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Who is 'Most Valuable'? Measuring the Player's Production of Wins in the National Basketball Association

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How does one measure the productivity of an individual participating in a team sport? The purpose of this inquiry is to answer this question via an econometric model that links the player's statistics in the National Basketball Association (NBA) to team wins. This model will then be employed in the measurement of each player's marginal product. Such a measurement is useful in answering the question offered in the title, or a broader list of questions posed by both industry insiders and other interested observers. Copyright © 1999 John Wiley & Sons, Ltd.

INTRODUCTION

At the conclusion of the 1997–1998 National Basketball Association (NBA) season, the Chicago Bulls were crowned NBA champions. Michael Jordan, the leading scorer of the Bulls, was named both Most Valuable Player (MVP) of the regular season and the NBA Finals by members of the national media. The Utah Jazz, for the second consecutive campaign, finished second to Chicago in the NBA finals. The leading scorer of the Jazz, Karl Malone, also finished second to Jordan in voting for regular season MVP. However, the IBM award, which purports to be a 'computerized rating that measures a player's overall contribution to a team' (NBA.com, 1998), was given to Malone.

Such confusion in the assigning of awards is essentially a trivial issue. However, the inquiry into who is most valuable points to a more important question: How does one measure the productivity of one individual participating in a team sport? For every coach and general manager in professional basketball, this question must be answered. Without an answer one is unable to ascertain who should play, what free agents should be pursued, or what trades should be consummated. Furthermore, of more immediate interest to the academic researcher, the issue of player productivity must be addressed if one is to examine such subjects as the extent of racial discrimination[1] and the impact alternative institutional arrangements have on worker compensation in professional basketball[2]. The purpose of this discourse is to present an econometric model that links the player's statistics in the NBA to team wins. This model will then be utilized in constructing a method for measuring each player's production of wins, or the player's marginal product.

The organization of this paper is as follows: the next section lists the data to be utilized. A review and critique of the academic literature is offered in the following section. This will be followed by the presentation of an econometric model designed to connect the player's statistics to team wins. The next section will describe how the results of this model can be utilized to measure an individual player's production of wins. The surprising answer to the question posited in the title will be offered in the following section, while the final section will offer concluding remarks regarding the application of this research.

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TEAM AND PLAYER DATA

The NBA tabulates a variety of statistics in an effort to measure both the productivity of the team and the individual players. Table 1 lists each of the factors[3] that will be employed in this discourse. The specific data utilized in constructing the models reported here will be aggregate team data from 4 years, beginning with the 1994–1995 campaign and concluding with the 1997–1998 season. Both the regular season and post-season will be considered. Given the difference in games each team plays in the post-season, per-game averages will be utilized rather than aggregate season totals. The mean values for these per-game averages are listed in Table 1.

Table 1. Team and Player Performance Variables

Statistics	Notation	Mean
Assist	AST	22.36
Assist-turnover ratio	ASTO	1.49
Blocked shot	BLK	5.03
Defensive rebound	RBD	28.44
Field goal attempt	FGA	79.95
Free throw attempt	FTA	26.29
Free throw made	FTM	19.39
Free throw percentage[a]	FT	0.74
Missed field goal attempt	MFG	43.39
Missed free throw attempt	MFT	6.90
Offensive rebound	RBO	12.81
Personal foul	PF	22.84
Point	PTS	97.97
Points-per-shot[b]	PPS	0.98
Steals	STL	8.15
Three point field goal made	3FGM	5.46
Turnover	TO	15.68
Two point field goal made	2FGM	31.09

D . . . represents the opponent's accumulation of the factor, i.e. the opponent's total scoring = DPTS.
[a] Free throw percentage is simply free throws made divided by free throws attempted.
[b] Points-per-shot (Neyer, 1995) is the number of points a player or team accumulates from its field goal attempts. Its calculation involves subtracting free throws made from total points, and then dividing by field goals attempted. Employing points per shot, rather than field goal percentage, allowed for the impact of three point shooting to be captured more efficiently.

CRITIQUE OF THE CURRENT METHODOLOGIES

The Media's Methods

The media subjectively assigns its awards by polling selected members of the press. However, given the nature of this system, it is not clear whether the players are evaluated according to their on-court contribution, or their off court image. Clearly, the democratic method cannot be relied upon to give an objective evaluation of each player's value.

The alternative to the democratic method is a host of 'computer' models that claim to objectively measure a player's production. An example is the IBM award, whose criteria for choosing its winner is the following formula (NBA.com, 1998):

$$\text{Player value} = \frac{[(\text{PTS} - \text{FGA} + \text{RBO} + \text{RBD} + \text{AST} + \text{STL} + \text{BLK} - \text{PF} - \text{TO} + (t * \text{Wins} * 10)) * 250)]}{[t\text{PTS} - t\text{FGA} + t\text{RBO} + t\text{RBD} + t\text{AST} + t\text{STL} + t\text{BLK} - t\text{PF} - t\text{TO}]}, \quad (1)$$

where t refers to the accumulation of each factor by the player's team.

In essence, the IBM award is a reincarnation of the TENDEX (Heeren, 1992) and Points Created[4] (Bellotti, 1993) models. Each of these 'computer' models theorizes that the proper measure of a player is the summation of his positive statistics less the summation of his negative statistics. Without any supporting statistical evidence, the authors of these methods assert the value of any additional statistic is identical, regardless of the specific statistic examined (i.e. points, rebounds, assist, etc.).[5] Certainly, the value of these statistics should best be ascertained via the application of statistical analysis, not via an arbitrary assumption.

A Review of the Academic Literature

The measurement of a professional athlete's productivity is a subject of numerous academic inquiries. In the context of a variety of issues, Scully (1974), Medoff (1976), Blass (1992) and Zimbalist (1992a,b) are among the most notable writers to estimate the productivity of a professional baseball player. With respect to professional basketball, various academic papers have presented models designed to statistically measure a player's production. The general form of these models has followed from the work of Zak, Huang and

Siegfried (ZHS, Zak *et al*., 1979). This model has inspired the work of Scott, Long and Sompii (SLS, Scott *et al*., 1985), McCormick and Clement (1992), and Hofler and Payne (1997).

The model presented by ZHS examined the relationship between wins and a variety of statistics. To incorporate both the team and its opponent's production, ratios were constructed of the team's accumulation of each factor relative to its opponent. The relationship between these ratios and wins was then proposed to follow the Cobb–Douglas functional form. The task laid forth in this paper is to link the player's production to team wins. Can the work cited in the literature accomplish this objective? Three potential problems exist with the basic approach offered by ZHS: the choice of functional form, the utilization of the opponent's statistics, and the issue of team tempo. Although the issue of team tempo is best clarified in the context of the model reported herein, the former two issues are examined directly below.

The Issue of Functional Form In addition to noting the popularity of the Cobb–Douglas production function and the ease by which one can interpret the estimated coefficients, ZHS also sought to theoretically justify their choice of functional form. According to these authors, the marginal product of each factor should depend upon the team's accumulation of other statistics. In the words of ZHS, the value of shooting skills should depend upon the team's ability to acquire the ball (i.e. via rebounds, turnovers) (Zak *et al*., 1979, p. 382) From this line of reasoning, teams that fail to rebound sufficiently are not only penalized by this shortcoming but also are handicapped because each resulting shot has less of an impact on team wins. According to this perspective, identical player performances on different teams will be of different value, depending upon the performance of a player's teammates. Such a feature may make the comparison of players across teams somewhat problematic.

