Marginal revenue product and salaries: Moneyball redux

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Abstract

Scully (1974) used a two equation regression model to estimate a baseball player's salary to compare to the actual salary the player earned in order to determine if a player is paid his net marginal revenue product. We replicate the spirit of that paper, but introduce several useful innovations to estimate net marginal revenue products for a large sample of free-agent baseball players. Our results suggest that the highest paid free agents are overpaid, while all other free agents are underpaid or paid appropriately. We found no evidence for the notion that some clubs may be more adept at finding "bargain" free agents.

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I. INTRODUCTION

One of the important issues in the sports economics literature is whether players are paid according to what economic theory predicts: profit-maximizing firms pay a salary equal to a player's marginal revenue product (MRP). Scully (1974) tackled the problem decades ago during the last remnants of the reserve clause era in major league baseball (MLB). His method and results are well-known and his paper sparked a burgeoning literature on the subject. More recent contributions include Scully (1989), Bruggink and Rose (1990), Fort (1992), Zimbalist (1992), MacDonald and Reynolds (1994), and Leeds and Kowalewski (2001). All of these papers utilize a two-equation regression model to estimate the appropriate salary given an individual player's production on the field. The method places strains on the data, although it is not computationally burdensome. Krautmann (1999) developed a simpler, more direct approach that required less data and utilized only one regression equation. This method has become the method of choice over the last few years (Krautmann and Ciecka (2009), Brown and Jepsen (2009) to name a few), however it does not provide an estimate of a player's MRP, rather it is a method to predict a player's salary assuming that the MRP rule holds.

The last use of the original Scully method appears to be MacDonald and Reynolds (1994), who estimated player MRPs using data from the 1986-87 MLB seasons. The results suggested that experienced players were paid salaries generally in line with their estimated MRPs, but younger players were paid considerably less. Baseball finance has undergone considerable change since the 1980's, notably a rapid increase in salaries that has coincided with a similar increase in revenues. The average team payroll has increased from $17.3 million in 1990 (39% of total expenses) to $109.6 million in 2008 (61% of total expenses).[1] Average team revenue increased from $51.9 million to $194 million over the

[1] Source: http://www.rodneyfort.com/SportsData/BizFrame.htm taken on February 8, 2010. These figures are taken from Financial World and Forbes magazine.

same time period. Gate revenue's share of total revenue has increased from an average of 33.3% in 1990 to 37% in 2008. Team values have increased from a median value of $102.5 million in 1990 to $415 million in 2008, yielding an annual growth rate of 16.9%. New expansion clubs have appeared in Miami, Tampa Bay, Denver, Phoenix and one club relocated from Montreal to Washington, D.C. A new, more extensive revenue sharing system was adopted in 2002 and a competitive balance tax on payrolls above a given threshold level was phased in in the late 1990's. Increased attendance demand resulted in the construction of 21 new ballparks at a total estimated cost to clubs and taxpayers of $7.8 billion.[2] Even after general inflation (the all items Consumer Price Index increased by 69% between 1990 and 2008), MLB operates on a much bigger dollar scale that it did in the 1980's.[3]

The purpose of this paper is to revisit the question of whether baseball players are paid their MRP by utilizing several improvements on past studies. Our method follows Scully (1974) in flavor but introduces several new innovations. Financial data for MLB clubs is not much more available than it was in the 1980's, however a consistent time-series of estimates has been provided by Financial World and Forbes magazine since 1990.[4] Although we do not utilize data going back to 1990 due to the lack of available data for other variables in the model, we do use a longer sample period than has been used in previous studies. We also utilize average ticket prices in our revenue function. Finally, we estimate our winning percentage function using a logistic regression, rather than the standard linear probability model that has been used in the past. Rather than estimate MRPs for players aggregated into groups, we estimate MRPs for individual players that signed contracts with new clubs after free agency. Our results suggest that significant changes have occurred in the MRP condition since the 1980's. The highest-priced free agents tend to be overpaid while other free agents are underpaid or paid appropriately. The next section of the paper develops a simple model of a profit-maximizing club owner and derives the MRP rule. The third section of the paper provides estimates of the league revenue function, while the fourth section

[2] Source: http://www.ballparks.com/ taken on February 8, 2010.
[3] Source: http://inflationdata.com/inflation/Consumer_Price_Index/ taken on February 8, 2010.
[4] These revenue data are not without their limitations. See Zimbalist (2010) for an in-depth analysis of salary and revenue data.

estimates net MRP for a large sample of free-agent MLB players. The final section provides concluding comments.

