicts that players should perform better in those seasons when the pay-performance gradient is high and when the marginal utility of lifetime income is high. These predictions are then tested using player-level data for 2005-2010.

The paper makes three main contributions to the literature studying the effects of pay structure on productivity. Firstly, by introducing exogenous shifts in players' pay-performance gradients at different points throughout their careers, the free agency system allows a test of whether a given player exhibits an increase in performance at those points. Secondly, the paper is able to calculate forecast errors in lifetime income and control for the effect of these in the performance regressions, thus correcting for omitted variable bias. Finally, the analysis uses accurate measures of individual productivity for *all* workers within a particular industry, rather than just a single firm as in previous related studies, and is therefore able to avoid selection bias arising from the endogenous adoption of a given compensation system.

2. Background

A sizeable literature has examined whether workers' levels of labor supply follow the same pattern as wages over their life cycle, as predicted by the theory of Lucas and Rapping (1969). In general, these have found relatively little support for the idea of intertemporal substitution of labor (MaCurdy 1981; Altonji 1986; Card 1994; Ham and Reilly 2002). A primary criticism is that while neoclassical models of labor supply assume that workers are free to set their hours, this is rarely true in practice (Farber 2005). Some recent papers have responded by examining groups of workers who are free to adjust their work hours and have found some evidence that temporary increases in wages do lead to increases in labor supply (Camerer *et al*. 1997; Oettinger 1999; Fehr and Goette 2007; Connolly 2008).

Meanwhile, a separate literature has analyzed the effect performance related pay has on worker productivity.[1] These generally find support for the idea that productivity is higher under piece rates than under fixed wages. This literature includes papers using firm-level data (Gielen, Kerkhofs, and van Ours 2010) and those using worker-level data (Booth and Frank 1999; Pekkarinen and Riddell 2008), but also a number of studies that look at workers within a single firm (Lazear 2000; Shearer 2004; Bandiera, Barankay, and Rasul 2005). These intra-firm studies collect direct measures of individual productivity and use longitudinal data, allowing them to control for the fact that more able workers are more likely to have performance-related contracts. However, as Pekkarinen and Riddell note, they are still likely to suffer from a selection problem, since compensation policy at the firm level is likely to be endogenous. This analysis in this paper avoids this problem by using longitudinal data for the workers in *all* firms in an industry (or, in this case, for players in all major league teams).

A handful of previous authors have examined what happens to performance among major league baseballers who elect to become free agents and sign contracts with different teams. Grad (1998) and Holden and Sommers (2005) noted that players might be motivated to put in extra effort in the year prior to filing for free agency in order to impress potential bidders. Krautmann (1990) argued instead that there is an incentive for

[1] All major league baseball players receive bonuses if their team reaches the post-season and some contracts also include bonuses for reaching specific performance targets, although they are not piece rates as studied by the authors listed.

a player to shirk immediately after signing a multiple-year contract. Both hypotheses predict that a player's performance will decline immediately after he signs a free agent contract, however none of the papers find significant evidence of this.

In contrast to the aforementioned studies, this paper examines the effects of eligibility for salary arbitration and free agency on the performance of all players, not just those players who sign new free-agent contracts. The returns to performance increase most sharply when players pass the threshold for eligibility for salary arbitration, before they are even eligible for free agency. Furthermore, focusing on the effects of filing for free agency introduces an endogeneity problem, since the decision of whether and when to file may be affected by a player's past performance.

3. The free agency system

The early days of professional baseball were plagued by players regularly shifting teams during the middle of seasons in search of pay increases. To combat this, team owners made an agreement before the 1879 season not to sign any of five "reserved" players on each others' teams. The number of reserved players rose to include the entire team by 1883 and in 1887 was made a formal contract clause. This so-called reserve clause formed the basis of the baseball labor market for almost a century. Essentially, it meant that teams could make take-it-or-leave-it offers to their players. Players had no means by which to persuade the team to increase their salary offer, except the threat of retirement: if a player refused to accept a contract, he was unable to play anywhere else in the major leagues.

Throughout the 1970s, the reserve clause system was progressively dismantled. Firstly, team owners agreed to a system of salary arbitration in 1973, following a strike by players the previous year. Under this system, if a player and team cannot agree on a contract, either party may file for arbitration. The arbitrator must choose between the final contract offers made by the player and team, based solely on the player's performance, the club's record and attendance and the salaries of players with the same amount of major league experience.[2] Both sides are obligated to accept this contract. In

[2] For players with less than 5 years of major league service, arbitrators may also take into account the salaries of players with one extra year of experience.

practice, most contracts are settled by players and teams before reaching arbitration. Under current rules, a player is eligible for salary arbitration if he has accrued more than three, but less than six, years of major league service. In addition, among those players with between two and three years of service who have accumulated at least 86 days of service during the previous season, the top 17% ranked by total service time are eligible for salary arbitration. This is known as the "Super Two" exception.[3]

Meanwhile, beginning in 1970, the legality of the reserve clause was challenged in a series of cases. Although the Supreme Court ruled that the reserve clause was legal in 1972, Catfish Hunter became the first free agent in 1974 after he won a contract dispute in arbitration. The contract he subsequently signed made him the highest paid player in baseball the following season. Finally, in 1975 Andy Messersmith and Dave McNally refused to sign new contracts. Although their teams renewed their contracts from the previous season, the players argued that since no contract had been signed, they would not be bound to the team for the following season and in December 1975 an arbitrator agreed. Although team owners finally conceded that the reserve clause was unenforceable, they argued that the cost of developing young players was so high they needed a guaranteed period of time during which they could recover their investment. Under an agreement reached with the players' union in 1977, a player is bound to his original team for his first six years, as per the reserve clause. However, after they have accumulated six years of major league service, players can now become free agents and sign with whichever team they wish. Of course, if players sign long-term contracts before the end of their sixth season, they relinquish this right.