An opposing view would be that the marginal value of each statistic is constant from team to team. According to this viewpoint, teams that lose frequently do so not because their accumulated statistics are of less value, but rather because they have either failed to accumulate a sufficient number of positive statistics or tallied too much of the negative factors. From this perspective, players with identical statistical performances offer the same impact on team outcomes. In other words, a player's statistical value is independent of whatever teammates he has been bestowed.

Given the widespread employment of the Cobb–Douglas production function, one can conclude that researchers in general support the arguments offered by ZHS. Fortunately, the issue of functional form is not strictly a function of the popularity of the theory. Rather, the proper functional form can be ascertained via statistical analysis.

The obvious starting point in such analysis would be to estimate the model via each functional form and then ascertain which model offers the greatest explanatory power of the dependent variable. Although one cannot compare the R^2 from two equations estimated via differing functional forms, one can construct a quasi-R^2 that allows for such a comparison.[6] The quasi-R^2 is ascertained by taking the anti-log of the double-logged residuals and then utilizing this series, along with the unaltered dependent variable, to re-estimate the R^2 for the Cobb–Douglas equation. One can then compare the R^2 from the linear form to the quasi-R^2 calculated from the double-logged model to ascertain which model offers a better fit for the data.

A more sophisticated test for functional form is offered by Mackinnon, White and Davidson (MWD, Mackinnon *et al*., 1983)[7]. The MWD test proposes estimating a particular equation with both a linear and double-logged specification. The predicted values of the dependent variable from each regression are used in the construction of two variables. The calculations are detailed in Equations (2) and (3):

$$Z_1 = (\ln(h) - g], \tag{2}$$

$$Z_2 = [\text{antilog}(g) - h], \tag{3}$$

where h is the estimated value of the dependent variable from the linear regression, and g is the estimated value of the dependent variable from the logged regression

The double-logged model is then re-estimated with Z_2 as an additional independent variable. If Z_2 is statistically significant according to the standard t-test, then this is taken as evidence that the linear formulation is likely to be the most appropriate. Similarly, if Z_1 is statistically significant in the re-estimation of the linear model then this is taken as evidence that the double-logged formulation should be chosen. Ideally one hopes that both tests offer consistent evidence, although this may not always be the case.

For each equation tested in this exposition both the quasi-R^2 and the results of the MWD test will be offered. The results of these tests indicate that a linear form, rather than the traditional Cobb–Douglas, is the correct functional form for each of the models utilized in this study.

The Utilization of the Opponent's Statistics The second issue one can take with the work offered by ZHS is the utilization of the opponent's statistics in ascertaining the value of the player's statistical production. SLS presented a similar Cobb–Douglas model and did utilize the results of its estimation to measure player productivity. However, by including the opponent's accumulation of each factor it was difficult to precisely determine the impact each player had on team wins. SLS was forced to assume that each player is equally responsible for the opponent's production. Such an assumption would imply that a point guard is just as culpable for an opponent's power forward garnering an exorbitant number of rebounds as the team's power forwards or centers. Given the differences in responsibilities across all positions, such an assumption would appear inconsistent with the nature of the sport.

Although the statistics the NBA currently tabulates will require the utilization of the SLS assumption with respect to certain aspects of the opponent's production, the problem with respect to rebounding will be avoided. Furthermore, if the NBA were to tabulate additional information in the future, such an assumption could be virtually eliminated. Given the information the NBA does currently tabulate, the utilization of the aforementioned assumption can be minimized if one first attempts to lay forth the theoretical determinants of wins.

CONNECTING A PLAYER'S STATISTICAL PRODUCTION TO WINS

The process of building any econometric model should begin with the theory the model is purporting to examine. The purpose of the model presented is to describe how the player's production of various factors translate into team wins. Such a purpose requires a sound theoretical foundation, in essence, a theory of basketball.[8]

The Theoretical Model[9]

The construction of a theory that explains why teams win or lose begins with the primary determinants of wins, points scored and points surrendered. These two factors can be connected to wins via the fixed effects model[10] reported in Equation (4).[11] Equation (4) was estimated with aggregate team data from the 1994–1995 through the 1997–1998 campaign[12] The results are reported in Table 2.

$$Y_{1n} = f_{1i} + \sum_{k=1}^{2} \alpha_{1k} X_{1kn} + \epsilon_{1n}, \tag{4}$$

where

$Y_1 = \text{WINS}$ $\quad X_{11} = \text{PTS } (+)$
$\quad X_{12} = \text{DPTS } (-)$

and f_i = team specific fixed effects; $n = 1, \ldots, z$ with $z = 114$. The theorized impact of each factor is listed in parentheses.

Not surprisingly, the total points a team scores and surrenders in a season explains 95% of the variation in team wins. Such a result indicates that how many points a team scores and

Table 2. Estimated Coefficient for Equation (4) (Dependent Variable is PCT[a])

Independent variables	Coefficient	S.E.	t-Statistic
PTS	0.031	0.002	19.228
DPTS	(0.032)	0.002	(15.771)
R^2	0.960	Mean dependent variable	0.491
Adjusted R^2	0.946	S.D. of the dependent variable	0.169
S.E. of regression	0.039	Sum of squared residuals	0.128
Observations: 114			

[a] The 29 team specific fixed effects are available from the author upon request.

surrenders per game is a good approximation of team wins. Therefore, the value of a player should be simply a function of how many points he scores and allows the opponent to score per contest. Given that we know how many points each player scores, the task before us should be to find an estimate for how many points each player surrenders. With such an estimate in hand, we should then know how many wins each player produces.

As noted by Berri and Brook (1999), such an approach, although simple and straightforward, is likely to be incorrect and misleading. To say that a player's value is simply a function of his scoring and defensive prowess neglects the fact the player is participating in a team sport. Professional basketball is not five games of one-on-one basketball, but rather one game of five-on-five. To evaluate a player strictly according to points scored and surrendered would lead one to neglect such factors as rebounding, turnovers, steals, and assists. In fact, if a player believed that this is how he is to be evaluated, then his wisest course of action would be to expend his finite efforts strictly towards out-scoring his defensive responsibility.

An alternative to the simplistic view of a player's production is to recognize that the number of points a team scores or surrenders is determined by various factors that can be quantified. A team's scoring should be a function of how the team acquires the ball, the efficiency of its ball handling, and its ability to convert its possessions into points. Likewise, the opponent's scoring should be determined by the same factors. In terms of the variables listed in Table 1, the following system of equations should connect the player's statistics to team wins:

$$Y_{2n} = f_{2i} + \sum_{k=1}^{7} \alpha_{2k} X_{2kn} + \alpha_9 Y_{2n} + \epsilon_{2n}, \tag{5}$$

$$Y_{3n} = f_{3i} + \sum_{k=1}^{9} \alpha_{3k} X_{3kn} + \epsilon_{3n}, \tag{6}$$

where

$Y_2 = \text{WINS}$	$X_{21} = \text{PPS}\ (+)$	$X_{31} = \text{DPPS}\ (+)$
$Y_3 = \text{DPTS}\ (-)$	$X_{22} = \text{FT}\ (+)$	$X_{32} = \text{DFT}\ (+)$
	$X_{23} = \text{FTA}\ (+)$	$X_{33} = \text{PF}\ (+)$
	$X_{24} = \text{RBO}\ (+)$	$X_{34} = \text{RBD}\ (+)$
	$X_{25} = \text{ASTO}\ (+)$	$X_{35} = \text{DASTO}\ (+)$
	$X_{26} = \text{DTO}\ (+)$	$X_{36} = \text{TO}\ (-)$
	$X_{27} = \text{RBD}\ (+)$	$X_{37} = \text{RBO}\ (-)$
		$X_{38} = \text{FGA}\ (+)$
		$X_{39} = \text{FTA}\ (+)$

and f_i = team specific fixed effects; $n = 1, \ldots, z$ with $z = 114$; $m = 1, \ldots, 29$ with 1 = Atlanta and 29 = Washington. The theorized impact of each factor is listed in parentheses.