REVENUE MODEL

The essence of the Scully (1974) method is that an improvement in player performance increases a clubs winning percentage at the expense of other clubs, which in turn draws more fans to the game and increases the club's revenue. The revenue function for a single club is given by:

$$R = P \cdot Q(P) = P \cdot (\alpha - \beta P + \gamma WP + \delta \boldsymbol{X}) \qquad (1)$$

where R = attendance revenue + television revenue + all other revenues

P = average ticket price

WP = season winning percentage

X = a vector of independent variables that affect demand

Although revenue includes revenue that is specific to each club (attendance, local television, concessions, etc.) and revenue that is shared by all clubs (national television, apparel, etc.), we normalize the price of this composite good Q using the average ticket price, based on the assumption that the composite good price is a monotonic transformation of the average ticket price. This is a departure from previous studies that do not incorporate a price in (1). With no capacity constraint on the ability to produce the composite good *Q* at a given price, the coefficient β gives the slope of the demand curve. For purposes of estimation, (1) is easily rewritten as:

$$R/P = \alpha - \beta P + \gamma WP + \delta \boldsymbol{X} \quad (2)$$

The vector ***X*** includes per capita income (total metropolitan income / metropolitan population) *Y*, a state unemployment rate *U*, and a dummy variable, *NEWSTA*, taking on the value one the year that a new stadium is opened. A list of sources for all variables is contained in the appendix.

The function relating team winning percentage to player performance is given by the logistical function:

$$ln(WP/1 - WP) = \delta + \theta SA + \mu(K/BB) + \rho CONT + \omega OUT \quad (3)$$

where *SA* = team slugging percentage (total bases / total at bats)

K/BB = team strikeout - walk ratio

CONT = a dummy variable equal to one if a team finishes within five games of the wild card winner

OUT = a dummy variable equal to one if a team finishes twenty or more games behind the wild card winner

The independent variables *SA* and *K/BB* are measures of hitting and pitching quality that have been justified by Scully (1974) and others elsewhere. The independent variables *CONT* and *OUT* were also used by Scully (1974) and others as proxies for team morale or perhaps managerial ability. They represent a shift in the team production function based on factors other than player performance. We have retained their use to allow for comparison of our results to previous work.

The fact that winning percentage is bounded between zero and one justifies the use of the logistic function. Previous studies have relied on a linear probability model for winning percentage. The predictions for the marginal effect on winning percentage require estimation of the parameters and the choice of a baseline winning percentage ($\partial WP/\partial SA = \hat{\theta} WP(1 - WP)$). Teams with a 0.500 winning percentage will show the largest marginal effect, holding player performance and team morale constant. We chose to use the previous season's winning percentage, denoted $\widetilde{WP}_i$, for each team as the baseline winning percentage. This places each team on a logistic function at different positions with different marginal effects. This could not be done with a linear probability model and we think it is an improvement.

The calculation for MRP is straight-forward after (2) and (3) have been estimated. For a specific hitter denoted as player i playing on team j, MRP is given by:

$$MRP_i = (\partial R_i/\partial WP_i)(\partial WP_i/\partial SA_i)dSA_{ij} = P_i\hat{\gamma}\hat{\theta}\widetilde{WP}_i\left(1 - \widetilde{WP}_i\right)dSA_{ij} \qquad (4)$$

The contribution to the team slugging average by a specific hitter is calculated using the hitters total at bats as a share of total team at bats multiplied by the hitters slugging average for a season. Thus if a hitter has a slugging average of 0.450 and accounts for 10% of the teams total at bats, his contribution to the team slugging average is 0.045. This is consistent with the method used by Scully (1974) and others. The method assumes that the team performance is simply the linear summation of the individual player performances and ignores other aspects of team production such as complementarities.

