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The effects of age, experience and managers upon baseball performance

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Abstract As workers age, they acquire valuable experience even while their physical abilities eventually decline. Bosses/managers have the potential to alter the complex relationships between experience and declining physical abilities for better, or for worse. We examine the performances of 39,698 Major League baseball players in the 20th century and find that: (1) hitting performance peaks at age 30, base stealing at 27, and pitching at 34; (2) except for pitching, even experienced managers usually have little influence on player performance, or that influence is negative. In general, managers and coaches play limited roles in occupations where natural ability trumps other factors.

Keywords Microeconomics · Learning by Doing · Human Capital · Theory of the Firm · Management · Age Versus Experience Tradeoff

JEL Classification J44 · D23

> *"Schooled by a wily veteran"*—newspaper description of 44-year old Jamie Moyer's April 2007 pitching victory for the Philadelphia Phillies over the Florida Marlins

As individuals age, they may acquire experience that increases their labor market productivity. However, sooner or later, the same process results in declines in their physical and mental abilities, reducing their labor market productivity. How do these opposing effects of experience and age (the vintage of an individual's human capital)

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influence one's performance over his/her career? How much does the accumulated experience of individuals enable them to overcome their declining physical and mental abilities that occur as they age? Further, can astute and skilled managers and bosses affect this performance trajectory?

Intuitively, the answers to these questions vary depending on the type of activity that is being measured. For example, many observers believe that in heavily physical activities, including sports competition, an individual's physical abilities often begin to deteriorate before that individual is 30. Acquired experience (learning by doing) may counteract the deteriorating effects of ageing, but it is dominated by the ageing effect relatively early in one's life. On the other hand, in symbolic and mental activities, negative effects of ageing do not set in until later years, and acquired experience often assume greater importance. The relative impacts of the ageing process and experience on productivity intrigue and perhaps plague numerous individuals, managers and public policy makers over a wider spectrum of fields and careers. Compensation schemes, retirement ages, driving privileges, some occupational licensing restrictions, and processes involving mentoring of individuals all in some way reflect implicit judgments about the countering effects of ageing and experience on performance.

In this paper, we investigate the effects of age, experience and managerial input on the performance of Major League Baseball players. Major League Baseball is conspicuous for its zealous measurement of players' performances and the richness of data on performance and player characteristics make it an ideal arena in which to study these questions. We exploit the detailed player information contained in the data to use multiple measures of performance and experience in testing our model. Furthermore, we match data on manager characteristics to the player dataset. This matching allows us to identify the managerial influence in players' productivity.

Our results suggest that experience does improve performance, but only to a certain point. We find that age (and the decline of physical talents) eventually overcomes the value of an additional year's experience. Finally, our findings indicate that the experience of a manager in major league baseball has negligible effects upon individual players' performances, except for pitching. If managers become more proficient over time, then it is not evident in the performances of their individual players.

The techniques we present here can be generalized to other occupations, subject only to measurement and data limitations.

1 Previous Work

There are two distinct prongs of research that relate to the work we present here. The first area relates to physiological evidence concerning the effects of ageing upon both physical abilities and mental abilities. The second area concerns baseball performance specifically.

1.1 The Physiology of Ageing

It is well-established in physiology that a typical individual's physical and mental abilities eventually decline as a result of the ageing process. Where physical capabilities are concerned, this deterioration has been documented with respect to musculature endurance (Bemben 1998), ability to lift weights (Anton et al. 2004), and running speed (Bortz and Bortz 1996). Giniger et al. (1983) are representative when they report that age brings with it declining dexterity, speed, motor coordination and strength.

With respect to mental abilities, entire journals, notably *Experimental Aging Research* and the *Neurobiology of Aging*, are devoted to providing rigorous details surrounding the deterioration of individuals' mental faculties as they age. Numerous textbooks (such as Blazer and Steffens 2009) summarize these findings. One recent paper (Salthouse 2009) reported the results of tests suggesting that the mental abilities of the typical individual peak at age 22 and commence declining already at age 27. Brain speed, reasoning and visual puzzle-solving ability all begin to fall off in the late 20s.

1.2 Age and Athletic Performance

Age-performance profiles of athletes often tend to be concave, with the peak performance occurring at different ages in various sports. Utilizing performance records, Schulz and Curnow (1988) concluded that peak contestant performance occurred at age 22 in track sprinting events, 24 for middle distance events, 24 for tennis, 27 for long distance events, 28 for baseball and 31 for golf. Fair (2007) computed rates of deterioration in athletic performance relative to age for baseball pitching and batting, sprinting, running, high jumping, swimming and chess. In the case of baseball, he found that batters' average peak performance occurred between 27.6 years and 28.3 years, while for pitchers, the peak appeared earlier at 26.5 years.

Fair's work is consistent with earlier small sample work of Krohn (1983), who estimated 28 to be the peak age for batting average performance, and the less rigorous work of Schulz et al. (1994) that baseball performance peaked at age 27 for a sample of players active in 1965. Sommers (2008), upon finding that the peak performances of more recent vintages of baseball players have been occurring several years later than that of previous cohorts, provocatively questioned whether some of this might be due to players' use of steroids. Bradbury (2009) similarly found peak performance occurring later in life (at about 29 years of age). Bradbury has aptly summarized the evidence across sports by opining, "the evidence indicates that athletes peak in their mid-to-late twenties" (p. 600).