In essence, this model presents the basic theory of basketball, with the primary determinants of offense and defense laid forth and then connected to wins. Equation (5) essentially relates wins to points scored and points surrendered. As noted, points scored is a function of how the team acquires the ball (DTO, RBD, DPTS), the efficiency of its ball handling (ASTO), and its ability to convert possessions into points (PPS, FTA, FT, RBO).[13] Given that this list of determinants includes how many points a team surrenders, Equation (5) is simply a restatement of the basic proposition that wins are determined by points scored and points surrendered.

The determination of the opponent's scoring begins with a factor not generally accounted for in previous academic studies[14], team tempo. Although not typically determined by the individual players, this factor that follows generally from the philosophy of the coaching staff is crucial in accurately measuring a player's statistical output. First, the number of shots (FGA, FTA) a team takes on average per game plays a significant role in determining how many opportunities the opponent will have. If a team chooses to play at a slower tempo, and hence take fewer shots, the opponent will find the amount of time they have the ball will decrease. Hence, given less time the opponent will, *ceteris paribus*, score fewer points. If one controls for RBOs and TOs, then the number of shots a team takes represents the number of opportunities the opponent has to score. Secondly, tempo also represents the number of opportunities a player is given to score, rebound, etc. A team playing at a faster tempo will have more opportunities, therefore, players from these teams will accumulate greater numbers of statistics. By weighting each player's production by the tempo the team played, this bias is mitigated.

In addition to team tempo, the ability of the opponent to convert its opportunities into points can be measured by several other quantifiable factors. First, similar to Equation (4), the efficiency of the opponent's ball handling is a significant determinant of scoring. This factor is measured by the opponent's assist-turnover ratio (DASTO). If the opponent can maintain possession of the ball, its ability to turn its possessions into points is measured via (DPPS, DFT, PF, RBD).

The Empirical Results

Having laid forth a rudimentary theory of basketball, it is now possible to ascertain the impact each of these factors has on the percentage of games a team wins. These two linear equations[15] were estimated with four seasons of data, beginning in 1994–1995 and concluding with the 1997–1998 campaign.[16] Given that these equations are simultaneously determined, the estimation method was three stage least squares. The results are reported in Tables 3 and 4.[17]

The results listed in Tables 3 and 4 indicate that much of the variation in PCT and DPTS can be explained by the chosen independent variables. Furthermore, each variable is both statistically significant at the 99% level and of the expected sign. Such findings are evidence that the productivity of both an NBA player and a team can be empirically derived, and thus, the value of an NBA player can be objectively and accurately determined.

Before a player's value can be ascertained, however, the marginal value of each statistic must be determined. The calculation of marginal values involves moving from the two-equation system to a single equation linking each factor directly to wins. This single equation, though, includes six ratios, PPS, FT, ASTO, DPPS, DFT, and DASTO. The interpretation and utilization of each would be eased if the components were examined individually. This can be accomplished by taking the derivative of PCT with respect to each of the elements of the aforementioned ratios.

Table 3. Estimated Coefficient for Equation (5) (Dependent Variable is PCT[a])

Independent variables	Coefficient	S.E.	*t*-Statistic
PPS	2.043	0.158	12.896
FT	0.887	0.194	4.573
FTA	0.013	0.002	5.426
RBO	0.029	0.005	6.340
ASTO	0.212	0.035	6.027
DTO	0.020	0.004	4.657
RBD	0.020	0.004	5.106
DPTS	(0.020)	0.001	(17.562)
R^2	0.963	Mean dependent variable	0.491
Adjusted R^2	0.945	S.D. of the dependent variable	0.169
S.E. of regression	0.039	Sum of squared residuals	0.120
Observations: 114			

[a] The 29 team specific fixed effects are available from the author upon request.

Table 4. Estimated Coefficient for Equation (6) (Dependent Variable is DPTS[a])

Independent variables	Coefficient	S.E.	*t*-Statistic
DPPS	49.790	3.451	14.429
DFT	15.817	5.967	2.651
PF	0.351	0.073	4.817
RBD	(0.254)	0.086	(2.946)
DASTO	9.477	0.705	13.448
TO	1.100	0.092	12.006
RBO	(1.416)	0.091	(15.516)
FGA	1.146	0.051	22.428
FTA	0.447	0.043	10.369
R^2	0.987	Mean dependent variable	98.235
Adjusted R^2	0.981	S.D. of the dependent variable	5.250
S.E. of regression	0.726	Sum of squared residuals	40.062
Observations: 114			

[a] The 29 team specific fixed effects are available from the author upon request.

With this information in hand, the impact of three-point field goals made[18], two-point field goals made, missed field goals, assists, turnovers, free throws made, and missed free throws could be ascertained for both the team and the opponent. These marginal values[19] are listed in Table 5, along with those that were not derived from the aforementioned ratios, in descending order from highest marginal value in absolute terms, to the lowest.

An examination of the marginal values indicates that there is a substantial difference in the impact each additional statistic has on wins. Interestingly, the factor with the greatest marginal impact is offensive rebounds. Such a result should not surprise, though, when one considers the impact of an additional missed field goal attempt and defensive rebound. Given that a team must first miss a shot before an offensive rebound is possible, the net impact of a team's offensive rebound is similar to the marginal impact of a defensive rebound.

These results also indicate the importance of ball handling. Both a player's turnovers and turnovers by the opponent have a greater marginal impact than any factor but three point field goals made and offensive rebounds. When one notes that an additional assist has only a third of the absolute impact a turnover has on wins, it is easy to conclude that a player should not be strictly evaluated in terms of how many assists he accumulates. Rather, the more important issue is how many turnovers the player commits.

Given that this is a linear model, the elasticity of PCT with respect to each factor will vary from team to team. However, one can glean valuable insights by examining the average elasticity across the teams considered in this study. From Table 5 it is revealed that if one ignores the tempo factors, which are discussed below, PCT is most responsive to missed field goal attempts. The relative importance of missed field goal attempts suggests that a player's shooting efficiency is more important than the total number of points the player scores. In other words, scoring 30 points a contest is not likely to lead to many wins if the player misfires on a large number of shots in his effort to achieve such a substantial point total.

The findings reported in Table 5 reveal that a player's production of wins is primarily a function of his ability to acquire and maintain possession of the ball, and his ability to convert his field goal attempts consistently. Factors such as assists and personal fouls, while having some impact on wins, are of relatively little importance. Therefore, a player's contribution to team success depends most heavily on his accumulation of rebounds, avoidance of turnovers, and shooting efficiency.