In the three decades since the introduction of the free agency system, average salaries have risen dramatically in the major leagues. Figure 1 plots the evolution of the average salary across the major leagues between 1950 and 2009, along with the league minimum salary. Average salaries began increasing rapidly after the introduction of free agency and have continued to rise at a reasonably steady rate since. The minimum salary has also been raised regularly since the early 1970s, although it has not kept pace with the average

[3] The existence of the Super Two exception means that teams are effectively prevented from manipulating their players' service times to avoid letting them become eligible for arbitration, as they do not know in advance what the service time threshold will be.

salary. The ratio of the average to minimum salary was around 4 in 1977, rose to a maximum of 11.5 in 2002 before falling back to 7.5 in 2009 as the minimum was doubled.

Players' salaries typically follow three distinct phases over the course of their careers. During their first three complete seasons, they are almost always signed to one-year contracts at the prevailing league minimum. For their next three seasons, during which they are not free agents but are eligible for salary arbitration, they tend to receive rapidly increasing salaries, regardless of whether they actually file for arbitration or not. Finally, after six years, players receive relatively stable salaries that are close to (and may even exceed) their marginal revenue product (Sommers and Quinton 1982; Blass 1992). This is seen in Figure 2, which depicts the average salary-experience profile in 1977 and 2010. Salaries typically increased with experience in both years (although initial salaries were about 5 times higher in real terms in 2010).[4] As predicted, earnings grew at a similar rate over a player's early career in both periods, however they grew much faster during the player's salary arbitration eligibility period in 2010.

Major league service time is used to determine whether a player is eligible for salary arbitration or free agency and is measured in years and days. The maximum amount of service time that a player may accumulate each year is 172 days, even though a season typically lasts longer than that. As well as time spent on a team's 25-man active roster, service time includes time spent injured (known as being on a team's disabled list) or on the suspended list. Time spent in the minor leagues does not generally count towards service time, however players who spend no more than 20 days on optional assignment in the minor leagues in a season are credited with service time for the length of their assignments.

4. A model of lifetime productivity

In order to examine how a player's productivity might vary over the life cycle, it is instructive to consider the decisions faced by teams and players. Teams must choose how much money and what length contract to offer a player, given their knowledge of the

[4] As Blass (1992) speculates, the fact that an upward-sloping career earnings profile already existed in 1977 (before free agency was established) might be the result of a compromise between the desire of teams to ensure performance incentives by paying piece rates and the desire of players to have a smooth source of income.

player's productivity up to the previous season and the constraints imposed by the salary bargaining system. Players must decide what level of effort to expend in each season, given their current and anticipated future earnings.

Suppose player i's performance in his tth season in the major leagues can be modeled as:

$$\gamma_{it} = g(t) + \theta_i + \eta_{it} + v_{it}, \tag{1}$$

where $g(t)$ is a fixed time path common to all players, reflecting their initial development and eventual physical deterioration (so that $g'(t) < 0$ after some t); θ is player quality, reflecting permanent differences in performance; η is productivity resulting from effort, which must be non-negative and is chosen by the player in each period; and v is productivity resulting from luck, which may be positive or negative and, among other things, may manifest itself in the form of injuries to player i or other players, differences in opponent quality and loss of confidence. Luck is assumed to be random and will be modeled as an AR(1) process, as follows:

$$v_{it} = \alpha v_{i(t-1)} + \varepsilon_{it},\ 0 < \alpha < 1, \tag{2}$$

where the ε are i.i.d. and $E_{t-1}(\varepsilon_{it}) = 0$.

From experience and scouting reports, teams are assumed to know $g(t)$ and θ, but not η or v, and they observe γ once each season is completed. In determining what contract to offer player i, any team j should therefore calculate what his expected performance will be s seasons in the future, given his performance in the most recent season, t:

$$\begin{aligned} E_t^j(\gamma_{i(t+s)}) &= g(t+s) + \theta_i + E_t^j(\eta_{i(t+s)} + v_{i(t+s)}) \\ &= g(t+s) + \theta_i + E_t^j(\eta_{i(t+s)}) + \alpha^s(\gamma_{it} - g(t) - \theta_i - E_t^j(\eta_{it})). \end{aligned} \tag{3}$$

where $E_t^j(\cdot)$ denotes the expectation operator, given the information team j has at the end of season t.

Hence, teams wish to estimate how much effort the player is likely to expend in each future period. Suppose this is the same for all players at a given point in their careers, so that $E_t^j(\eta_{i(t+s)}) = \overline{\eta}_{t+s}$, $\forall j$, $\forall s > 0$. Then, if teams are profit maximizers and may only offer one-year contracts, they will pay player i a salary determined by:

$$w_{i(t+1)} = \pi_k(E_t^j(\gamma_{i(t+1)}))$$
$$= \pi_k(\alpha\gamma_{it} + (1-\alpha)\theta_i + g(t+1) - \alpha g(t) + \overline{\eta}_{t+1} - \alpha\overline{\eta}_t), \quad (4)$$

where $\pi_k(\cdot)$ is the wage function, which should be the same for all players who are in salary bargaining class k in season t+1. It is assumed that $\pi'(\cdot) > 0, \ \forall k$; however, $\pi'(\cdot)$ should be highest among those who are free agents and lowest among those who are ineligible for salary arbitration.

In each season, players wish to choose consumption, c, and effort in order to maximize lifetime utility, subject to the constraint that the discounted expected value of lifetime consumption must equal discounted expected lifetime earnings:[5]

$$\max_{c_\tau, \eta_\tau} E_t^i\left(\sum_{\tau=0}^{T} \beta^\tau u(c_{i\tau}, \eta_{i\tau})\right), \text{ subject to } \sum_{\tau=0}^{T} \frac{E_t^i(w_{i\tau} - c_{i\tau})}{(1+r)^\tau} = 0, \quad (5)$$

where β is the player's discount factor, r is the interest rate and T is the number of seasons the player expects to play in the major leagues.

The utility function is assumed to take the following form:

$$u(c_{it}, \eta_{it}) = \ln c_{it} - A\eta_{it}^2, \ A > 0. \quad (6)$$

Effort raises a player's earnings in the next season, but involves disutility in the current season. Substituting equations 4 and 6 into equation 5 and solving the appropriate Lagrangian, it can be seen that optimal effort in season t requires:

$$-2\beta^t A\eta_{it} + \frac{\lambda_{it}}{(1+r)^{t+1}} \alpha\pi_k'(\alpha\gamma_{it} + (1-\alpha)\theta_i + g(t+1) - \alpha g(t) + \overline{\eta}_{t+1} - \alpha\overline{\eta}_t) = 0, \quad (7)$$

where λ_{it} is the Lagrange multiplier, which may be interpreted as the marginal utility of lifetime income. This may change from season to season if players discover that their actual salary differs from what they expected at the onset on their career. In general, we cannot solve for λ_{it} when there is uncertainty about future income and productivity (Card 1990). The first term in equation 7 measures how much disutility a person experiences from a marginal unit of effort in a given period, while the second term measures how much a marginal unit of effort raises lifetime utility by raising lifetime income.