One of the challenges associated with attempts to isolate the impact of age upon athletic performance is sample selection bias. As Schell (2005) put it, "...what might appear as improving or declining play with age in the profile is partly a selection process regarding which players continue to play" (46). Good players continue to play; less capable players either quit or are shown the door. Schell attempted to deal with this problem by using "milestones" (a series of 1,000 at bat observations for baseball players) to compare players of like experience. He found that batting averages hit their peak about 5,000 at-bats, which roughly corresponded to 29.8 years of age.

These results are interesting, but we hasten to note that that athletic performance is not synonymous with physical ability. Due to practice, experience and superior knowledge, individuals' performance might improve even as their raw physical abilities begin to wane. Therefore, the relationship between age and performance may mask the separate influences of ageing and experience on one's performance.

Untangling the connections between age, experience and performance requires a closer examination of the role of experience in athletic performance.

Fair's 2007 work dealing with the impact of age on baseball performance does not address the role of experience, which while positively related to age, is not the same as age for many Major League Baseball players. Sturman (2003) presents a review of the literature on age, experience and performance and concludes that job experience typically enhances productivity (holding age constant), but that the relationship is non-linear. Notably, Sturman differentiates between age and experience, though many studies do not. Other researchers such as Krautman and Solow (2009) have demonstrated that contractual terms and other market characteristics can alter the impact that age and experience have upon performance.

1.3 The Role of Baseball Managers

An interesting related question focuses on the extent to which managing, mentoring, coaching and "bossing" can improve a baseball player's performance. Several researchers have studied the question of whether a baseball manager can improve or devalue the experience of his players. The evidence presented on this point is mixed (Porter and Scully 1982; Kahn 1993, Singell 1993; Ohkusa and Ohtake 1994; James 1997).

Potentially, individuals can learn the right lessons, and learn them more quickly, if they have access to skilled, knowledgeable managers, though retrograde managers can have destructive effects as well.

The "matching hypothesis" of Chapman and Southwick (1991) is central to this question. Some teams and players may perform better (worse) for specific managers so that matching teams and players to specific managers plays an important role in assessing the impact of a manager on his players' performance. There is only moderate evidence to support such a conclusion. We provide some rough tests of these propositions in the empirical work presented below.

1.4 Caveats

Several caveats are in order. Implicit in most of the studies we have reviewed is the possibility of self-selection bias. Employees who have been fired from their jobs, or have left their jobs because they have reached the conclusion that they are not proficient at their work, are not in the data samples. Hence, the extent to which age, or a lack of experience, contribute to deficient performance may be underestimated.

Further, many previous studies, especially outside of the realm of economics, have relied upon supervisory evaluations (rather than objectively measured performance such as in baseball). Possibilities for bias abound in such cases, though even in baseball, a manager's subjective evaluations will determine how often and in what situations a player actually is on the field.

Finally, not all jobs are of the same complexity. In general, work experience is a better predictor of performance when the job in question is not complex. In the context of baseball, the positions of catcher, shortstop and pitcher are more complex than those of a first baseman or outfielder. Ceteris paribus, we expect experience (and perhaps coaching) to count more for players who occupy "complex" positions than for other players.

2 A Model of Age, Experience and Performance

In this section, we present the theoretical model and provide the empirical specification of the model that will guide our empirical work.

Assume that the objective of a major league baseball team is to win games. The number of games won by a baseball team in any given year is a function of the quality of the players and the quality of the team's manager, who, as one of Papandreou's "peak coordinators" (1952) is responsible for planning, motivating the players, putting the optimal combination of players on the field, and influencing their actions at any given point in a season. We specify this production function:

$$GW_t = f(P_t, H_t, F_t, R_t, M_t) \tag{1}$$

where P_t represents the pitching input, H_t the hitting input, F_t the fielding input, R_t the running input and M_t the managerial input, all at time *t*. The specification is similar to that of Singell (1993). We assume that GW_t' >0 over all the inputs.

Each of the inputs represents a different type of labor input, and each type of labor input changes the games won in one of three ways. First, we consider the player's skill endowment with which he arrives at the major leagues. This skill endowment depends on innate talent (the physical characteristics of the player) as well as human capital accumulation (skills learned by playing in little league, minor league or schools). Second is the degree of learning-by-doing of the player. As the player gains experience, we expect that his skill set, and hence his contribution to team winning, will increase. The ability of the player at time t (A_t) is a function of the physical skills of the player (S_t) and his Major League baseball experience.

$$A_t = g(S_t, A_{t-1}(GP_t)) \tag{2}$$

where GP_t represents games played in the current season. We suspect that the skills of the player initially increase with age at the beginning of a player's major league career but likely decrease with age toward the end of his career. Thus, we expect a non-linear relationship between the player's age and ability. We expect that the learning by doing effect, embodied in the games played variable, likely will increase over time, but as the player ages, the increase will occur at a decreasing rate.

The third source of increased performance is the interaction between the player and the manager. It is plausible that the ability of a team's manager affects the performance of the players.