Table 5. Marginal Values and Average Elasticities

	Marginal value	Elasticity
Player statistics		
Offensive rebound	0.058	1.506
Three point field goal made	0.052	0.574
Turnovers	(0.042)	(1.333)
Opponent's turnover (steal)	0.037	1.188
Two point field goal made	0.026	1.648
Defensive rebound	0.026	1.483
Missed field goal	(0.025)	(2.222)
Made free throw	0.021	0.847
Assist	0.014	0.616
Missed free throw	(0.012)	(0.173)
Personal foul	(0.007)	(0.333)
Tempo statistics		
Field goal attempt	(0.023)	(3.805)
Free Throw Attempted	(0.009)	(0.488)
Defensive statistics		
Opponent's three point field goals made	(0.026)	(0.286)
Opponent's two point field goal made	(0.013)	(0.818)
Opponent's missed field goal (blocked shot)	0.013	1.104
Opponent's assist	(0.012)	(0.565)
Opponent's free throw missed	0.009	0.126
Opponent's free throw made	(0.003)	(0.127)

CALCULATING THE VALUE OF A PLAYER'S PRODUCTION

Having established the impact each statistic has on PCT, it is now possible to calculate the number of wins each player produces. The ingredients in this calculation include the statistics kept for the players, team tempo statistics, and team defensive variables. Each of these must be considered separately if the wins of the team are to be accurately connected to the actions of the players. To ease the exposition, the process utilized to determine the number of wins a player produces will be laid forth in a step-by-step fashion.

Step One: Examining the Statistics Kept for the Player

In addition to the factors listed in Table 5, the list of statistics utilized in evaluating a player also includes blocked shots and steals. Although blocked shots and steals were not explicitly a factor in the system of equations, the value of each can be derived from the variables that were included in the model. As mentioned, the opponent's turnovers include team steals. Given that each of the opponent's turnovers leads to an additional 0.037 wins, the value of an additional steal is assumed to have the same impact. In considering the opponent's turnovers, then, steals are utilized in evaluating individual players while, as explained below, the opponent's turnovers that were not steals are employed in constructing the team defensive factor.

The value of a blocked shot[20] is ascertained in a similar fashion. From Table 5 it can be seen that an opponent's missed shot produces 0.013 wins. In essence, a blocked shot produces a missed shot for the opponent. Therefore, the opponent's missed shots that were blocked are allocated to the individual player's production of wins. Missed shots of the opponent that were not caused by a blocked shot are included in the calculation of the team defensive factor.[21]

Having established values for each of the statistics kept for the individual players, the first step in measuring the player's production of wins involves multiplying a player's accumulation of each statistic by the corresponding marginal value for the player statistics listed in Table 5. This value is then divided by the number of minutes a player played, giving us one number representing the player's per-minute production. Equation (7) illustrates how this calculation is performed:

$$\text{Per-minute production} = \frac{\sum [\text{marginal value of statistic} * \text{accumulation of statistic}]}{\text{Total minutes played}}. \quad (7)$$

Step Two: Examining the Statistics Kept for the Team

At this point the other ingredients, team tempo, and team defense, come into play. For each of these factors, one can determine the team's production, but the individual's contribution is unclear. For example, given that it is not possible to separate each player's impact on the opponent's shooting, the approach taken herein is that each player's responsibility will be assigned according to the minutes each player played.[22]

To incorporate team tempo into the player's production of wins one must determine the team's per-minute tempo factor. This is calculated by first multiplying the values of a field goal and free throw attempt, listed under tempo statistics in Table 5, by the team's total accumulation of these statistics for the regular season or playoffs one is considering. This value is then divided by the total minutes the team has played. Equation (8) below illustrates this calculation:

$$\begin{aligned}&\text{Per-minute team tempo factor}\\&= \frac{[(\text{Team field goal attempts} * -0.023) + (\text{Team field throw attempts} * -0.009)]}{\text{Total minutes played}}. \quad (8)\end{aligned}$$

As illustrated in Equation (9), similar calculations are made with respect to the team's per-minute team defensive factor:[23]

$$\text{Per-minute team defense factor} = \frac{\sum[\text{Marginal value of team defense statistic} * \text{accumulation of statistic}]}{\text{Total minutes played}}. \quad (9)$$

The rationale for determining these values for the team has been hinted at before. Given that a faster tempo results in the opponent scoring more, additional shot attempts have a positive impact on the total points the opponent scores, and thus a negative impact on wins. As mentioned, it is primarily the coaches that determine the tempo the team plays, not the individual shooters. To simply allocate the negative impact of shot attempts to those who take the shot would in essence reward those players who do not, and in many cases cannot efficiently, take many shots. Hence, the team tempo factor is constructed so that its impact is allocated according to minutes played, not shot attempts. This value is then added to the player's per-minute production, hence weighting this production by the tempo the team plays.

A similar adjustment is made with respect to team defense. Each of the team defensive factors[24] is currently not allocated to the individual players. Given that the rules of the NBA require that teams play only a man-to-man defense, each opposing player must be defended by a specific individual. Therefore, it is theoretically possible to assign each shot an opposing player takes to a specific player. Hence, the opponent's made and missed shots could be utilized to calculate the player's individual production.

Currently, though, shots are not recorded in this fashion systematically. Given this deficiency, all that can be determined is the team's relative defensive strength, as measured by the team defensive factor. As with team tempo, the team defensive factor is added to the player's per-minute production.

Step Three: Calculating the Player's Relative Value

Having established the team's per-minute tempo, per-minute team turnover, and per-minute team defensive factor, the calculation of the player's production of wins can proceed. As mentioned, the player's per-minute production is weighted according to each of these team factors by adding each to the player's individual production. With this calculation complete, each of the factors listed in Table 5 have been blended into the calculation. However, two more adjustments must be made.

As noted in Berri and Brook (1999), an examination of the marginal values reveals an inherent bias. Rebounds, a substantial positive factor, are generally accumulated by centers and power forwards. Player turnovers, a substantial negative factor, are generally committed by guards. Hence the per-minute production of centers and power forwards are inflated relative to guards. Given that the structure of basketball implies that point guards and centers are complementary factors of production, as opposed to substitutes, teams generally employ each of these factors at any time. Hence, each player's production needs to be evaluated relative to the position the player plays.[25] Therefore, after each player's per-minute production is adjusted for the team factors listed earlier, the average production at each position is subtracted.

Before wins can be calculated, one final adjustment needs to be made. If one were to sum each player's production after it was adjusted by the mean at each position, the total number of wins in the NBA produced by the players would be zero. To allocate all of the wins to the players, one final calculation must be made. In each regular season, 1189 games are won. Dividing this number by the total number of minutes played in the league produces the average per-minute production of wins in the league. This number is then added to the per-minute production of wins, to determine each player's regular season production of wins.[26]

With each of the steps in the calculation of a player's production of wins laid forth, the actual calculation can be summarized. Such a summary is offered with Equation (10):

$$\text{Production of wins} = [\text{PM} + \text{TF} + \text{TDF} - \text{PA} + \text{TA}] \times \text{Total minutes played}, \quad (10)$$

where PM = per-minute player production, TF = per-minute team tempo factor, TDF = per-minute team defensive factor, PA = average per-minute production at position[27] and TA = average player's per-minute production.

WHO IS 'MOST VALUABLE'?

Michael Jordan Versus Karl Malone

After all of these additions and subtractions, it is now possible to answer the question posed at the outset of this paper. Which player is most valuable to his team, Michael Jordan or Karl Malone? Before such a question can be answered, one must first define what is meant by 'most valuable'. The definition employed in this discussion connects value to production. Most valuable is not defined as 'most popular', 'most talented', or 'most prolific scorer'. Rather, most valuable is simply defined as the player whose production is estimated to represent the most wins.[28] Table 6 lists the relevant ingredients needed to measure the regular season production of wins for both Michael Jordan and Karl Malone.