[5] Equation 5 ignores the fact that players continue to earn and spend money after they retire. This is likely to be reasonable, since earnings from professional baseball are far greater than what most players earn later in their lives.

If the wage function is linear, so that $w_{i(t+1)} \equiv \varsigma + \omega_k E_t^j(\gamma_{i(t+1)})$, and the discount rate equals the interest rate, so that $\beta = (1+r)^{-1}$, then equation 7 simplifies to:

$$\lambda_{it}\alpha\beta\omega_k - 2A\eta_{it} = 0, \tag{8}$$

from which the optimal level of effort can be determined:

$$\eta_{it}^* = \frac{\lambda_{it}\alpha\beta\omega_k}{2A}. \tag{9}$$

Equation 9 can be linearized around the means of λ_{it} and ω_k (denoted $\overline{\lambda}$ and $\overline{\omega}$, respectively) to give:

$$\eta_{it}^* = -\frac{\alpha\beta\overline{\lambda}\,\overline{\omega}}{2A} + \frac{\alpha\beta\overline{\lambda}}{2A}\omega_k + \frac{\alpha\beta\overline{\omega}}{2A}\lambda_{it}. \tag{10}$$

If players put in the optimal amount of effort each season, their observed performance can be found by substituting equation 10 into equation 1:

$$\gamma_{it} = g(t) + \theta_i - \frac{\alpha\beta\overline{\lambda}\,\overline{\omega}}{2A} + \frac{\alpha\beta\overline{\lambda}}{2A}\omega_k + \frac{\alpha\beta\overline{\omega}}{2A}\lambda_{it} + v_{it}. \tag{11}$$

Equation 11 implies that a player's performance in any season will comprise a deterministic time trend, a time-invariant term, components that are proportional to the pay-performance gradient and the marginal utility of lifetime income, and an autoregressive error term. This equation will form the basis of the empirical analysis in Section 6. An important feature of equation 11 is that ω must have a positive coefficient. Changes in the slope of the wage function have only a substitution effect, because players know in advance that they will occur at fixed points during their career.

5. Data

The primary data for this paper are taken from Sean Lahman's Baseball Archive (available from www.baseball1.com) for the period 2005-2010. This contains annual data on the performance of each player in the major leagues. This study will focus on two measures of performance: on-base plus slugging (OPS) for non-pitchers and earned run average (ERA) for pitchers. A player's OPS is the sum of his on base percentage (defined as times-on-base per plate appearance, excluding sacrifice hits, fielder's obstruction or catcher's interference) and his slugging percentage (defined as total bases scored per atbat).[6] ERA is defined as earned runs conceded per 9 innings pitched. Hence, a higher OPS but a lower ERA indicates higher productivity. Non-pitchers are excluded from regressions for OPS in seasons where they have fewer than 50 plate appearances and pitchers are excluded from regressions for ERA in seasons when they pitch fewer than 25 innings.

Since the Baseball Archive dataset does not record the time players spend on the disabled list, it is impossible to calculate a player's service time using it. However, data on players' career service time at the beginning of each season from 2005 to 2010 were obtained from the Cot's Baseball Contracts website (www.mlbcontracts.blogspot.com) and merged with the Baseball Archive data.[7] Service time data are available for 85% of observations on pitchers and 87% of observations on non-pitchers. Information on the start and finish years of every contract signed between 2005 and 2010 was also obtained from the same source, along with whether the contract specified any performance bonuses (such as additional pay for being selected for the annual All-Star Game or attaining a certain batting average or ERA). Each player's annual salary was obtained from the Baseball Archive and is expressed in 2010 dollars, using the Consumer Price Index.

Means for the estimation sample are given in Table 1. A relatively small number of observations (60 for non-pitchers; 301 for pitchers) are dropped because they are missing variables used in the regressions; specifically, they have breaks in their service time data, which is used to calculate salary forecast errors. On average, non-pitchers tend to have more service time and higher salaries. Around half of non-pitchers and two-thirds of pitchers are in their first three years in the major leagues and are thus ineligible for salary arbitration. 13-14% of players in each sample are eligible for salary arbitration but are not free agents (including those in their last year before free agency), while the remainder are free agents. Reflecting the fact that non-pitchers tend to have longer careers, they are

[6] OPS is preferred to batting average as it takes into account a player's ability to draw walks and score extra-base hits, as well as to hit singles. Nonetheless, the results in the next two sections were very similar when batting average was used to measure non-pitchers' performance.

[7] Cot's Contracts is maintained by Jeff Euston, who updates the service time data each year largely based on information from the Associated Press and local newspapers covering individual clubs. *Sports Illustrated Interactive* described it as "the unofficial clearinghouse for MLB contracts" and "the most reliable public source" on baseball contract data (Donovan 2008).

more likely than pitchers to have performance bonuses and to be in the middle of multiple-year contracts.

6. Analysis

The model outlined in Section 4 predicts that a person's chosen level of effort – and therefore productivity – should be highest in periods when the payoff to that effort is highest. Baseball provides an ideal setting in which to test this prediction for three reasons. Firstly, even though a player's effort is not directly observable, his performance in each period is measurable and is publicly observable. Secondly, the rules surrounding eligibility for salary arbitration and free agency provide an exogenous source of variation in the pay-performance gradient over a player's career. Finally, teams have no ability to fire players for underperforming after a contract has been signed, but if a player shirks he reduces his likelihood of signing a lucrative contract in the future.