We modify Eq. 1 by introducing subscripts in order to identify years (*t*), players (*i*), and teams (*j*) and superscripts to indicate the activity:

$$GW^j{}_t = f\left[P^j{}_{it}\left(A^P{}_{t-1}, M_t\right), H^j{}_{it}\left(A^H{}_{t-1}, M_t\right), F^j{}_{it}\left(A^F{}_{t-1}\right), M^j{}_{it}\left(A^M{}_{t-1}\right), R^j{}_{it}\left(A^R{}_{t-1,}M_{t,}\right)\right] \tag{3}$$

where $A^P{}_{t-1}$ represents the experience of the player, in this case a pitcher (P), accrued until the current year. M, H, F and R represent managerial, hitting, fielding and running inputs, respectively.

Each of the inputs in (3) interacts to contribute to the success of the team. Our focus is on the role of experience and the ability of the manager to augment player skills. If players learn while doing, then their accumulated experience is a plausible measure of this learning and is a major facet of their abilities. Baseball outcomes are determined interactively by the pitching, hitting, fielding and managerial inputs. Along with stochastic elements and the competitive reactions of the other teams, these inputs ultimately determine the games won by a team.

Equation 3 omits the managerial variable in the argument relating to fielding because it is generally agreed that the scope for managerial difference making with respect to fielding is smaller than it is for player hitting and pitching. A batted ball not fielded by one player will be fielded by another player and, in any case, the most commonly cited measure of fielding competence, the fielding percentage, does not take into account the range of a fielder, or his assists.

We now consider the interaction between the inputs. We assume that the three player inputs are strongly separable from each other, and therefore, we may focus on each input individually.

Equations 4–6 treat the reduced form equations for pitching and hitting that we will estimate.

$$\mathrm{P}_{it} = \mathrm{k}(\mathrm{S}_t, A_{t-1}(\mathrm{GP}_t), \mathrm{M}_t) \tag{4}$$

$$\mathrm{H}_{it} = \mathrm{m}(\mathrm{S}_t, \mathrm{A}_{t-1}(\mathrm{GP}_t), \mathrm{M}_t) \tag{5}$$

$$\mathrm{R}_{it} = \mathrm{n}(\mathrm{S}_t, \mathrm{A}_{t-1}(\mathrm{GP}_t), \mathrm{M}_t) \tag{6}$$

Following Arrow (1962), we consider the vintage of human capital to be one of the indicators of the quality of a capital input. Our notion of vintage is the birth date of the player. Over time, we expect the skill set of a player to deteriorate, albeit at different rates and at different points in time, for each player. Define the year at which the skill set of the player turns down as time z. Hence, $\mathrm{S}_z < \mathrm{S}_{z-1}$, which implies $\mathrm{P}_z < P_{z-1}$. However, the world is not *ceteris paribus* in this case. Over time, a player will play more games because $\mathrm{A}_{z-1} > \mathrm{A}_{z-2}$. That is, the learning-by-doing effect is expected to be positive. This effect counteracts the declining skill effect, beginning at time *z*. Prior to time *z*, the effects on performance are both positive and reinforce each other. Note that our review of scientific literature suggests that time *z* may be as early as age 28.

The side-by-side existence of learning-by-doing and the skill deterioration implies a non-linear specification for Eqs. 4 and 5.

3 The Data Set

Our raw panel data set consists of season by season observations of all baseball players who played in the American and National Leagues, 1901–2000. Our focus is upon the hitting and pitching records of these players. Our primary data source is

Sean Lahman's Baseball Database, Version 5.6 (www.baseball1.com). We also utilized www.baseball-reference.com and www.baseball-almanac.com to fill in occasional blanks.

Since we primarily focus on the impact of ageing and accumulated experience over time upon performance, we eliminate all individuals who played or managed only one season in Major League Baseball. We also delete any season in which a player or manager was involved in fewer than ten games. We ignore all minor league experience and performance.[1] This yields 39,698 distinct player season observations for batters and 19,394 distinct player season observations for pitchers. Each of these observations is matched with the one or more managers who guided the player's team during that season.

4 Empirical Results

The panel nature of our dataset allows us to account for unobserved player specific heterogeneity. In our empirical strategy, we employ the fixed effects method to take into account omitted variables that are person-specific, time-invariant and may be correlated with the regressors in our specification.[2] This estimation is equivalent to a conventional least squares regression with a dummy variable for each player in each season. Hence, our focus is upon performance variations within specific players rather than between players.

Our results are segmented into two parts, those dealing with a standard player performance model that focuses on the effects of player's age and experience on performance and those that extend the standard model to focus on the contributions of the managers. Within each part we consider five performance activities that involve measures of hitting and pitching, and one relating to base running. We further dichotomize our results into performance years before and those after 1973, when the designated hitter (DH) was introduced in the American League.

The introduction of the designated hitter changed many aspects in baseball. It allows pitchers in the American League to focus on pitching; only in extremely rare situations do they ever hit. It allows at least one batter to focus only on hitting because he will not take a defensive position in the field. Proponents argue that this specialization increases the quality of play and that it results in more runs being scored, making it more popular with the fans who purchase tickets.

[1] The fabled Bill James, however, argues that "Minor league batting statistics will predict major league batting performance with essentially the same reliability as previous major league statistics" (http://baseball1.com/bb-data/bbd-bj1.html). This is a provocative empirical hypothesis that has not yet been thoroughly explored.