From Table 6[29] it can be seen that in the 1997–1998 regular season Jordan played 3181 min for the Bulls, and per-minute produced an estimated 0.0052 wins. On average, Jordan produced approximately one win for Chicago every 193.4 min he played. The Utah Jazz employed Karl Malone for 3030 min in 1997–1998, during which Malone produced approximately 0.0062 wins per-minute. Given this result, it is estimated that Malone produced one win for Utah every 160.9 min he was on the court. Overall, Malone produced an estimated 18.8 wins for Utah while Jordan provided the Bulls with approximately 16.4 regular season victories. Hence, by the methods presented, Karl Malone's regular season productivity eclipsed Michael Jordan.

Success, however, is not measured in professional sports solely by an athlete's regular season performance. The true measure of greatness is how a player performs in the post-season. Recall that the team and individual post-season honors for the 1997–1998 season went to the Chicago Bulls and Michael Jordan, not the Jazz and Malone. Was this because Jordan's performance surpassed Malone when the games were the most significant? To answer such a question objectively and accurately, the same methods are again applied to analyze each player's performance the NBA post-season. Table 7 lists the relevant ingredients necessary to estimate the number of wins each player produced in the 1998 playoffs.

The post-season value of each player is summarized in each player's per-minute wins and total win production. Although Jordan had only a slight edge in per-minute productivity to Malone (0.00442 versus 0.00437), Jordan is credited with 0.38 additional post-season victories primarily due to the additional 77 min Jordan played. Hence, between these two players, Jordan was the most productive in the post-season.

Does this result imply Jordan was the most productive when the games mattered the most? To further explore this issue, the performance of each player in the 1998 NBA Finals was examined, the results of which are detailed in Table 8. From this table it can be seen that when the games truly mattered the most, Malone was both the better per-minute and aggregate performer. Why then did the Bulls win the 1998 championship? In addition to Jordan's above average per-minute performance[30], the Bulls also received above average performances from three of the other six players who averaged at least 12 min a game in the Finals. In contrast, of the players the Jazz most frequently employed in the NBA Finals, only one player in addition to Malone was able to offer an above average per-minute performance. Hence, despite Malone's ability to produce more than Jordan, the Jazz as a team were unable to overcome the Bulls.

Table 6. Calculating Regular Season Wins for Jordan and Malone

Factor	Michael Jordan	Karl Malone
Per-minute production	0.0081	0.0126
Per-minute team tempo	(0.0089)	(0.0084)
Per-minute team defense	(0.0001)	(0.0002)
Per-minute position average	(0.0040)	(0.0002)
Per-minute player average	0.0021	0.0021
Per-minute wins	0.0052	0.0062
Minutes	3181	3030
Wins	16.44	18.83

Table 7. Calculating Wins Post-season for Jordan and Malone

Factor	Michael Jordan	Karl Malone
Per-minute production	0.0078	0.0100
Per-minute team tempo	(0.0084)	(0.0080)
Per-minute team defense	(0.0003)	0.0002
Per-minute position average	(0.0032)	(0.0001)
Per-minute player average	0.0021	0.0021
Per-minute wins	0.0044	0.0044
Minutes	872	795
Wins	3.86	3.48

Table 8. Calculating Wins in the Finals for Jordan and Malone

Factor	Michael Jordan	Karl Malone
Per-minute production	0.0067	0.0100
Per-minute team tempo	(0.0081)	(0.0076)
Per-minute team defense	(0.0001)	(0.0000)
Per-minute position average	(0.0036)	(0.0003)
Per-minute player average	0.0020	0.0020
Per-minute wins	0.0041	0.0048
Minutes	250	243
Wins	1.03	1.16

The Most Valuable Player

From the proceeding discussion one might conclude that Malone was the most valuable performer during the regular season and Finals, hence confirming the IBM result. However, the proceeding analysis was limited to the examination of only two players. When one analyses all players in the NBA for the 1997–1998 regular season, another name emerges as the most productive player. Table 9 lists the ten most productive players for the 1997–1998 regular season.[31] The player who emerges as the most productive player during both the 1997–1998 regular season is the infamous Dennis Rodman. Karl Malone produced an estimated two wins fewer than Rodman during the regular season, while Jordan produced more than four fewer estimated regular season victories.

Why is Rodman estimated to be more productive than either Jordan or Malone? The primary reason lies in the type of production Rodman offers his team. Rodman is predominantly known for his prolific rebounding ability, and led the NBA in this statistical category seven consecutive seasons beginning with the 1991–1992 campaign. In essence, Rodman's rebounding prowess is a significantly positive factor. An analysis of Chicago's allocation of minutes during the 1997–1998 season reveals that Rodman likely split his time on the court between the position of center and the position of power forward. In this season, the average power forward garnered 0.233 rebounds per minute, while the average center gathered 0.263 rebounds per minute. Had Rodman been as productive as the average player at these positions, he would have averaged 8.8 rebounds per game, rather than the 15.0 rebounds he did gather per contest. According to the presented methods, the difference of 6.2 rebounds per game was worth an estimated 18.4 regular season wins to the Chicago Bulls. Although the measure offered in this discourse examines every aspect of a player's statistical production, one can see that Rodman's rebounding alone is the primary reason he was so valuable to Chicago.[32]

Table 9. Top Ten Regular Season Wins Producers

Player	Team	Minutes	Wins Rank	Wins per minute	Wins	IBM rank	IBM
Dennis Rodman	Bulls	2856	1	0.0073	20.79	6	88.31
Karl Malone	Jazz	3030	2	0.0062	18.83	1	99.69
Jayson Williams	Nets	2343	3	0.0080	18.79	20	75.82
David Robinson	Spurs	2457	4	0.0071	17.50	3	96.66
Tim Duncan	Spurs	3204	5	0.0054	17.45	2	98.70
Michael Jordan	Bulls	3181	6	0.0052	16.44	8	85.58
Charles Barkley	Rockets	2243	7	0.0072	16.22	17	77.77
Gary Payton	Super Sonics	3145	8	0.0050	15.75	9	84.50
Charles Outlaw	Magic	2953	9	0.0052	15.37	15	80.29
Jason Kidd	Suns	3118	10	0.0048	14.88	13	81.38

And noted in Table 10, for the entire post-season, the player members of the media have frequently named the 'greatest player ever' emerged as the most productive. Michael Jordan produced an estimated 3.86 wins in the 1998 post-season to lead all post-season performers. However, his final total is only 0.1 wins more than teammate Scottie Pippen and only 0.2 victories greater than Rodman. Clearly, Jordan's performance alone did not carry the Bulls to their sixth championship in the 1990s. In fact, on a per-minute basis both Pippen and Rodman eclipsed the production offered by Jordan.

The Accuracy of the Presented Method

The idea that Dennis Rodman offers production that either surpasses or is nearly equivalent to the illustrious Michael Jordan rests entirely upon the validity of the model and methods presented in this investigation. Does the method utilized to evaluate the players result in an accurate depiction of the player's contribution? In an effort to answer this question, the estimated wins of each player was summed across each team. This summation was then compared to the actual wins each team registered in both the 1997–1998 regular season and the playoffs. The results are reported in Table 11.