Equations 4 and 11 jointly represent a solution to the model presented earlier and the empirical analysis will consist of two steps, estimating each equation in turn. Since it is assumed that the pay-performance gradient is exogenously determined, it can therefore be estimated by considering the salaries and performance across the full sample of players. The estimated pay-performance gradient can then be added to a regression modeling players' performances.

a. Pay-performance gradients

The pay-performance gradient facing a particular player will vary for two reasons. Firstly, as noted in Section 4, the gradient will increase over the course of a player's career, as he becomes eligible first for salary arbitration (after 3 years) and then for free agency (after 6 years). In addition, Kahn (1993) argues that teams may wish to tie players who are in their fifth season to long-term contracts at free agency salary levels before they are able to leave the team as free agents. This suggests that players who are in their last year before free agency should be considered as a fourth distinct group. These four groups will be termed "salary bargaining classes". Dummy variables were defined, indicating whether a player has at least three years of service time or satisfies the Super Two exception and has less than five years of service time (*SARB*), has at least five but less than six years of service time (*LAST*) or has at least six years of service time and is therefore eligible for free agency (*FREE*). These are determined by a player's service time at the beginning of the current season, since players may be only granted rights to free agency and salary arbitration once a year – after the conclusion of the season.

Figures 3 and 4 illustrate how the relationship between a player's performance and his salary in the following season varies according to his salary bargaining class that season. For both pitchers and non-pitchers, the pay-performance relationship among those with less than 3 years of service time (and who are thus ineligible for salary arbitration) is essentially flat at the level of the minimum salary. After a player becomes eligible for salary arbitration, the relationship between pay-performance gradient increases sharply and is even steeper for those who are free agents.

A second reason why the pay-performance gradient may vary between players is that, while the model in Section 4 assumed all contracts last only a year, in practice some players are signed to multiple-year contracts, which specify *ex ante* a certain salary in each year of the contract. Hence, players in the middle of multiple-year contracts will know their following year's salary with certainty and this will not be affected by how well they perform during the current season.[8] This is expected to reduce their incentive to expend extra effort (Krautmann 1990; Grad 1998; Holden and Sommers 2005). A dummy variable was defined (*LASTYR*), identifying those cases where a player is in the last year of his contract (including single-year contracts).[9] In those cases where a player has at least one more year to run on his current contract, the pay-performance gradient must be zero.

Equation 4 implies that teams should take into account a player's level of ability when deciding what salary to offer him, because it will determine what fraction of the observed performance in one season is likely to persist in all future seasons. Therefore, in order to estimate the pay-performance gradient for players at each stage of their careers, salary regressions were run for pitchers and non-pitchers in the last years of their contracts, including as regressors a set of dummies for a player's bargaining class and

[8] A contract may be declared void, but only in exceptional cases, such as when a player has provided fraudulent information.

[9] Players who are in the last year of their contracts but whose contracts give them the option to unilaterally re-sign for the following season are given zeros for the last year dummy.

their interactions with performance in the previous season, $\gamma_{i(t-1)}$ (either ERA or OPS), along with a set of player fixed effects, as follows:

$$w_{it} = \varphi_1 SARB_{it} + \varphi_2 LAST_{it} + \varphi_3 FREE_{it} + \varphi_4 \gamma_{i(t-1)} + \varphi_5 SARB_{it}\gamma_{i(t-1)} + \varphi_6 LAST_{it}\gamma_{i(t-1)} + \varphi_7 FREE_{it}\gamma_{i(t-1)} + \mu_i + u_{it}. \qquad (12)$$

If teams simply paid a certain amount for a given unit of performance in the previous season, without taking into account a player's inherent ability, μ would be zero in equation 12. The results of estimating this model are given in the first and third columns of Table 2. In the second and fourth columns of the table, the player effects are added. The returns to performance are found to be larger when the player effects are omitted, which is expected, since much of the variation in performance in this case is likely to be due to differences in permanent ability.

The results in Table 2 confirm that teams pay more for each unit of previous season's performance (higher OPS or lower ERA) when hiring players who are eligible for salary arbitration or free agency. As found by Kahn (1993), teams pay more for players who performed well in the most recent season, even among players with the same long-run level of performance (as captured by the player effects). Compared to models that included second- or third-order polynomials in performance, Bayes' Information Criterion indicates that the linear specification is preferable for both pitchers and non-pitchers.

The coefficient estimates from the fixed effects specifications will be used to estimate the pay-performance gradient. The estimates of φ_4, φ_5, φ_6 and φ_7 indicate how players in different bargaining classes will be rewarded for their effort at the end of a season. However, *during* a season, players may not know for certain what bargaining class they will be in the following season. Therefore, non-parametric estimates of the probabilities of being in a given bargaining class the following season were calculated for players at each level of service time at the *beginning* of a season.[10] These probabilities were then

[10] Specifically, a local mean-smoothed line (with bandwidth 0.2) was fit between each bargaining class dummy and the service time at the beginning of the previous season, separately for pitchers and non-pitchers.

used to create an appropriately weighted average of the estimated one-season-ahead pay-performance gradients for each player in each season (ω_k in equation 11):

$$\hat{\omega}_{it} = \begin{cases} 0 & \text{if } LASTYR_{it} = 0 \\ \hat{\varphi}_4 + P(SARB_{i(t+1)})\hat{\varphi}_5 + P(LAST_{i(t+1)})\hat{\varphi}_6 & \\ \qquad + P(FREE_{i(t+1)})\hat{\varphi}_7 & \text{if } LASTYR_{it} = 1 \end{cases} . \tag{13}$$

b. Career performance models

Tables 3 and 4 present the results of estimating equation 11, using the estimated pay-performance gradient for each player in each season, $\hat{\omega}$. In all models, a quadratic in service time, as measured at the beginning of a season, (*SERV*) is included to capture the fixed time path of performance, $g(t)$. Player fixed effects are included to control for inherent ability, θ. A dummy variable (*BONUS*) is also added for those players whose current contracts include any performance bonuses, since such payments might be expected to improve performance for reasons unrelated to intertemporal optimization. Hence, the following regression equation is used:

$$\gamma_{it} = \alpha_1 \hat{\omega}_{it} + \alpha_2 SERV_{it} + \alpha_3 SERV_{it}^2 + \alpha_4 BONUS_{it} + \theta_i + v_{it} , \tag{14}$$

where γ is OPS for non-pitchers and ERA for pitchers. As in Section 4, the error term v is assumed to follow an autoregressive process of order 1. Bootstrapped standard errors are reported to account for the fact that $\hat{\omega}$ is constructed from a first-stage regression.[11]

To start with, the marginal utility of lifetime income is assumed to be constant over time, meaning that λ can be omitted from the regression equation, as it will be captured by the player fixed effect. This is equivalent to assuming that players never make any forecast errors regarding their lifetime income. It would also be appropriate if players are unable (or unwilling) to smooth consumption over their careers.[12] The estimates in the first columns of Tables 3 and 4 reveal that the pay-performance gradient has a significant positive effect on the performance of both pitchers and non-pitchers, consistent with

[11] Since the sample comprises almost every player in the period considered, a case could be made that the bootstrap is unnecessary. In practice, there is little difference between the conventional and bootstrap standard errors.