[2] We performed the Hausman Test (1979) to decide whether the model should contain random or fixed effects. While the random effects method is a more efficient estimator than the fixed effects model, it yields inconsistent coefficient estimates if the error term is correlated with the regressors. On the other hand, a fixed effects estimator is always consistent, but may be inefficient. The null hypothesis in the Hausman Test examines whether the coefficient estimates from the random effects model are the same as those from the fixed effects model. A rejection of the null hypothesis suggests that the error term is correlated with the regressors, and therefore the fixed effects model should be used. In all of our specifications, the null hypothesis was rejected at the .01 level, leading us to choose the fixed effects model.

Even so, the DH has not been universally popular. Critics argue that the use of the DH separates players into overly specialized classes and results in "batting cage" hitters who cannot field and pitchers who cannot hit. This rankles the more traditional tastes of some baseball aficionados who denounce the asymmetries introduced by the DH and its biasing effects upon player and team performance statistics. Whatever their view of the DH may be, few would argue that it has not altered the career trajectories of individual players, and that is why we dichotomize our sample. Our statistical results are presented in Tables 1, 2, 3, 4, and 5.

Table 1 Fixed effects regressions: on base plus slugging percentage

	(1)	(2)	(3)	(4)
	Pre-designated Hitter (<1973)		Designated Hitter (≥1973)	
N of observations constant	24494	24367	14759	14530
	−.2069	−.2227	−.1279	−.1519
Age	.0544	.0545	.0512	.0520
	t=13.56*	t=13.53*	t=7.22*	t=7.24*
AGE SQ	−.0008	−.0008	−.0009	−.0009
	t=13.34*	t=13.23*	t=8.10*	t=8.09*
Cumulative games played	−.00008	−.00008	−.0001	−.0001
	t=4.28*	t=4.48*	t=5.49*	t=5.63*
Cumulative games played SQ	−1.14 E-09	2.97 E-10	−1.18 E-09	2.05 E-10
	t=0.20	t=0.05	t=0.19	t=0.03
National league	.0317	.0312	.0703	.0712
	t=6.12*	t=6.01*	t=13.30*	t=13.
Years in league	−.0072	−.0073	.0087	.0088
	t=4.47*	t=4.55*	t=2.87*	t=2.67*
Manager years experience	−.0014	−.0016	−.0015	−.0021
	t=4.61*	t=5.10*	t=1.61	t=2.16**
Manager years experience SQ	.00004	.00004	.00006	.00007
	t=4.68*	t=4.73*	t=1.48	t=1.84**
Managers played in majors		.0121		.0065
		t=2.07**		t=1.30
Manager played in world series		−.0043		.0066
		t=1.22		t=1.41
Managers managed in world series		.0099		.0104
		t=2.83*		t=2.31**
Managerial residual		.0272		.0035
		t=0.94		t=0.06
F-statistic	101.9	68.2	61.1	41.1
R^2	.037	.037	.037	.038

*, ** statistically significant at the .01 level or .05 level respectively (one-tailed tests)

Table 2 Fixed effects regressions: batting average

	Pre-designated Hitter (<1973)		Designated Hitter (≥1973)	
N of observations constant	24494	24367	14759	14530
	.0054	−.0023	−.0022	.0696
Age	.0155	.0156	.0116	.0117
	t=11.70*	*t*=11.75*	*t*=5.37*	*t*=5.36*
Age SQ	−.0002	−.0002	−.0002	−.0002
	t−=11.24*	*t*=11.24*	*t*=5.83*	*t*=5.84*
Cumulative games played	.00003	.00003	.00003	.00003
	t=5.50*	*t*=5.32*	*t*=5.23*	*t*=5.03*
Cumulative games played SQ	−1.15 E-08	−1.11 E-08	−9.16 E-09	−8.78 E-09
	t=6.23*	*t*=5.99*	*t*=4.74*	*t*=4.50*
National league	−.0030	−.0028	.0047	.0046
	t=1.75	*t*=1.64	*t*=2.94*	*t*=2.81*
Years in league	−.0047	−.0047	−.0030	−.0029
	t=8.84*	*t*=8.87*	*t*=3.04*	*t*=2.94*
Years experience manager	−.0003	−.0003	.0003	−.0002
	t=2.69*	*t*=2.87*	*t*=0.90	*t*=0.82
Years experience manager sq	6.16 E-06	6.60 E-06	8.27 E-06	7.65 E-06
	t=2.24**	*t*=2.35**	*t*=0.68	*t*=0.62
Managers played in majors		.0050		−.0001
		t=2.58**		*t*=0.09
Manager played in world series		.0007		.0016
		t=0.57		*t*=1.15
Managers managed in world series		.0016		.0005
		t=1.36		*t*=0.37
Managerial residual		.0055		.0073
		t=0.57		*t*=0.41
F-statistic	63.34	42.15	22.84	14.81
R^2	.023	.014	.039	.013

*, ** statistically significant at the .01 level or .05 level respectively (one-tailed tests)

4.1 Basic Model Estimation

In this section, we present statistical results for our estimations of Eqs. 4–6, but include only a limited measure of managerial competence and experience—the number of years the manager has managed in the major leagues. We link our theoretical model to our empirical work by means of the following estimating model:

$$\begin{aligned} \mathrm{OC}_{\mathrm{it}} = {} & \beta_0 + \beta_1 \mathrm{Age}_{\mathrm{it}} + \beta_2 {\mathrm{Age}_{\mathrm{it}}}^2 + \beta_3 \mathrm{CGP}_{\mathrm{it}} + \beta_4 {\mathrm{CGP}_{\mathrm{it}}}^2 + \beta_5 \mathrm{NL}_{\mathrm{it}} + \beta_6 \mathrm{YL}_{\mathrm{it}} \\ & + \beta_7 \mathrm{MYE}_{\mathrm{it}} + \beta_8 {\mathrm{MYE}_{\mathrm{it}}}^2 + \mathrm{a}_{\mathrm{i}} + \mathrm{e}_{\mathrm{it}} \end{aligned} \tag{7}$$