The calculation of MRP for a specific pitcher i for team j is given by:

$$MRP_i = (\partial R_i/\partial WP_i)(\partial WP_i/\partial K/BB_i)dK/BB_{ij} = P_i\hat{\gamma}\hat{\mu}\widetilde{WP}_i\left(1-\widetilde{WP}_i\right)dK/BB_{ij} \quad (5)$$

The contribution to the team strikeout-walk ratio by a specific pitcher is calculated using the pitchers total number of innings pitched as a share of total innings pitched multiplied by the pitchers strikeout-walk ratio for a season. This is also consistent with Scully (1974) and others and assumes a linear production technology. We found that the estimates for gross MRP for pitchers were very unreliable when compared to actual salaries, so we do not report them. Pitchers can be divided into three categories: starters, middle relievers and relievers. Starting pitchers are paid far less per inning pitched that relief pitchers and this makes the results very hard to interpret. If the samples of free agents were evenly divided between starters and relievers, the differences might cancel out in the overall average gross MRP, however our sample years were typically heavily weighted towards starting pitchers or relief pitchers. Zimbalist (1992) also excluded gross MRP estimates for pitchers on similar grounds. We also discovered that a large proportion of free-agent pitchers spent a considerable amount of time on the 60-day disabled list in the first season of their new contract. Consequently their net MRP was smaller than expected, but not due to their own performance or the mistake of the owner.

ESTIMATES OF REVENUE AND WINNING PERCENTAGE FUNCTIONS

The revenue function in (2) was estimated using data collected from the 2000 through 2007 MLB seasons, providing a total pooled sample size of 224 observations per variable. Fixed effects were included to account for variations in team revenue not explained by the independent variables in (2). A weighted least squares method was used to account for heteroskedasticity across teams. Although Scully (1974) included a dummy variable to distinguish between National League and American League teams, we did not. The National and American League used the same revenue sharing formula over our sample, so we see little reason to include the dummy variable in (2). After testing for non-linearity, we found the following linear regression results (t-ratios appear in parantheses):

$$R/P = -1{,}526{,}318 + 4{,}182.51WP + 282{,}376.3Y + 519{,}957.9NEWSTA - 180{,}302.2P$$

(-3.43) (7.10) (22.04) (2.93) (-13.85)

$N = 224 \qquad Adjusted\ R^2 = 0.894 \qquad F = 61.87$

The state-wide unemployment rate was statistically insignificant and hence omitted from the final regression results. The fixed effects estimates are omitted for the sake of brevity. All of the regression coefficients are statistically significant at 95% confidence and the F statistic suggests that the linear model is appropriate in explaining variations in team revenue. A one-point increase in winning percentage raises consumption of the composite good by 4,182.51 “units” ($\hat{\gamma} = 4{,}182.51$) and revenue by 4,182.51 multiplied by the average ticket price for the team being considered. This cannot be interpreted as attendance since our revenues include all revenue sources, of which only half or less is gate attendance for most clubs. A new stadium has a large positive effect on consumption which agrees with the effect found by Coffin (1996) on attendance. Per capita income also has a large positive effect, confirming that baseball's composite commodity is a normal good. An increase in the composite good "price", normalized to be the ticket price, has a negative effect on consumption, however the coefficient value is difficult to interpret due to the normalization. It is curious that it has a smaller effect on consumption than per capita income, suggesting that the composite good might be a luxury good.

The winning percentage function (3) was also estimated using fixed effects and weighted least squares to account for heteroskedasticity. The model was estimated separately for the National and American Leagues owing to the use of the designated hitter in the American League. Team hitting statistics are somewhat higher and pitching statistics are somewhat lower for the American League relative to the National League where pitchers are required to hit. The results for each league are given below. The fixed effects estimates are omitted for the sake of brevity.