[12] In this case, equation 9 reduces to $\eta_{it} = \dfrac{\alpha\beta\omega_{t+1}}{2A}$.

lifetime utility maximization. A one standard deviation increase in the pay-OPS gradient (equal to 3.091) raises a non-pitcher's OPS by 0.006. A one standard deviation increase in the pay-ERA gradient (equal to 0.212) raises a pitcher's ERA by 0.088. These coefficients imply elasticities of 0.006 and -0.013, respectively.

Excluding λ will introduce bias if it is correlated with the pay-performance gradient, which is likely. Unfortunately, as noted in Section 4, there is no closed form solution for λ. However, if λ is assumed to be proportional to a player's contemporaneous expectation of his lifetime income, the former can be proxied for with the latter, which may be written:

$$W_{it} = \sum_{\tau=0}^{T} \beta^{\tau} E_t^i(w_{i\tau}) = W_{i0} + \sum_{\tau=1}^{T} \beta^{\tau} (E_t^i(w_{i\tau}) - E_0^i(w_{i\tau}))$$
$$\approx W_{i0} + \sum_{\tau=1}^{t} \beta^{\tau} (w_{i\tau} - E_0^i(w_{i\tau})). \qquad (15)$$

The last equality is approximately true because while players discover whether they have graduated to a higher bargaining class (*SARB*, *LAST* or *FREE*) before each season begins, this information is unlikely to affect their forecasts of their bargaining classes in future seasons, given the unpredictability of service time, meaning that $E_t^i(w_{i\tau}) = E_0^i(w_{i\tau})$, $\forall \tau > t$. Equation 15 implies that expected lifetime income in any season is the sum of the player's initial expectation, W_{i0} (which is incorporated into the player effect), and his forecast errors up to that season. These forecast errors can be calculated, at least to the extent that players miscalculate their salary bargaining class in future seasons. These errors can be considerable; for example, 77% of non-pitchers and 65% of pitchers at least double their salary the year after they become eligible for salary arbitration.

Since service time data was only available for 2005 onwards, it is only possible to measure forecast errors made during seasons since then. Annual forecast errors were calculated by taking the appropriate predicted salary increment from Table A1, given a player's bargaining class in season t ($\hat{\varphi}_1$, $\hat{\varphi}_2$ or $\hat{\varphi}_3$), and subtracting the player's expectation of this salary increment, as formed at the onset of his career. A discounted sum of the annual forecast errors was then formed, using a discount rate of 10% (Hancock and Richardson 1985):

$$\hat{W}_{it} = \begin{cases} 0 & \text{if } LASTYR_{it} = 0 \\ \sum_{\tau = t_{2005}}^{t} 1.1^{t_{2005} - t} (SARB_{it}\hat{\varphi}_2 + LAST_{it}\hat{\varphi}_3 + FREE_{it}\hat{\varphi}_4 & \\ \qquad - P(SARB_{it})\hat{\varphi}_2 - P(LAST_{it})\hat{\varphi}_3 - P(FREE_{it})\hat{\varphi}_4) & \text{if } LASTYR_{it} = 1 \end{cases} . \quad (16)$$

The second columns of Tables 3 and 4 report the results of estimating equation 14 when $\hat{W}$ is added as a regressor. The forecast error term is found to be insignificant for both pitchers and non-pitchers, while the other coefficients are little affected.

Even though exact service time was not available before 2005, a player's service time can be estimated in earlier seasons using data on games played per season. The service time data reveal that, on average, non-pitchers who attain a year of service time play at least 110 games (out of 162). Similarly, for pitchers to complete a full year of service requires an average of 60 games for relievers and 30 games for starters (defined as those who start at least one game during the season). Using these correspondences, a rough estimate of the service time completed by players can be constructed for every past season. From this, the discounted sum of each player's accumulated forecast errors can be calculated, using the same approach as in equation 16, but including every past season. Once again, this was found to have an insignificant effect on performance (as revealed in the third columns of Tables 3 and 4).

The previous regressions all assume a linear relationship between salary and performance in the preceding season. While Figures 1 and 2 suggest that this is a reasonable assumption, a less restrictive approach was used in the final columns of Tables 3 and 4. Here, the salary-OPS gradient was predicted from a local linear regression of salary on OPS, conducted separately for each bargaining class. As before, each player is assigned a weighted average of these values, with the same weights used as in equation 13. Since the pay-performance gradient now varies by performance within each bargaining class, it will be endogenous when used as a regressor in equation 14. Therefore, the bargaining class dummies and the dummy for whether the player is in the last year of his contract were used as instruments. These are clearly related to the pay-performance gradient, but are unlikely to have any direct effect on the career pattern of performance.[13] Compared to the situation where the gradient is linear, the estimated coefficient on the pay-performance gradient is similar for pitchers, but somewhat lower for non-pitchers; however, it is remains significant in both cases.

7. Conclusion

This paper examines whether the greater returns to performance faced by professional baseballers who are eligible for salary arbitration and free agency lead to performance improvements. Although players are guaranteed employment for a specified number of seasons after they sign a contract, they may not receive another contract (or may receive a less lucrative contract) if they shirk. In this case, the higher a player's expected returns to effort, the more effort he should expend in the current season. Data on exact major league service time for players between 2005 and 2010 provide exogenous determinants of players' pay-performance gradients. The empirical evidence suggests that among both pitchers and non-pitchers, performance does indeed increase during those seasons when the pay-performance gradient is highest. Although theory suggests that performance should also be negatively related to expectations of lifetime income, no evidence is found to support this.