Table 3 Fixed effects regressions: walks and hits per inning pitched

	Pre-designated Hitter (<1973)		Designated Hitter (≥1973)	
N OF OBSERVATIONS CONSTANT	10282	10282	8778	8656
	13.46	13.22	17.47	17.66
Age	12.68	.1464	−.1861	−.1982
	t=2.88*	*t*=3.33*	*t*=2.71*	*t*=2.84*
Age SQ	−.0026	.0029	.0024	.0026
	t−=3.55	*t*=4.06*	*t*=2.43**	*t*=2.64*
Cumulative innings pitched	−.0219	−.0223	−.0200	−0.199
	t=33.33*	*t*=33.96*	*t*=23.56*	*t*=23.39*
Cumulative innings pitched SQ	.00003	.00003	.00003	.00003
	t=21.25*	*t*=21.76*	*t*=15.29*	*t*=15.15*
National league	−.2447	−.2445	−.6305	−.6199
	t=3.98*	*t*=3.92*	*t*=11.03*	*t*=10.73*
Years in league	.0202	.0217	.1113	.1082
	t=1.27*	*t*=1.37	*t*=2.74*	*t*=2.65*
Manager years experience	-.0158	−.0099	−.0302	−.0173
	t=4.08*	*t*=2.48**	*t*=2.67*	*t*=1.47*
Manager years experience SQ	.0005	.0004	.0010	−.0006
	t=4.08*	*t*=3.30*	*t*=2.00**	*t*=1.32
Manager played in major leagues		.1803		-.0091
		t=2.34**		*t*=0.15
Manager played in world series		−.1209		.0033
		t=2.75*		*t*=0.06
Manager managed in world series		−.2178		-.2232
		t=5.02*		*t*=4.16
Managerial residual		−2.134		-1.255
		t=5.92*		*t*=2.76
F-statistic	236.1	164.6	143.4	96.6
R^2	.180	.188	.135	.138

*,** statistically significant at the .01 level or .05 level respectively (one-tailed tests)

where OC is a hitting, pitching or running outcome measure for player *"i"* in time *"t,"* for example, batting average; Age is the highest age of that player during a season; CGP is the "experience" component derived from our theoretical model, namely cumulative Major League games played prior to this season; NL is a dummy variable taking a value of 1 if the player was in the National League during that season; YL is the number of years that player has been in the Major Leagues at the beginning of the season; and, MYE is years of experience of the manager as a manager. a_i represents the player-specific unobserved heterogeneity, and e_{it} is the idiosyncratic error term.

Table 4 Fixed effects regressions: walks and hits per inning pitched

	Pre-designated Hitter (<1973)		Designated Hitter (≥1973)	
N of observations constant	10282	10282	8778	8656
	3.56	3.40	6.72	6.84
Age	.1097	.1228	−.1091	−.1153
	t=3.83*	*t*=4.30*	*t*=2.38*	*t*=2.47**
Age SQ	−.0019	−.0021	.0016	.0017
	t−=4.06*	*t*=4.59*	*t*=2.46**	*t*=2.54**
Cumulative innings pitched	−.0117	−.0120	−.0114	−.0114
	t=27.43*	*t*=28.08*	*t*=20.19*	*t*=20.04*
Cumulative innings pitched SQ	.00002	.00001	.00002	.00002
	t=17.34*	*t*=17.87*	*t*=13.43*	*t*=13.29*
National league	−.0528	−.0486	−.4635	.4595
	t=1.31*	*t*=1.20	*t*=12.15*	*t*=11.89*
Years in league	.0152	.0163	.0815	.0827
	t=1.48*	*t*=1.58	*t*=3.00*	*t*=3.03*
Manager years experience	−.0126	−.0084	−.0183	−.0113
	t=5.03*	*t*=3.23*	*t*=2.42**	*t*=1.43
Manager years experience SQ	.0004	.0003	.0005	.0003
	t=5.34*	*t*=3.83*	*t*=1.63	*t*=1.07
Manager played in major		.1424		−.0173
		t=2.85**		*t*=0.43
Manager played in world series		−.0928		.0397
		t=3.25*		*t*=1.06
Manager managed in world series		−.1675		−.1130
		t=5.95*		*t*=3.15*
Managerial residual		−.1.24		−.6148
		t=5.30*		*t*=2.02**
F-statistic	169.7	120.8	138.8	92.4
R^2	.137	.145	.131	.133

*,** statistically significant at the .01 level or .05 level respectively (one-tailed tests)

4.1.1 Hitting: The Basic Model

The first measure of performance we consider is the "on base plus slugging percentage," or OBPSL (Table 1). This oft-used measure of hitting is useful because it measures not only the number of times the player gets on base, but also how many bases that player gains because of his hits and walks (slugging percentage). Thus, it attempts to recognize the quantitative significance of a player's hitting.