National League:

$$ln(WP/1-WP) = -8.62 + 0.0352SA - 0.00004SA^2 + 0.278\,K/BB + 0.093CONT - 0.20OUT$$

(-2.82) (2.45) (-2.26) (6.50) (2.95) (-6.18)

$N = 120$ $\quad Adjusted\ R^2 = 0.796$ $\quad F = 25.46$

American League:

$$ln(WP/1-WP) = -13.08 + 0.0542SA - 0.00006SA^2 + 0.271\,K/BB + 0.111CONT - 0.21OUT$$

(-4.39) (3.88) (-3.52) (7.37) (2.39) (-5.84)

$N = 104$ $\quad Adjusted\ R^2 = 0.883$ $\quad F = 46.63$

All of the regression coefficients for each league are statistically significant at 95% confidence. The degree of fit is quite high, particularly for the American League, however the F statistic for each regression suggests that the specification is appropriate. Diminishing returns to hitting was found in both regressions, but not for pitching. The marginal effect on winning percentage for slugging average is approximately 0.0352(0.25) = 0.0088 and 0.0542(0.25) = 0.01355 for the National and American Leagues respectively. Hence a 1 point increase in slugging average increases winning percentage by 0.88 and 1.355 points for the respective leagues. Larger increases in slugging average will have somewhat smaller marginal effects on winning percentage due to the negative SA^2 coefficients.

CALCULATING NET MRP

Having calculated gross MRP estimates, Scully (1974) and others obtain a net MRP estimate by subtracting an estimate of payments to other factors of production and player training and development costs. Different studies have used different conventions to estimate these costs. The important point is that these should only be costs that vary with the team stock of talent and should not include fixed costs. Many of the costs that major league teams face are fixed costs, such as stadium financing and maintenance costs, promotional costs, transportation costs and equipment costs. Scully (1974) included many costs that appear to be fixed costs and these figures were subsequently adjusted for inflation and used by Macdonald and Reynolds (1994). Zimbalist (1992) simply assumes that the appropriate costs are 10% of the estimated gross MRP, but this ignores the fact that most of these costs will be similar regardless of the player being considered (except perhaps when signing a highly valued free agent). One can always debate what sorts of costs make up the difference between gross MRP, where $MRP = MRC$, and net MRP, where $MRP = W_S$ (the wage rate per unit of talent given by the talent supply curve), in a monopsony model.

Ideally calculating net MRP from gross MRP is accomplished by recognizing that $W_S = MRP/(1 + \varepsilon_S^{-1})$. The supply elasticity of talent, ε_S, can be estimated using the log of actual player salaries and performance indicators that are consistent with the estimation of gross MRP: *SA* for hitters and *K/BB* for pitchers. Attention would need to be paid to the proper identification of the talent supply function. A reduced form approach cannot be used because the competitive wage rate (where $MRP = S$) is not observed in a monopsony, so a disequilibrium modeling approach is necessary. In the end, we followed the convention used by Zimbalist (1992) and subtract 10% of each players gross MRP to arrive at a players net MRP figure.

Our estimates of gross MRP are calculated by inserting the estimated coefficients into (4) and (5) and using the actual team winning percentages and average ticket prices for the same season that the free-agent player is acquired. Net MRP was estimated for every free-agent hitter over the 2000 through 2007 MLB seasons.[5] Players who spent at least one period during a season on the 60-day disabled list were excluded from that season.[6] Generally, players who experience periods on the 60-day disabled list possessed large negative net MRPs, due largely to their injuries. Some large variations in net MRP and actual salaries were apparent for individual players, however these often occur due to injuries (net MRP –

[5] These estimates can be viewed in a spreadsheet file at http://www.uleth.ca/~rockerbie

[6] Players who are assigned to the 60-day disabled list (DL) typically have serious injuries that require rehabilitation. They may not return to the major league roster before the 60-day period has expired, however they may be replaced on the team roster by another player. Clubs can apply for reimbursement of salary for players on the 60-day DL through insurance policies they purchase on their players, hence the player's MRP is zero whilst on the DL, but the club suffers no salary expense. Historical transactions for the 60-day DL can be found at the MLB website http://mlb.mlb.com/mlb/transactions/

salary < 0) or an unexpectedly good season (net MRP – salary > 0). They might also occur due to positive or negative externalities in team production that our model does not account for.