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[13] Better players are more likely to be signed to multiple-year contracts, but within a player's career, there is no reason to believe that contracts (having been signed in advanced) will be timed to end during periods of high performance.

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Table 1
Means for the Regression Samples

Variable	Non-pitchers	Pitchers
OPS	0.7331	–
ERA	–	4.4272
Real salary (in $ millions)	1.5990	1.0745
Pay-performance gradient	2.5227	-0.1488
Forecast error in salary since 2005 (in $ millions)	-0.5169	2.2045
Career forecast error in salary (in $ millions)	0.1473	2.1798
Not salary arbitration eligible	0.5384	0.6747
Salary arbitration eligible	0.1168	0.1182
Last year before free agency	0.0223	0.0100
Free agent	0.3226	0.1970
Career service time	4.5443	3.2002
Bonuses in contract	0.2128	0.1497
Last year of contract	0.7941	0.8669
Number of observations	2,914	2,893

Note: Salary is in 2010 dollars, adjusted using the Consumer Price Index price deflator. The samples are restricted to those observations used in the regressions in Tables 3 and 4 and exclude cases where forecast errors cannot be calculated due to breaks in service time data.

Table 2
Salary Regressions for Non-Pitchers and Pitchers

Variable	Non-pitchers		Pitchers	
	(1)	(2)	(3)	(4)
Salary arbitration eligible	-4.9789***	-2.8193***	2.8117***	2.5164***
	(0.8987)	(0.8375)	(0.3297)	(0.2709)
Last year before free agency	-4.3919**	-0.9041	5.2860***	4.936***
	(1.7719)	(1.5709)	(0.7029)	(0.6039)
Free agent	-13.2416***	-4.2922***	7.3224***	5.9380***
	(0.8890)	(1.0725)	(0.3431)	(0.3727)
OPS in previous season	0.2608	-1.4476**	–	–
	(0.6282)	(0.6645)		
Salary arbitration eligible × OPS in previous season	9.2074***	6.5252***	–	–
	(1.2006)	(1.1026)		
Last year before free agency × OPS in previous season	9.7279***	5.0053**	–	–
	(2.4179)	(2.1329)		
Free agent × OPS in previous season	22.2303***	10.0562***	–	–
	(1.1842)	(1.3817)		
ERA in previous season	–	–	-0.0127	0.0173
			(0.0090)	(0.0279)
Salary arbitration eligible × ERA in previous season	–	–	-0.3385***	-0.2563***
			(0.0721)	(0.0592)
Last year before free agency × ERA in previous season	–	–	-0.5006***	-0.5377***
			(0.1595)	(0.1383)
Free agent × ERA in previous season	–	–	-0.8786***	-0.6394***
			(0.0743)	(0.0719)
Constant	0.2765	1.5421***	0.5228***	0.4719***
	(0.4637)	(0.5042)	(0.1471)	(0.1424)
Player effects	No	Yes	No	Yes
R-squared	0.4644	0.8565	0.4115	0.8589
Number of observations	1,605	1,605	1,910	1,910

Notes: Only players in the last year of their contracts are included.
Standard errors are presented in parentheses. *, ** and *** denote significance at the 10%, 5% and 1% level, respectively.

Table 3
Regressions for OPS among Non-Pitchers

Variable	(1)	(2)	(3)	(4)
Salary-OPS gradient	0.0016**	0.0020**	0.0015*	0.0008**
	(0.0007)	(0.0008)	(0.0009)	(0.0003)
Career service time	-0.0119***	-0.0114***	-0.0121***	-0.0120***
	(0.0035)	(0.0040)	(0.0039)	(0.0035)
Career service time	-0.0646***	-0.0836***	-0.0613**	-0.0641***
squared/100	(0.0223)	(0.0282)	(0.0271)	(0.0212)
Bonuses in contract	0.0009	0.0008	0.0008	0.0016
	(0.0057)	(0.0060)	(0.0066)	(0.0061)
Forecast error in salary since 2005 (in $ millions)	_	-0.0040 (0.0042)	_	_
Career forecast error in salary (in $ millions)	_	_	0.0007 (0.0041)	_
Constant	0.8310***	0.8335***	0.8309***	0.8295***
	(0.0131)	(0.0144)	(0.0132)	(0.0117)
Autocorrelation coefficient	0.1355	0.1355	0.1350	0.1361
Within R-squared	0.0822	0.0832	0.0823	0.0834
Number of observations	2,053	2,053	2,053	2,053

Notes: All regressions include a full set of player fixed effects and allow for the error term to follow a first-order autoregressive process.

Bootstrapped standard errors (from 100 replications) are presented in parentheses.

*, ** and *** denote significance at the 10%, 5% and 1% level, respectively.

In columns (1)-(3), the salary-OPS gradient is predicted from a regression including all other regressors plus a set of salary bargaining class dummies and their interactions with a dummy for those in the last year of their contract.

In column (4), the salary-OPS gradient is predicted from a local linear regression of salary on OPS, conducted separately for each bargaining class. This is instrumented for by a set of salary bargaining class dummies and a dummy for those in the last year of their contract.

Table 4
Regressions for ERA among Pitchers

Variable	(1)	(2)	(3)	(4)
Salary-ERA gradient	0.5761***	0.6000***	0.5384**	0.6244**
	(0.2067)	(0.2240)	(0.2551)	(0.2532)
Career service time	0.0062	0.0100	-0.0049	-0.0144
	(0.0598)	(0.0617)	(0.0701)	(0.0595)
Career service time	0.4840	0.5620	0.4053	0.7674*
squared/100	(0.3772)	(0.4459)	(0.3575)	(0.4308)
Bonuses in contract	-0.0493	-0.0488	-0.0488	-0.0589
	(0.0924)	(0.0488)	(0.0960)	(0.0960)
Forecast error in salary since	–	-0.0086	–	–
2005 (in $ millions)		(0.0299)		
Career forecast error in salary	–	–	0.0248	–
(in $ millions)			(0.0531)	
Constant	4.3643***	4.3538***	4.3609***	4.4180***
	(0.1568)	(0.1621)	(0.1409)	(0.1509)
Autocorrelation coefficient	0.0998	0.0998	0.0990	0.1011
Within R-squared	0.0086	0.0087	0.0088	0.0130
Number of observations	1,879	1,879	1,879	1,879

Notes: All regressions include a full set of player fixed effects and allow for the error term to follow a first-order autoregressive process.