The results appear to indicate that the methodology paints an accurate depiction of each player's production. Of the 29 teams listed, the difference between the summed player wins and the actual team wins is less than one for nine organizations. For only four teams is the difference in excess of five victories and not one team registered an error of ten wins. The average error, in absolute terms, was 2.6 wins. Such evidence would suggest the evaluations of Jordan, Malone, and Rodman are accurate estimations.

CONCLUSION: THE APPLICATION OF THE RESEARCH

How productive is each NBA player? The methods presented in this discourse take the given NBA data and provide an accurate answer to this question. As noted, if the NBA tabulated a wider range of statistics, this accuracy could be improved. Nevertheless, the picture painted by the presented methods does provide a fair evaluation of each player's contribution to his team's relative success or failure. Such evaluations can obviously be utilized with respect to free agent signings, player-for-player trades, the allocation of minutes, and also to determine the impact changes in coaching methods or strategy have had on an individual's productivity.

With respect to the academic literature the methods reported here are also likely to be useful. Previous methods cited appear to have used the incorrect functional form, an incorrect set of data, and failed to account for the importance of team tempo. The correction of each of these shortcomings has led to an accurate appraisal of playing talent that can be utilized in the study of such issues as racial discrimination and worker remuneration under the auspices of differing institutional arrangements.

Table 10. Top Ten Post-season Wins Producers

Player	Team	Minutes	Wins rank	Wins per minute	Wins	IBM rank	IBM
Michael Jordan	Bulls	872	1	0.0044	3.86	8	92.90
Scottie Pippen	Bulls	836	2	0.0045	3.76	11	88.65
Dennis Rodman	Bulls	722	3	0.0051	3.65	27	72.28
Karl Malone	Jazz	795	4	0.0044	3.48	1	111.40
John Stockton	Jazz	596	5	0.0052	3.08	13	85.99
Shaquille O'Neal	Lakers	501	6	0.0056	2.80	7	98.30
David Robinson	Spurs	353	7	0.0075	2.63	3	107.35
Mark Jackson	Pacers	494	8	0.0052	2.55	12	87.04
Hersey Hawkins	Super Sonics	337	9	0.0067	2.25	21	75.69
Byron Russell	Jazz	698	10	0.0031	2.20	31	71.10

Table 11. Testing the Accuracy of the Method

Team	Total wins[a]	Summation of total player wins	Difference
Atlanta	51	51.7	(0.7)
Boston	36	30.8	5.2
Charlotte	55	50.1	4.9
Chicago	77	72.3	4.7
Cleveland	48	47.4	0.6
Dallas	20	21.8	(1.8)
Denver	11	13.1	(2.1)
Detroit	37	44.4	(7.4)
Golden State	19	18.2	0.8
Houston	43	38.6	4.4
Indiana	68	67.1	0.9
LA Clippers	17	18.8	(1.8)
LA Lakers	68	67.9	0.1
Miami	57	56.3	0.7
Milwaukee	36	36.7	(0.7)
Minnesota	47	45.5	1.5
New Jersey	43	45.9	(2.9)
New York	47	49.6	(2.6)
Orlando	41	37.4	3.6
Philadelphia	31	36.3	(5.3)
Phoenix	57	54.9	2.1
Portland	47	45.2	1.8
Sacramento	27	28.0	(1.0)
San Antonio	60	59.0	1.0
Seattle	65	60.6	4.4
Toronto	16	19.2	(3.2)
Utah	75	75.0	(0.0)
Vancouver	19	26.4	(7.4)
Washington	42	41.5	0.5

[a] Total wins = Regular season wins + Post-season wins.

Does this analysis answer all the questions one might have regarding a player's production? Although this analysis does offer a fair evaluation of *how* productive a player is, it does not tell us *why* a player achieves such productivity. The answer to this question likely begins with the player's innate ability, but also includes such factors as experience, coaching, and team chemistry. Separating each of these influences is clearly a subject for future research. Certainly the answer to the question of why each player achieves his respective productivity begins with the question of how productive the player has been. To a large extent, the answer to this latter inquiry has been answered by the research presented in this exposition.

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NOTES

1. For a review of the literature examining this issue prior to 1990s see Kahn (1991). More recent studies of racial discrimination were conducted by Jenkins (1996) and Bodvarsson and Brastow (1999), among others.
2. For studies examining this issue in professional baseball see Scully (1974), Medoff (1976), Blass (1992) and Zimbalist (1992a,b) among others. With respect to professional basketball the issue of worker compensation under free agency has been examined by Scott, Long and Sompii (SLS, Scott *et al.*, 1985).
3. The sources of the player and team statistics utilized in this study was the *Official NBA Guide* (Carter and Sachare, 1995; Broussard and Carter, 1996, 1997, 1998).
4. Although these 'computer models' have not been typically employed in academic studies, the Points Created method was utilized by Jenkins (1996) in a recent examination of salary discrimination in professional basketball.
5. To test whether or not each factor does have an equal impact on wins, the following model was

estimated under the assumption of equal coefficients and with the coefficients unconstrained.

PCT = f(PTS, FGA, RBO, RBD, AST, STL, BLK, PF, TO).

An F test was then performed to test whether or not these estimated coefficients are indeed equal. The result of this test was that the null hypothesis (equal coefficients) was rejected. Results are available from the author upon request.