Table 1 presents the average difference between the estimated net MRP and salary for each season expressed as a percentage of the estimated net MRP. The table breaks down the average differences by the top and bottom 25th percentile of free-agent salaries, as well as the salaries in between and the overall average difference across all salaries. A negative percentage indicates an overpayment of salary relative to net MRP and a positive percentage indicates an underpayment. The overall average percentage difference suggests that free-agents are overpaid relative to their net MRP in each year of the sample with the exception of the 2000 season and that the overpayment has been generally increasing over time. The result for the 2001 season is heavily weighted by the $22 million annual salary earned by Alex Rodriguez, a free-agent signing by the Texas Rangers club. His estimated net MRP for that season was only $4.74 million, largely due to the poor performance of the club coupled with lower than average ticket prices.[7] Excluding Rodriguez from the calculations results in an estimated overpayment of 48.13%, still a large figure. The 2001 season also saw MLB negotiate a new television contract with the FOX broadcasting network, a six-year package totaling $2.5 billion. This was a large increase over the previous television contract, a six-year deal totaling $1 billion. Although this revenue increase is included in the revenue data used here, it would appear that some club owners greatly overpaid their free-agent acquisitions in anticipation of these higher revenues.

The results in Table 1 for different salary groups are quite revealing. The bottom 25% of free-agent salaries suggest that these players are *underpaid* relative to their net MRP by an overall average of

[7] This contract still remains as the largest free-agent contract in MLB history, a ten-year contract for a total of $250 million. Rodriguez was subsequently traded before the 2004 season to the New York Yankees, however the Rangers agreed to continue paying a significant portion of his salary.

just over 50% for the 2000 – 2007 seasons, with no apparent trend. While signing these players might not result in a World Series victory, or even close, it will be greatly profitable for the club owner. Scully's (1989) result that low-skilled players are overpaid is not comparable to the results here since we are categorizing free-agent players by salary level, not skill level. For the scrupulous club owner, our method of categorization might be more important since dollars, not slugging percentage, is the bottom line. The middle 50% of free-agent salaries suggest that these players are also underpaid on the average by 13.6% over the entire sample period. The 2007 season result estimates an overpayment of 43.6% for this group, suggesting that the practice might be coming to an end (we found no extraordinary player results in this group for the 2007 season). Excluding the 2007 season increases the average underpayment to 19.1%.

The top 25% of free-agent salaries carries a hefty price tag for owners. The average overpayment over the sample period is 107.5% and is 102.3% excluding the Rodriguez 2001 contract. Club owners are clearly not very adept at estimating a player's MRP after joining their club. Some of these free-agents may have been essential acquisitions to success on the field, but they are generally big losers at the cash register. Some clubs appear to be more adept than others at acquiring free-agent bargains. We calculated the best (highest net surplus) and worst (lowest net surplus) and free-agent acquisitions in each season and found that in four of the eight seasons we sampled, the Boston Red Sox made the best acquisition, while no club appeared more than once for the worst acquisition. The Red Sox did not earn the highest profit over the sample period since even underpaying a free-agent player is not profit-maximizing. We also determined the rank of each club in each season for the highest average positive surplus from their free agent acquisitions to detect if some clubs are better than others at evaluating free agent talent and extracting the most surplus. We could not find any evidence that any club had a consistently higher rank than others, in fact, most clubs displayed considerable variation in rank from one season to the next.