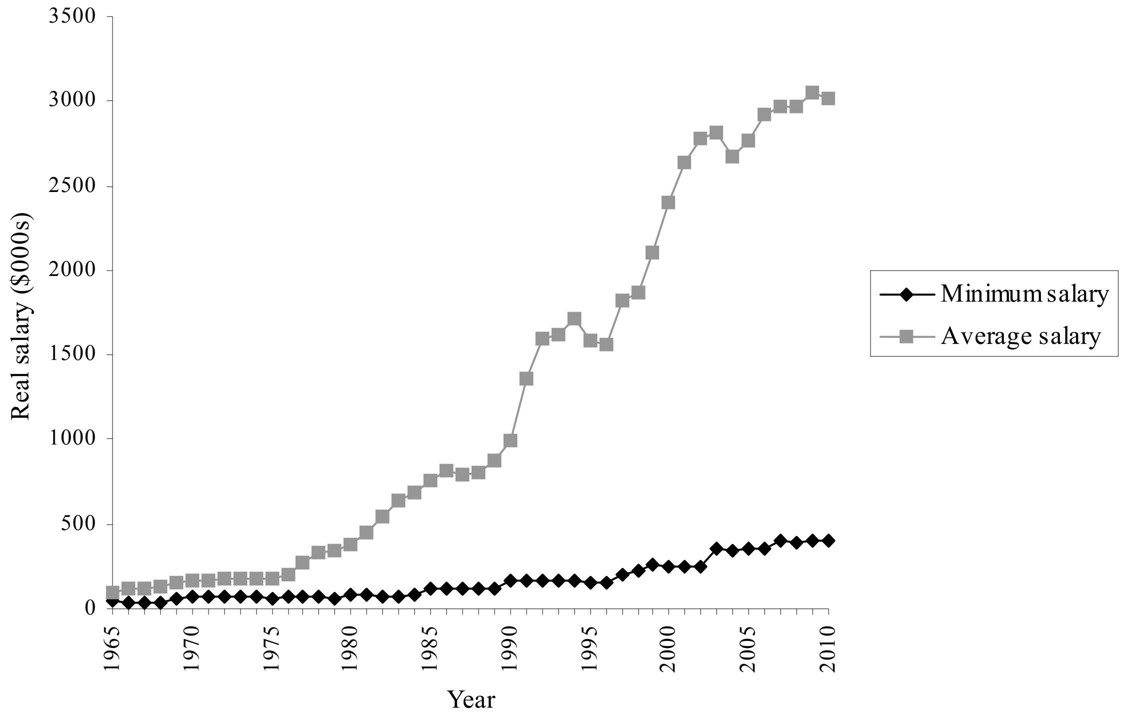
Bootstrapped standard errors (from 100 replications) are presented in parentheses.

*, ** and *** denote significance at the 10%, 5% and 1% level, respectively.

In columns (1)-(3), the salary-ERA gradient is predicted from a regression including all other regressors plus a set of salary bargaining class dummies and their interactions with a dummy for those in the last year of their contract.

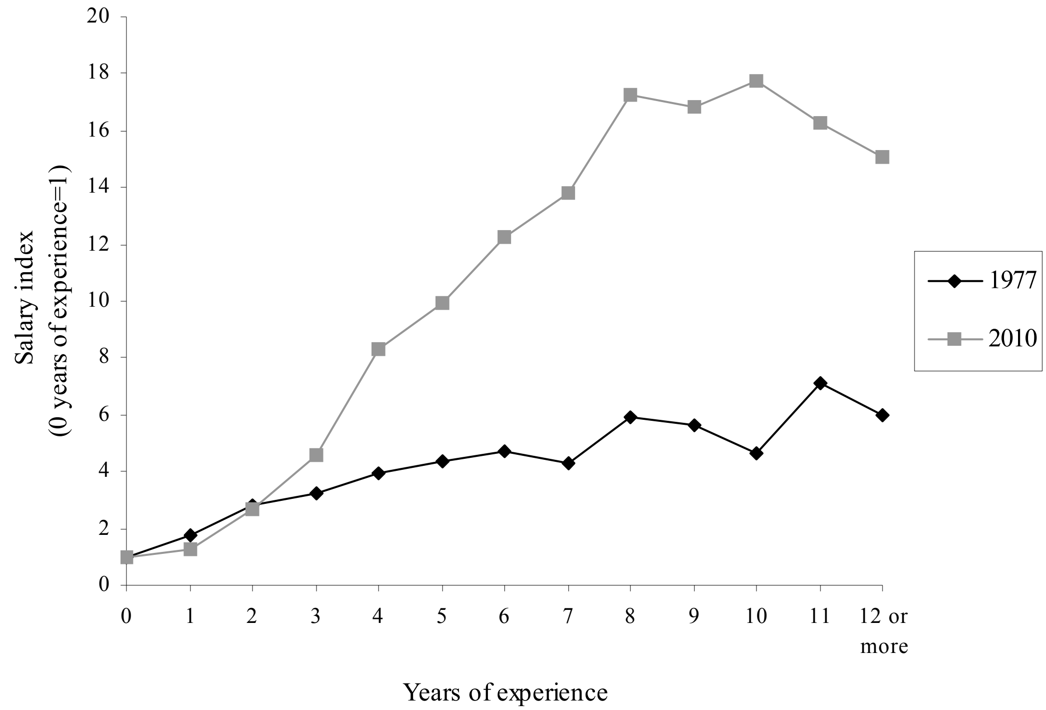
In column (4), the salary-ERA gradient is predicted from a local linear regression of salary on ERA, conducted separately for each bargaining class. This is instrumented for by a set of salary bargaining class dummies and a dummy for those in the last year of their contract.