We also utilize a second measure of hitting prowess, batting average (BAVE), in Table 2. BAVE is the most popular and easily understood measure of batting

Table 5 Fixed effects regressions: stolen basis per year

	Pre-designated Hitter (<1973)		Designated Hitter (≥1973)	
N of observations constant	24553	24426	14791	14561
	−3.98	−3.92	−7.91	−8.03
Age	.6361	.6486	1.090	1.082
	t=6.34*	*t*=6.43*	*t*=4.22*	*t*=4.14*
Age SQ	−.0116	−.0118	−.0204	−.0202
	t−=7.36*	*t*=7.48*	*t*=5.20*	*t*=5.09*
Cumulative games played	.0086	.0086	.0110	.0110
	t=20.64*	*t*=20.62*	*t*=13.78*	*t*=13.70*
Cumulative games played SQ	−4.69 E-06	−4.69 E-06	−4.12 E-06	−4.12 E-06
	t=33.47*	*t*=33.37*	*t*=13.77*	*t*=17.58*
National league	−.6652	−.6596	.1110	.2109
	t=5.14*	*t*=5.07	*t*=0.57	*t*=1.08
Years in league	−.3238	−.3228	−.5897	−.6026
	t=8.11*	*t*=8.05*	*t*=5.01*	*t*=5.05
Manager years experience	−.0043	.0097	0.0236	.0380
	t=0.55	*t*=1.20	*t*=0.69	*t*=1.06
Manager years experience SQ	−.0006	−.0007	−.0031	−.0035
	t=2.88*	*t*=3.42*	*t*=2.15	*t*=2.36**
Manager played in major		−.1350		.4905
		t=0.93		*t*=2.67*
Manager played in world series		.0016		−.4740
		t=0.02		*t*=2.77*
Manager managed in world series		−.2160		−.1444
		t=2.46**		*t*=0.88
Managerial residual		−2.134		1.332
		t=2.94*		*t*=0.62
F-statistic	348.0	231.8	140.8	92.44
R^2	.012	.116	.080	.081

*,** statistically significant at the .01 level or .05 level respectively (one-tailed tests)

performance, but is not as informative as OBPSL as a measure of hitting prowess because it discloses nothing about the significance of a hit.

One can see in regressions (1) and (3) in Tables 1 and 2 that nearly all independent variables attain statistical significant at the 5% level or better (one-tailed tests). The results indicate that as a player ages, both his OBPSL and BAVE productivity increase, though at a decreasing rate as indicated by the negative sign on the age squared coefficients. However, except in most unusual circumstances, as players' human capital ages, they also play more games. We find that the accumulation of games played by a player adversely affects his OBPSL, presumably reflecting the wear and tear associated with playing more games. This effect is magnified as more games are played, as indicated by the negative coefficient on the cumulative games squared played variable. By contrast, the accumulation of games played over time increases BAVE. However, the games played benefit comes at the cost of "power"—that is, reductions in that player's OBPSL.

The American and National baseball leagues constitute "major league baseball," and since 1997 have engaged in limited interleague competition during their regular seasons. Nevertheless, the leagues differ with respect to the American League's use of the DH (since 1973), their ball parks and geographic locations, and distinctive traditions. Hence, in both Tables 1 and 2, we include a National League dummy variable (0,1) to capture league-specific differences. *Ceteris paribus*, players in the National League generate higher OBPSL averages, particularly post-DH. The explanation usually offered for this phenomenon is arguable—National League hitters bat against relief pitchers more often than hitters in the American League because the DH rule enables American League managers to keep their starting pitchers in the game longer. There is modest evidence in favor of this proposition, but it depends upon relief pitchers being less capable than starting pitchers, a proposition for which there is some evidence, depending on the circumstances. The run of the mill relief pitcher is less effective than the typical starter, but "closers" (those pitchers brought in to hold a late inning lead) are marginally more effective than starters or ordinary relievers. We note briefly that our empirical results with respect to BAVE are not so clear.

Our estimation also seeks to differentiate between the years a player has spent in the majors and the total number of games he has played in the majors; thus it takes account of the intensity of the use of the player over time. The coefficient of the 'years in the league' variable changes sign from negative to positive when we move from pre-DH to post-DH years (Table 1). This result suggests that the DH rule enables some specialized players to remain in the major leagues and continue to contribute in terms of their OBPSL.

A particular focus of this study is the influence that managers may have upon worker performance. In both Tables 1 and 2, we examine whether baseball managerial experience, measured by years managed in the major leagues (MANAGER YEARS EXPERIENCE), has an influence upon players' hitting performances. The answer is yes, but not necessarily in the way one might guess. The coefficients of the managerial experience variable are mildly negative in seven of eight regressions and statistically significant in five of those instances. This is consistent with the views of baseball cognoscenti such as Bill James (1997), who have argued for years that the ultimate influence of a manager on player and team performance is small. While there always have been claims that a specific manager has been incompetent and has reduced his team's performance, virtually no one has offered the view that influence of managers as a group upon hitting performance is negative.

We will examine the contribution of managers to baseball performance in greater detail below. However, our initial judgment here is that managers may have a less favorable impact upon individual player performances than previously thought. Our preliminary results suggest that natural ability and experience are substantially more important performance factors in baseball than are managerial inputs, at least where hitting is concerned.