SUMMARY

This study developed a simple model of a profit-maximizing club owner to determine the MRP of a potential free-agent acquisition. The profit-maximizing rule of setting salary equal to net MRP was tested and found to be wanting. The study followed Scully (1974, 1989) in spirit but introduced a number of useful innovations. First, only free-agent players were considered since players in the middle of long-term contracts may not be expected to provide a net MRP equal to their salary that was negotiated several seasons ago. This suggestion was first made by Krautmann (1999) and we employed it here. Second, our club revenue data is the most up to date we could find and includes all revenue sources, whereas Scully (1974, 1989) and Zimbalist (1992) estimate revenue from gate attendance and average ticket price. The importance of using all revenue sources can be noted in our results for the 2001 season when television revenues increased substantially. Third, our regression equation to predict winning percentage used a logistic function instead of the linear probability function, making the estimated marginal effect of slugging percentage dependent upon the overall performance of the club. Finally, we estimated the net surplus (positive or negative) for every free-agent player over a much longer sample period than the one or two season samples of previous studies. We believe it is important to consider longer samples in order to avoid implying that the results for a single season are representative of many seasons. We also excluded players who spent time on the 60-day disabled list since their net MRPs are expected to be unusually low and their salaries are not paid by club owners during their time on the disabled list.

Two tentative results emerge from our results. First, the salary equals net MRP rule does not hold up well in our sample, suggesting that team owners are not profit-maximizing, even over a period of eight seasons (although the results for the 2000 season are very close). As often suspected by baseball fans, our results suggest that higher priced free agents are overpaid, but bargains can be had with lesser-paid free agents. If some clubs are able to exploit this result consistently, we did not detect them in our sample. Second, the monopsony assumption that the elasticity of talent supply is very inelastic does not seem to fit our results. We subtract only 10% of gross MRP to arrive at a net MRP estimate, consistent with Zimbalist (1992). This implies a talent supply elasticity of 9.0, still a very large elasticity. A higher supply elasticity would only drive a larger wedge between our net MRP estimates and actual salaries.

APPENDIX

Data sources

R = MLB club revenue from all sources	Taken from http://www.rodneyfort.com which is data compiled from Forbes magazine and Financial World magazine.
P = Average ticket price	Taken from http://www.rodneyfort.com which is data compiled from Team Marketing Report.
WP = Club winning percentage	Taken from Sports Reference, LLC http:// www.sports-reference.com
Y = Metropolitan area income per capita	Local metropolitan area personal income and population taken from Bureau of Economic Analysis, Regional Accounts, http://www.bea.gov/regional/reis/
U = State-wide unemployment rate	Taken from Bureau of Labor Statistics, http://www.bls.gov/schedule/archives/metro_nr.htm
NEWSTA = dummy variable = 1 for a new stadium	Determined from http://www.ballparks.com/
SA = Team slugging average (total bases / at bats)	Taken from Sports Reference, LLC http:// www.sports-reference.com
K/BB = team strikeout to walk ratio	Taken from Sports Reference, LLC http:// www.sports-reference.com
CONT = a dummy variable =1 if a club finished the season within five games of the wild-card winner in each league.	Determined from Sports Reference, LLC http:// www.sports-reference.com
OUT = a dummy variable = 1 if a club finished the season within twenty or more games behind the wild-card winner in each league.	Determined from Sports Reference, LLC http:// www.sports-reference.com

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Table 1

Overpayment and underpayment of salary as a percentage of net MRP

Season	Top 25%	Middle 50%	Bottom 25%	Overall
2007	>$6 million -162.60%	-43.60%	<$1.25 million 48.93%	-73.89%
2006	>$4 million -143.51%	9.33%	<$875,000 35.52%	-39.09%
2005	≥$4.5 million -86.32%	21.26%	≤$850,000 46.84%	-21.21%
2004	≥$3 million -61.58%	32.49%	<$700,000 60.93%	-6.97%
2003	≥$3.75 million -124.24%	40.69%	<$635,000 48.58%	-17.28%
2002	>$2.5 million -90.36%	31.10%	<$700,000 61.91%	-14.49%
2001	>$3.5 million -151.46%	-15.09%	<$700,000 45.15%	-70.95%
2000	>$2.3 million -39.58%	32.73%	<$625,000 52.82%	3.71%