6. The quasi-R^2 label is suggested by Studenmund (1992), although the estimation of this factor without the corresponding label is also detailed in Gujarati (1995).
7. The following discussion comes from both Green (1992) and Gujarati (1995). As Gujarati notes, a similar test is offered by Bera and Jarque (1982).
8. Is an economist qualified to construct a theory of basketball? Certainly my limited skills upon the basketball court indicate a lack of credentials. However, countless hours of watching and discussing the sport does allow one to develop some insights into the nature of the game. It is from this experience that I offer my observations. To the extent this experience is inadequate, the following observations will suffer. I do not think, though, that the sport of basketball is the intellectual equivalent of 'rocket science' or even the mundane subject of economics. In other words, even a casual observer should be able to offer relevant insights.
9. The model utilized here is similar to that which was employed in Berri and Brook (1999). The basic differences are as follows: (1) The model presented here incorporates explicit measures of the opponent's scoring and ball handling. The Berri–Brook model ignored these factors, an omission that suggests the previous model was misspecified. (2) The Berri–Brook model failed to account for the team specific fixed effects, a failing corrected herein. (3) The issue of functional form is also more completely addressed in this exposition via the MWD test, an issue not fully explored by Berri and Brook. (4) The model presented here accounts for both regular and post-season performance, whereas the previously cited model only focused on the regular season. (5) The accuracy of the reported methods is examined in greater detail. Despite these improvements, much of the discussion regarding the utilization of a two-equation system and the measurement and employment of team tempo follows from the earlier work.
10. A panel data set is utilized in this study, with the cross-sectional units consisting of the 29 current NBA teams. As noted by Hylan *et al.* (1999) in their study of professional baseball, not controlling for individual specific fixed effects can bias the estimates of the coefficients for the independent variables. To account for this potential bias, the models presented herein employ team specific fixed effects, rather than the more traditional common constant term utilized generally in the academic literature (see the previously cited Zak *et al.*, 1979; Scott *et al.*, 1985; Hofler and Payne, 1997; as well as Chatterjee *et al.*, 1994; for examples in the literature that did not account for team specific fixed effects).
11. Equation (4) was estimated with a Cobb–Douglas production form. The quasi-R^2 for the double-logged model was 0.92, indicating that the linear formulation is the more appropriate form. The MWD test offers additional evidence in support for this finding. The t-statistic for Z_2 is 4.83, indicating that the appropriate model is not a Cobb–Douglas, but rather a linear form. However, the t-statistic for Z_1 is 1.79, indicating that at the 8% level of significance one cannot reject the hypothesis that the true model should be a double-logged functional form. Although this latter result casts some doubt on the utilization of the linear form, the other reported results appear to indicate the appropriateness of the linear equation.
12. One could question whether it is appropriate to aggregate data over four distinct seasons. Although researchers analysing sports economics data frequently ignore this issue (with respect to baseball and basketball see the previously cited Scully, 1974; Medoff, 1976; Scott *et al.*, 1985; Blass, 1992; Zimbalist, 1992a,b; Berri and Brook, 1999), a Chow test (Chow and Gregory, 1960) was conducted to see if breaks exist in the aggregate four-season data set. The results of this inquiry indicate that the aggregated data set utilized in Equation (4) is appropriate. Results are available from the author upon request.
13. FTA is included to capture the ability of a player to draw a personal foul from his opponent. This factor was also omitted from the previously cited work of Berri and Brook.
14. With the exception of Berri and Brook (1999).
15. The model presented is slightly more efficient than the structural, three-equation model. A single equation would offer further efficiency gains. However it is necessary to estimate two equations if both the positive and negative impact free throw attempts have on team wins is to be accurately measured.
16. The Chow test, referenced earlier with respect to Equation (4), was also conducted for the reduced form equation derived from the model reported in Equations (5) and (6). This test indicated that aggregating data across these 4 years was appropriate. Results are available from the author upon request.
17. This system of equations was also estimated utilizing the Cobb–Douglas functional form. The quasi-R^2 for each Equation (5) and (6) was 0.936 and 0.986, respectively. For the reduced form equation, the quasi-R^2 was 0.917. The reduced form R^2 for the linear formulation is 0.943. From Tables 3 and 4 it can be seen that these results are each less than the R^2 reported for the linear estimation of Equations (5) and (6), although the difference is quite small with respect to the latter equation. The results with respect to the MWD test also point to the superiority of the linear equation. The

t-statistics for Z_2 for the double-logged formulation of Equations (5) and (6) was 7.05 and 2.53, indicating the linear formulation is more appropriate. The t-statistics for Z_1 in Equation (5) was 1.07, indicating that one would only accept the Cobb–Douglas form at the 28% significance level. The results for Equation (6) were even more convincing with a t-statistic of 0.57, or a p-value of 0.568. The results with respect to both the quasi-R^2 and the MWD test all indicate that the linear formulation, rather than the widely utilized Cobb–Douglas form, is the most appropriate functional form for both Equations (5) and (6).

18. By taking the derivative of wins with respect to the numerator of PPS, one can determine the value of a point from a field goal attempt. The derivative of wins with respect to the denominator of PPS yields the value of a field goal attempt. The impact of a made three-point field goal is then ascertained by multiplying the value of a point from a field goal attempt by three, and then adjusting this total by the value of a field goal attempt. The value of a two-point field goal made is determined in a similar fashion, while the value of a missed field goal is simply the value of a field goal attempt. Except for the independent impact of a player's ability to draw a foul, as measured by the inclusion of free throw attempts, the value of a free throw made and missed is determined in a similar fashion. The derivative of PCT with respect to both free throws made and attempted was calculated. Then the value of a free throw made is the respective derivative, plus the dual impact of a free throw attempt via FT and FTA. The value of a missed free throw is simply the dual value of a free throw attempt.
19. As mentioned, PCT is determined by dividing wins by the number of games played. Given that the independent variables are per-game totals, and hence are simply team totals divided by games played, the marginal impact each factor has on PCT can also be interpreted as the marginal impact an additional statistic has on wins. For example, from Table 4, a team that increases its per-game offensive rebound total by one will increase PCT by 5.1%. Because both sides of the equations are divided by games played, one could also say that an additional offensive rebound leads to an additional 0.051 wins. The number of wins each factor produces will be important when the player's production of wins is calculated.
20. Blocked shots were not a statistically significant determinant of wins or DPTS. Given that the opponent's missed shots are implicitly included in the model, it is not surprising that blocked shots offered no additional explanatory gains.
21. Certainly a number of blocked shots are unnecessary, since an opponent misses a certain percentage of their shots regardless of the defense a team plays. It is difficult, though, to determine how many of the blocked shots were likely to miss without the assistance of the shot blocker. Given that many blocked shots occur closer to the basket, it is likely that a higher percentage of these shots would have been successful than the opponent's overall PPS would indicate. Given this difficulty, the value of each blocked shot is set equal to the impact of the opponent's missed shot, even though it is acknowledged that this practice overstates the value of a blocked shot for those shot attempts that were likely to be unsuccessful.
22. Such an approach follows from the work of Scott *et al.* (1985).
23. As noted, the accumulation of the opponent's turnovers and the opponent's missed shots does not include the player's production of steals and blocked shots, respectively. Furthermore, because a certain number of turnovers a team accumulates are assigned only to the team, not any individual players, this factor is also added to the list of defensive factors examined in Equation (9).
24. An astute reader may note that the value of an opponent's statistic is substantially less than the value of the corresponding team statistic. For example, the value of a missed field goal made is -0.025 for the team but only 0.013 for the opponent. This difference in value comes about because of the substantial role team tempo plays in determining the opponent's scoring. The value of the opponent's statistic is ascertained given the tempo the team has chosen to play. As noted in the text, it is this choice of tempo that is a primary determinant of the opponent's scoring.
25. To determine the positions of each player, the following sources were consulted: *The Pro Basketball Bible* (Barry and Cohn, 1994, 1995, 1996), *The Complete Handbook of Pro Basketball* (Hollander, 1995, 1996, 1997; Hollander and Compton, 1998); and *The Official NBA Register* (Puro *et al*., 1995; Bonavita *et al*., 1996, 1997, 1998). After determining the position each player likely played most of his minutes, the minutes of each team were examined in an effort to ascertain precisely how much time each player played at each position. In these calculations it was assumed that a team always utilized a point guard, shooting guard, small forward, power forward, and center. Therefore the minutes played at each position for the team must be equal.
26. A similar calculation is necessary to determine a player's win production in the post-season.
27. The average positional values are calculated after each player's production is adjusted according to the listed team factor. The average per-minute production at the center position, for example, is determined by summing each center's adjusted production, and dividing by the summation of the centers' minutes played. If a player played more than one position, then as mentioned, his minutes were examined to estimate how much time was spent at each position. His production was then evaluated at each of the positions he played.
28. One could define most valuable as the player who produces the most wins per-minute, and certainly in terms of efficiency such an argument appears

valid. However, by defining most valuable in terms of total wins one not only captures prolific per-minute performance but also the durability of the player. If one considers that a player cannot contribute to his team if he is not able to play, such a definition appears justified.