4.1.2 Pitching: The Basic Model

Our two measures of pitching performance, walks and hits per inning pitched (WHIP) and earned run average (ERA), are inverse measures of performance. We start with the influences on WHIP, examined in Table 3. The pre-DH age coefficient assumes a positive sign, meaning that pitching performance deteriorates with age. The reverse is true for the post-DH period. The cumulative innings pitched variable assumes a negative sign, suggesting that additional lifetime pitching innings (ceteris paribus) make a pitcher smarter and more capable.

The years a pitcher has spent in the major leagues is positively related to WHIP. Holding age and lifetime innings pitched constant, there is no performance benefit from spending additional years in the major leagues.

The coefficient on the National League dummy variable in Table 3 is negative, an a priori expectation in 1973 and thereafter because of the existence of the designated hitter in the American League. American League pitchers face a larger proportion of highly qualified batters. We also find this to be true, though the estimated coefficients are much smaller in pre-DH years as well.

The role of managerial experience of the manager in regressions (1) and (3) in Table 3 suggests that increased managerial experience can reduce WHIP. This conclusion holds both for pre-DH and post-DH.

Table 4 presents results for pitchers' earned run averages (ERA), a traditional measure of pitching performance. The signs of the regression coefficients are nearly identical to those in Table 3 for WHIP. Once again, the influence of managers on ERA is beneficial (that is, the signs of these coefficients are negative). More experienced managers (at least as measured by years managed in the major leagues) are associated both with lower WHIPs and ERAs. This suggests that pitching involves practices and habits that can be taught and learned more easily than those related to hitting.

4.1.3 Running: The Basic Model

Table 5 focuses on the running skills of the players as measured by their stolen bases per year. Regressions (1) and (3) reveal that stolen bases are an increasing function of both age and cumulative games played; however, both exert their influences at gradually decreasing rates. Managerial experience does not have a statistically significant effect upon players' stolen bases per year. This is not surprising since raw player talent in the form of speed and quickness largely determines who can steal bases and who cannot. A manager might be able to enhance raw talent, but he cannot create it. The coefficient estimate on the squared term of the managerial experience is negative and statistically significant, implying that the effect of managerial experience on player performance decreases with years of managerial experience.

National League dummy coefficients are not consistent with respect to base stealing and the 'years in the major leagues' variable asserts a consistent and statistically significant negative influence. It probably captures the decline in the raw physical abilities of players over the years.

4.2 Focusing Further on the Role of Managers

Arguably, the specification of managerial ability and experience in regressions (1) and (3) in Tables 1, 2, 3, 4, and 5 is unsophisticated. Perhaps it is not a simple count of years spent managing in the major leagues that is important, but rather whether the manager also has major league playing experience, and whether he has played or managed in high pressure situations such as a World Series. In regressions (2) and (4) of Tables 1, 2, 3, 4, and 5, we investigate if these more refined measures of managerial talent and experience influence the hitting, pitching and base stealing performance of individual players. Each of these three new managerial variables (major league playing experience, PIM; World Series playing experience, PWS; and, World Series managing experience, WSM) is specified as a 0,1 dummy. In addition, in Eqs. 2 and 4 of Tables 1, 2, 3, 4, and 5, we have included a managerial residual variable, $\mathrm{MAN}^{\mathrm{res}}$, which we explain below.

Our estimating equation here is:

$$\begin{aligned}\mathrm{OC}_{\mathrm{it}} = {} & \beta_0 + \beta_1\mathrm{Age} + \beta_2\mathrm{Age}^2 + \beta_3\mathrm{CGP} + \beta_4\mathrm{CGP}^2 + \beta_5\mathrm{NL} + \beta_6\mathrm{YL} + \beta_7\mathrm{MYE} \\ & + \beta_8\mathrm{MYE}^2 + \beta_9\mathrm{PIM} + \beta_{10}\mathrm{PWS} + \beta_{11}\mathrm{MWS} + \beta_{12}\mathrm{MAN}^{\mathrm{res}} + \mathrm{a_i} + \mathrm{e_{it}} \qquad (8)\end{aligned}$$

Our utilization of several different measures of managerial productivity invites concerns about multicollinearity among these variables if all are entered simultaneously into our estimating equations. We dealt with this concern in two ways. First, we observed our coefficient estimates as we incrementally added the managerial variables, one by one, to our estimating equations. The coefficient estimates and their t-statistics did not change significantly when a smaller subset of managerial variables was utilized. Second, we calculated the variance inflation factor (VIF) for each coefficient and found that the highest VIF was 1.4, suggesting once again that our equations do not suffer from severe multi-collinearity.[3]

An additional measure of managerial performance that invites consideration is each manager's lifetime winning percentage in the games he has managed. However, managers must work with the talent they have available and lifetime winning percentage is highly collinear with our four other managerial variables. To deal with this issue, we ran a separate regression in which we estimated each manager's lifetime winning percentage as a function of years managed and the three other managerial dummy variables. We then specified the residuals of that regression as a new independent variable, one which we label the "managerial residual." This procedure emulates a manual two-stage least squares estimation and allows us to represent the separate heterogeneity from the lifetime winning percentage of the manager independently of his having played in the majors, played in the World

[3] The variance inflation factor (VIF) for coefficient β_1 equals $1/(1-\mathrm{R}_{12})$, where R_{12} is the coefficient of determination found by regressing X_1 on all other X's (Greene, 2008). If there is no collinearity between X_1 and the other X's, then R_{12} will be zero and VIF will be one. As the degree of collinearity increases, so also does the VIF.