Figure 1
Average and Minimum Salaries, 1965-2010



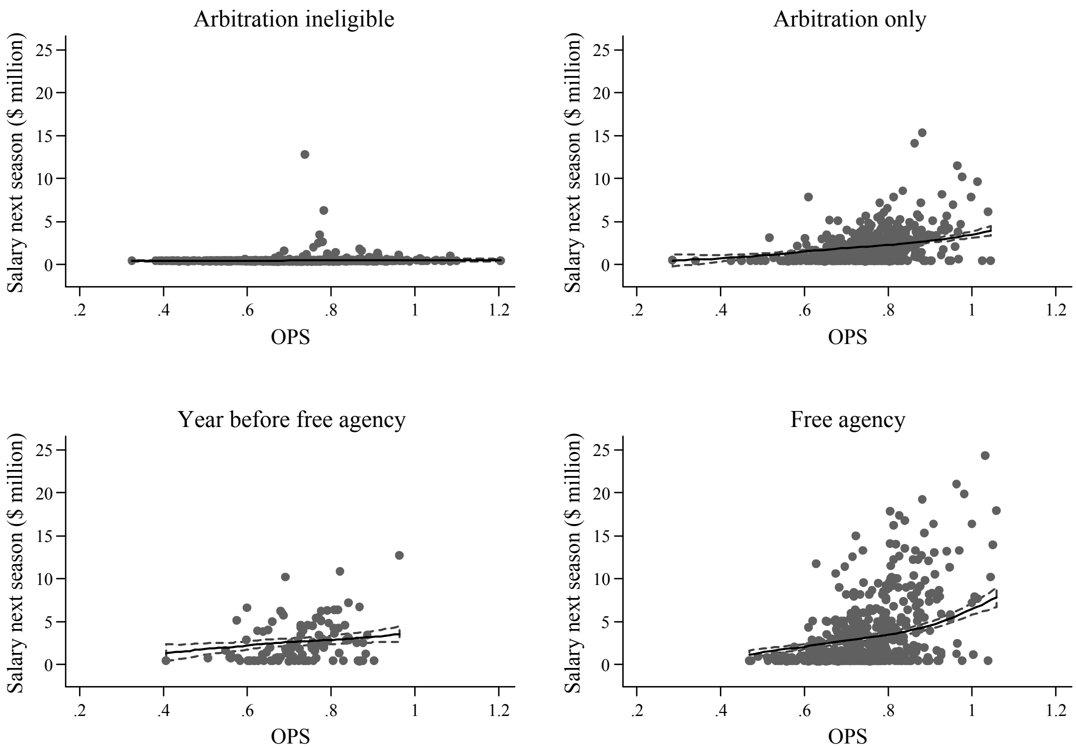
Notes: The average salary data were obtained from the Major League Baseball Players Association.
Both series are expressed in 2010 dollars, adjusted using the Consumer Price Index deflator.

Figure 2
Salary-Experience Profiles for 1977 and 2010



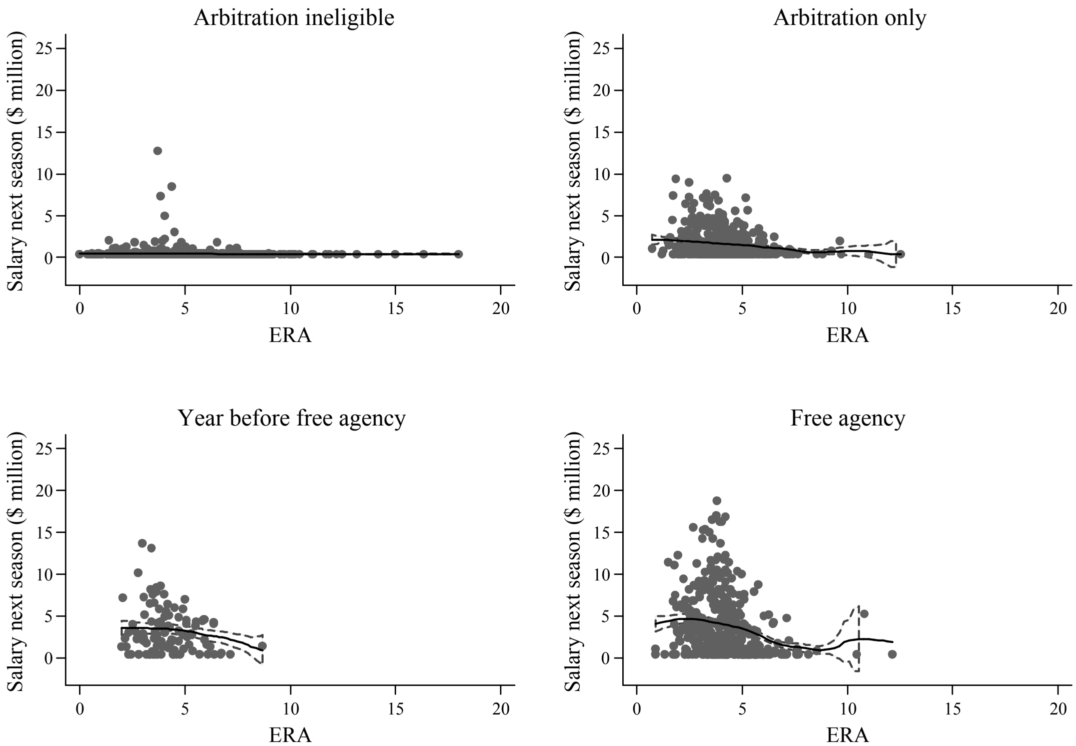
Notes: The 1977 data are from Rodney Fort's website (http://www.rodneyfort.com); the 2010 data are from the Baseball Archive.
The data points are the coefficients from separate regressions of annual salary on a set of dummies for estimated years of major league experience in 1977 and 2010.

Figure 3
Performance and Following Season Salary among Non-Pitchers



Notes: The solid line is the local mean smoothed line (using bandwidth 0.1); the dashed lines denote the 95% confidence interval around this.
Data are for 2005-2010 and only include players in the last year of their contracts.
Salary is in 2010 dollars, adjusted using the Consumer Price Index price deflator.

Figure 4
Performance and Following Season Salary among Pitchers



Notes: The solid line is the local mean smoothed line (using bandwidth 1); the dashed lines denote the 95% confidence interval around this.
Data are for 2005-2010 and only include players in the last year of their contracts.
Salary is in 2010 dollars, adjusted using the Consumer Price Index price deflator.