



Basketball IV

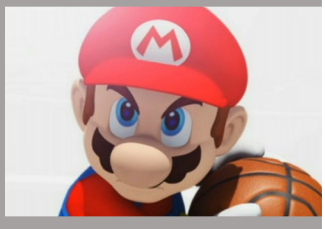


Produced by Dr. Mario
UNC STOR 390





NBA Salaries



- Recall Baseball Salary Estimation
 - Based on Value Over Replacement Player (VORP)
 - Defined Replacement Player as Bottom 20%
 - Assumed Replacement Player Costs \$0
 - Team of Replacement Players Cost \$0 (44-118 Record)
 - Average Team's Salary was \$77M (81-81 Record)
 - \$77M Needed for Replacement Team to Get to Average
- Application to NBA Salaries (Based off 2006-2007)
 - Average Team Payroll Was Approximately \$66M
 - Minimum Player Salary \$400,000
 - Define Replacement Player as Bottom 10% in WINVAL
 - WINVAL of Replacement Player = -6
 - Team of Replacement Players Lose to Average Team by 30 Points
 - Average Team Scores 98.7 Points Per Game



NBA Salaries

- NBA Salary Information Across the Years

- Data from Basketball-Reference.com
- Data Preview

```
head(salary)
```

```
A tibble: 6 x 7
```

league	player_id	salary	season	season_end	season_start	team
<chr>	<chr>	<int>	<chr>	<int>	<int>	<chr>
NBA	abdelal01	395000	1990-91	1991	1990	Portland Trail Bl~
NBA	abdelal01	494000	1991-92	1992	1991	Portland Trail Bl~
NBA	abdelal01	500000	1992-93	1993	1992	Boston Celtics
NBA	abdelal01	805000	1993-94	1994	1993	Boston Celtics
NBA	abdelal01	650000	1994-95	1995	1994	Sacramento Kings
NBA	abdulka01	1530000	1984-85	1985	1984	Los Angeles Lakers

- Salary Summarized by Season

```
head(salary.Data)
```

```
A tibble: 6 x 4
```

season_start	n	mean.salary	sd.salary
<int>	<int>	<dbl>	<dbl>
1984	24	3.49	1.62
1985	23	4.76	1.41
1986	16	1.36	1.26
1987	23	6.05	1.26
1988	25	6.78	1.45
1989	24	4.46	2.13