Series, or managed in the World Series. This variable, then, is a more direct proxy for managerial ability.

An inspection of the signs and statistical significance of the estimated managerial coefficients in regressions (2) and (4) in Tables 1, 2, 3, 4, and 5 reveals a seemingly contradictory mish-mash of signs and significance. In 11 of 40 cases, the coefficients of the four managerial variables suggest that managerial quality actually reduces player performance; three of these coefficients are statistically significant. In 29 of the 40 possibilities, the coefficients suggest that managerial quality enhances player performance, but only 14 of these coefficients are statistically significant.

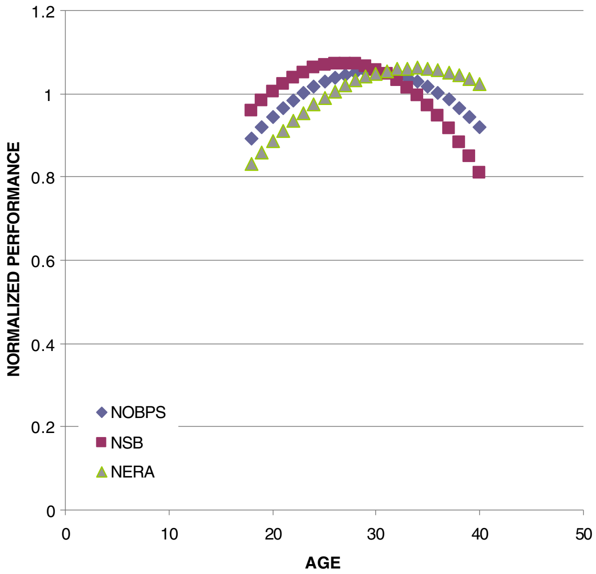
There are, however, several points of consistency. Managerial qualities have little to do with player hitting prowess, or with players' base stealing. On the other hand, pitching appears to be more amenable to coaching. Of the 16 pitching coefficients, 10 indicate that a specific managerial characteristic is associated with improved pitcher performance and are statistically significant. This is consistent with our findings in regressions (1) and (3) of Tables 1, 2, 3, 4, and 5, where we relied upon less complicated specifications.

The managerial residual variable, which we have posited is a rough overall measure of managerial ability, has explanatory value. All four of the pitching coefficients on this variable have the expected sign (negative) and all are statistically significant. Once again, however, batting and base stealing appear to be impervious to managerial instruction.

These results lend a form of support to the notion that the overall influence of baseball managers may be positive, but relatively small—a conclusion that a variety of other methodologically diverse studies broadly support (Porter and Scully 1982; Kahn 1993; Singell 1993; Ohkusa and Ohtake 1994; James 1997). Relying upon our more detailed specification of managerial qualities and subdividing classes of baseball performance, we now are able to make a more refined statement. Baseball managers appear to have little or no positive influence upon players' batting performances and zero or even negative influence upon players' stolen base performance. The positive impact of managers is substantially confined to pitching performance.

4.3 Age-Performance Profiles

In many previous studies, considerable attention has been paid to the age-performance profiles of players. At what age does baseball player performance peak? Our review of the literature revealed estimates ranging between 27 years and 29 years of age. As Graph 1 indicates, our results are roughly consistent with these findings. *Ceteris paribus*, OBPSL performance tops out at age 30 and stolen base performance at age 27. ERA performance, however, reaches its peak at age 34. Pitching performance clearly peaks later than hitting and stolen base performance. This finding further supports the notion that major pitching is a sophisticated endeavor that is amenable to learning and affected by experience. By contrast, an activity such as stealing bases is critically dependent upon speed and quickness and when those deteriorate, experience cannot overcome the effects of ageing human capital.



Graph 1 Age-performance profiles

In Graph 1, we present the age-performance profiles for OBPSL, stolen bases (SB) and ERA. Note that we have normalized OBPSL, stolen bases (SB) and ERA performances around an index of 1.00, so the age-performance profiles in Graph 1 are comparable in terms of their units. Managerial ability, or lack thereof, has almost nothing to do with the OBPSL and SB age-performance profiles and quantitatively rather little to do with the ERA profile. Thus, even when managerial characteristics count, they don't count very much.

5 Conclusions

Bradbury (2009) observed that, "Baseball provides an excellent natural laboratory for the study of human ageing because it requires a range of athletic and mental skills, and the play of the game allows for the measurement of individual achievement" (p. 610). Economists would love to have comparable human capital and performance data for workers in other occupations. Alas, that is not the case and therefore studies such as that reported here attempt to extrapolate baseball empirical results to other occupations and labor markets. This is not an easy task because of the stylized nature of baseball competition and performance.

Nevertheless, we believe that the results we have reported here with respect to the influence of baseball managers upon baseball performance has relevance to other segments of modern economic life. A salient feature of baseball is that natural talent and ability substantially determine player performance. It is almost impossible to teach an average individual to hit a 98 mile per hour fastball. As a consequence, managers and coaches have reduced importance in baseball. Similarly, managers and coaches may have a limited role in other pursuits where natural ability trumps other factors.

Speaking generally, we posit that managers/coaches/bosses/leaders/mentors have less impact upon individual player/worker performances than they and their bosses/owners/boards would like observers and shareholders to believe. The empirical validity of this proposition increases when occupational performance is highly sensitive to individual differences in the natural ability endowments of workers and diminishes when repetitive tasks are involved.

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