29. From Table 6, as well as Tables 7 and 8, one can see the impact per-minute team tempo and per-minute team defense have on a player's per-minute productivity. For the most part the elements that comprise the per-minute team defense measure cancel each other out. In contrast, the team per-minute tempo measure appears to play a substantial role in determining a player's per-minute productivity. However, if one considers the difference between the maximum and minimum per-minute team tempo measure for the 1997–1998 regular season is only 0.0009, one can conclude that this factor does not substantially alter the relative measure of a player's value.
30. Average per-minute performance is 0.0021. An average team will assign 240 player minutes each game and these players will produce a combined 0.5 wins per contest. The average per-minute performance is then simply 0.5/240.
31. For the sake of comparison, the player's IBM evaluation and ranking is also listed.
32. One does not necessarily need a detailed statistical analysis to see evidence of Rodman's value. A simple review of recent history also provides additional clues to Rodman's impact. In 1992–1993, the Chicago Bulls won 57 regular season contests and their third consecutive championship. The following year, with Michael Jordan retired, the Bulls were victorious 55 times during the regular season but failed to win a title. In 1994–1995, without the services of power forward Horace Grant, and except for the final 17 games of the regular season Michael Jordan, the Bulls managed only 47 regular season wins and again, no championship. The next season, 1995–1996, the Bulls had the services of Michael Jordan for the entire campaign. Chicago also added power forward-center Dennis Rodman. With the addition of Rodman the Bulls set the record for regular season wins at 72 games and once again won the NBA championship. Clearly the dramatic improvement the Bulls achieved with the addition of Rodman is further evidence of his value.

REFERENCES

Barry R, Cohn J. 1994. *Rick Barry's Pro Basketball Bible: 1994–95 Edition*. Basketball Books Ltd: Marina Del Rey, CA.

Barry R, Cohn J. 1995. *Rick Barry's Pro Basketball Bible: 1995–96 Edition*. Basketball Books Ltd: Marina Del Rey, CA.

Barry R, Cohn J. 1996. *Rick Barry's Pro Basketball Bible: 1996–97 Edition*. Basketball Books Ltd: Marina Del Rey, CA.

Bellotti R. 1993. *The Points Created Basketball Book, 1992–93*. Night Work Publishing Co: New Brunswick.

Bera AK, Jarque CM. 1982. Model specification tests: a simultaneous approach. *Journal of Econometrics* **20**: 59–82.

Berri DJ, Brook SL. 1999. Trading Players in the NBA: For Better or Worse. In *Sports Economics: Current Research*, Fizel JL, Gustafson E, Hadley L (eds). Praeger Publishing: Westport, CT; 135–151.

Blass AA. 1992. Does the baseball labor market contradict the human capital model of investment? *The Review of Economics and Statistics* **74**: 261–268.

Bodvarsson O, Brastow. R. 1999. A test of employer discrimination in the NBA. *Contemporary Economic Policy* **17**: 243–255.

Bonavita M, Broussard M, Stewart S (eds). 1996. *The Sporting News: Official NBA Register (1996–97)*. The Sporting News Publishing Company: Saint Louis, MO.

Bonavita M, Broussard M, Stewart S (eds). 1997. *The Sporting News: Official NBA Register (1997–98)*. The Sporting News Publishing Company: Saint Louis, MO.

Bonavita M, Broussard M, Roberts B (eds). 1998. *The Sporting News: Official NBA Register (1998–99)*. The Sporting News Publishing Company: Saint Louis, MO.

Broussard M, Carter C (eds). 1996. *The Sporting News: Official NBA Guide (1996–97)*. The Sporting News Publishing Company: Saint Louis, MO.

Broussard M, Carter C (eds). 1997. *The Sporting News: Official NBA Guide (1997–98)*. The Sporting News Publishing Company: Saint Louis, MO.

Broussard M, Carter C (eds). 1998. *The Sporting News: Official NBA Guide (1998–99)*. The Sporting News Publishing Company: Saint Louis, MO.

Carter C, Sachare A (eds). 1995. *The Sporting News: Official NBA Guide (1994–95)*. The Sporting News Publishing Company: Saint Louis, MO.

Chatterjee S, Campbell MR, Wiseman. F. 1994. Take that jam! An analysis of winning percentage for NBA teams. *Managerial and Decision Economics* **15**: 521–535.

Chow GC. 1960. Test of equality between sets of coefficients in two linear regressions. *Econometrica* **28**: 591–605.

Green WH. 1992. *ET: The Econometrics Toolkit Version 3*. Econometric Software: Bellport, NY; 245–246.

Gujarati DN. 1995. *Basic Econometrics*. McGraw Hill, Inc: New York.

Heeren D. 1992. *Basketball Abstract, 1991–92 Edition*. Prentice Hall, Inc: Englewood Cliffs, NJ.

Hofler RA, Payne. JE. 1997. Measuring efficiency in the National Basketball Association. *Economic Letters* **55**: 293–299.

Hollander Z (ed.). 1995. *The Complete Handbook of Pro Basketball '1995'*. Signet Books: New York.

Hollander Z (ed.). 1996. *The Complete Handbook of Pro Basketball '1996'*. Signet Books: New York.

Hollander Z (ed.). 1997. *The Complete Handbook of Pro Basketball '1997'*. Signet Books: New York.

Hollander Z, Compton E (eds). 1998. *The Complete Handbook of Pro Basketball '1998'*. Signet Books: New York.

Hylan TR, Lage MJ, Treglia. M. 1999. Did collusion adversely affect outcomes in the baseball player's labor market?: a panel study of salary determination from 1986 to 1992. In *Sports Economics: Current Research*, Fizel JL, Gustafson E, Hadley L (eds). Praeger Publishing: Westport, CT; 175–218.

Jenkins JA. 1996. A reexamination of salary discrimination in professional basketball. *Social Science Quarterly* **77**: 594–608.

Kahn LM. 1991. Discrimination in professional sports: a survey of the literature. *Industrial Labor Relations Review* **44**: 395–418.

Mackinnon J, White H, Davidson R. 1983. Tests for model specification in the presence of alternative hypothesis: some further results. *Journal of Econometrics* **21**: 53–70.

McCormick RE, Clement. RC. 1992. Intrafirm profit opportunities and managerial slack: evidence from professional basketball. In *Advances in the Economics of Sports*, Scully GW (ed.). JAI Press Inc: Greenwich, CN.

Medoff MH. 1976. On monopsonistic exploitation in professional baseball. *Quarterly Review of Economics and Business* **16**: 113–121.

NBA.com Website. 1998. Karl Malone wins IBM award, http://www.nba.com/news_feat/00692159.html [7 May 1998].

Neyer R. 1995. Who are the 'True' Shooters? In *STATS Pro Basketball Handbook, 1995–96*. STATS Publishing: New York; 322–323.

Puro G, Sachare A, Veltrop K (eds). 1995. *The Sporting News: Official NBA Register (1995–96)*. The Sporting News Publishing Company: Saint Louis, MO.

Scully GW. 1974. Pay and performance in major league baseball. *American Economic Review* **64**: 917–930.

Scott F Jr, Long J, Sompii K. 1985. Salary vs. marginal revenue product under monopsony and competition: the case of professional basketball. *Atlantic Economic Journal* **13**: 50–59.

Studenmund AH. 1992. *Using Econometrics: A Practical Guide*. Harper Collins Publishers: New York.

Zak TA, Huang CJ, Siegfried JJ. 1979. Production efficiency: the case of professional basketball. *Journal of Business* **52**: 379–393.

Zimbalist A. 1992a. Salaries and performance: beyond the Scully model. In *Diamonds are Forever: The Business of Baseball*, Sommers P (ed.). The Brookings Institution: Washington DC; 109–133.

Zimbalist A. 1992b. *Baseball and Billions*. Basic Books: New York.