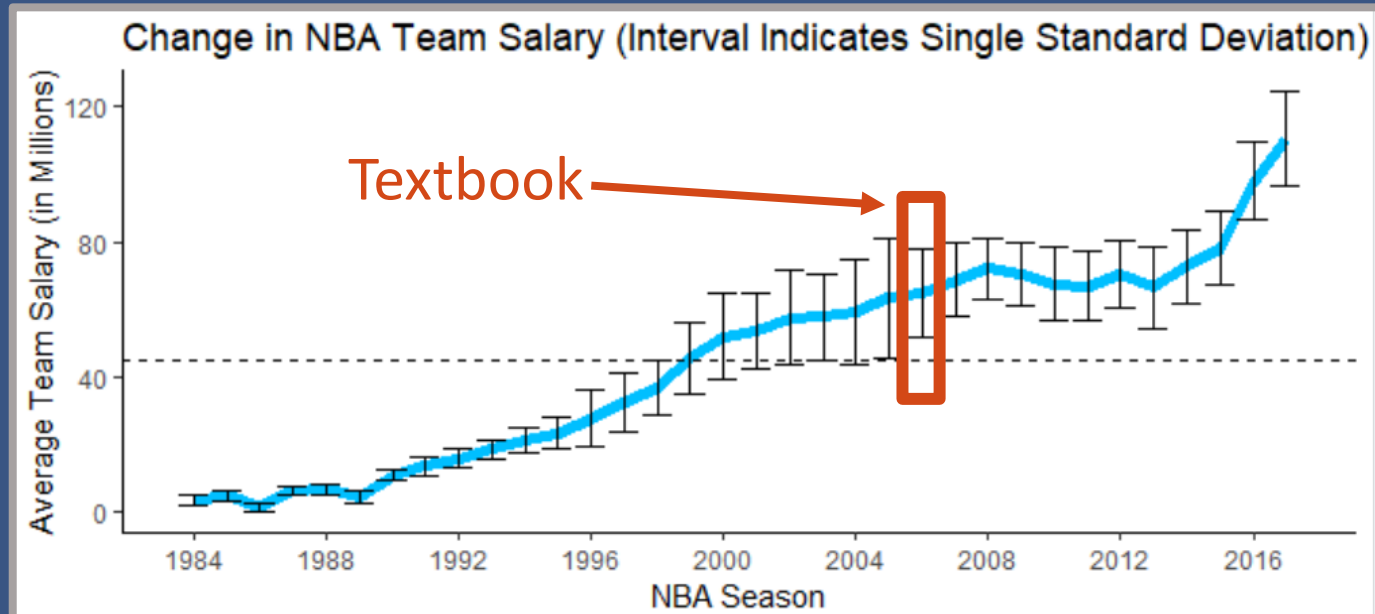
NBA Salaries

- NBA Salary Information Across the Years

- Code for Summary Table

```
Salary.Data=Salary %>%  
  group_by(team,season_start) %>%  
  summarize(total.salary=sum(salary)/1000000) %>%  
  ungroup() %>%  
  group_by(season_start) %>%  
  summarize(n=n(),mean.salary=mean(total.salary),  
            sd.salary=sd(total.salary))
```

- Figure Showing Change





NBA Salaries

- Pythagorean Theorem For Basketball
 - Modeling Win Percentage Using Points

$$Win \% \approx \frac{\left(\frac{Points\ Scored}{Points\ Allowed} \right)^\alpha}{\left(\frac{Points\ Scored}{Points\ Allowed} \right)^\alpha + 1}$$

- From Textbook, $\alpha=13.91$ Based on Data Before 2007
- Question: Has This Result Stayed Consistent?
- Data from 2014 to 2018 Found on Kaggle

```
head(Games[,2:9])
```

```
A tibble: 6 x 8
```

Team	Game	Date	Home	Opponent	WINorLOSS	TeamPoints	OpponentPoints
<chr>	<int>	<date>	<chr>	<chr>	<chr>	<int>	<int>
ATL	1	2014-10-29	Away	TOR	L	102	109
ATL	2	2014-11-01	Home	IND	W	102	92
ATL	3	2014-11-05	Away	SAS	L	92	94
ATL	4	2014-11-07	Away	CHO	L	119	122
ATL	5	2014-11-08	Home	NYK	W	103	96
ATL	6	2014-11-10	Away	NYK	W	91	85





NBA Salaries

- Pythagorean Theorem For Basketball
 - Modifying Data for Estimating α

```
Games2 = Games %>%  
  mutate(Season=rep(c(2014,2015,2016,2017),each=82*30)) %>%  
  group_by(Team,Season) %>%  
  summarize(win.Per=mean(WINorLOSS=="w"),  
            Scored=mean(TeamPoints),  
            Allowed=mean(OpponentPoints))
```

```
head(Games2)
```

```
A tibble: 6 x 5
```

```
Groups:   Team [2]
```

Team	Season	win.Per	Scored	Allowed
<chr>	<dbl>	<dbl>	<dbl>	<dbl>
ATL	2014	0.732	103.	97.1
ATL	2015	0.585	103.	99.2
ATL	2016	0.524	103.	104.
ATL	2017	0.293	103.	109.
BOS	2014	0.488	101.	101.
BOS	2015	0.585	106.	103.





NBA Salaries

- Pythagorean Theorem For Basketball
 - Minimize Sum of Squares (Predicted Win % Versus Actual Win %)

```
pythag.func=function(data,par){  
  R=data$Scored/data$Allowed  
  y=data$Win.Per  
  resid=y-(R^(par[1]))/(R^(par[1])+1)  
  return(sum(resid^2))  
}
```

```
result=optim(par=c(13),fn=pythag.func,data=Games2,method="BFGS")
```

- Based on Recent Data, Best α is 14.4564

```
print(result$par[1])  
.] 14.4564
```





NBA Salaries

- Application of Pythagorean Theorem to Replacement Players
 - Losing 30 Points to Average Team Means Final Score 68.7 to 98.7
 - Winning Percentage for Team of Replacement Players

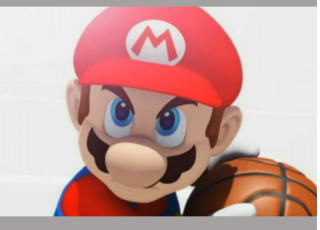
$$Win \% \approx \frac{\left(\frac{68.7}{98.7}\right)^{14.4564}}{\left(\frac{68.7}{98.7}\right)^{14.4564} + 1} = 0.005282$$

```
alpha=result$par[1]  
R=68.7/98.7  
ReplWinPer=(R^(alpha))/(R^(alpha)+1)
```

- Expected Number of Wins for Team of Replacement Players

$$Wins = (Win \%) \times (82 \text{ Games}) \approx 0.433$$

- Team of Replacement Players Would Win 0 Games
- Team of Average Players Would Win 41 Games



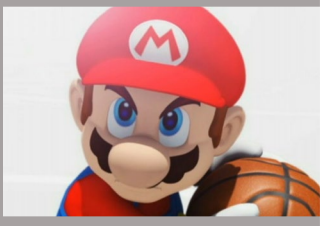


NBA Salaries

- Cost of Winning (Based on Book)
 - Cost \$2M to Get 0 Wins Over 82 Games
 - \$2M is \$64M Less Than the Average Salary (2006-2007)
 - Assumption: Costs \$64M to Be Average
 - This Implies:

$$\text{Price Per Win} = \frac{\$64M}{41} = \$1,560,976$$

- Criticism 1
 - Average Salary may not be the Salary of an Average Team
 - Recommendation: Regress Salary on Wins and Predict When Wins = 41
- Criticism 2
 - Team Salaries are Highly Skewed and Influenced by Outliers
 - Recommendation: Use Median

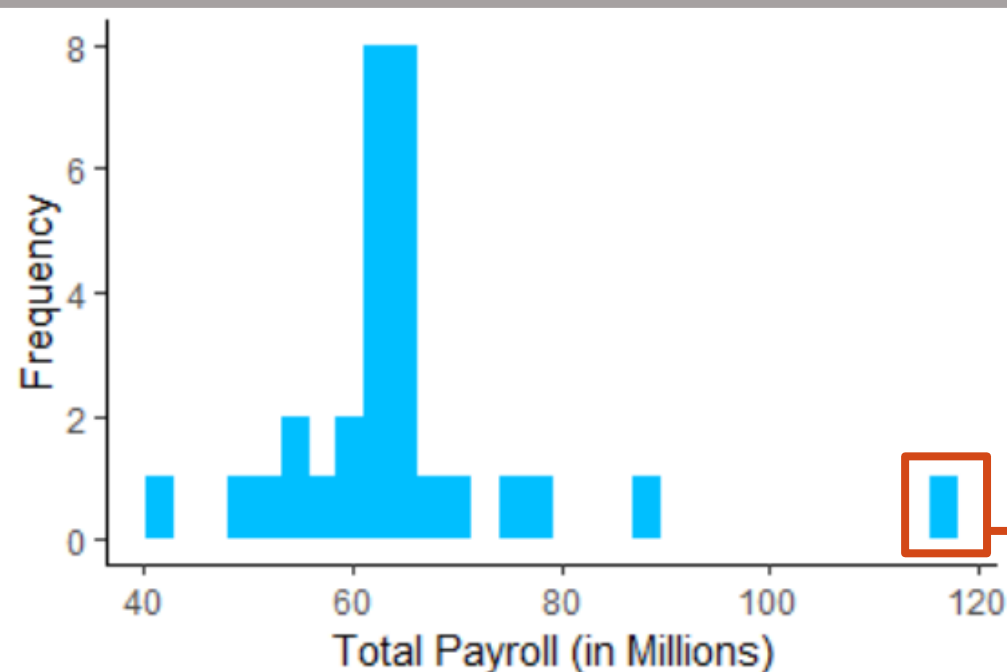
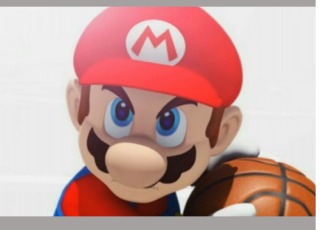




NBA Salaries

- Visual of Team Payrolls

```
salary06 = salary %>%  
  filter(season_start==2006) %>%  
  group_by(team) %>%  
  summarize(total.salary=sum(salary)/1000000) %>%  
  arrange(desc(total.salary))
```



```
head(salary06)
```

A tibble: 6 x 2

team	total.salary
<chr>	<dbl>
New York Knicks	117.
Dallas Mavericks	88.4
Los Angeles Lakers	77.1
Portland Trail Blazers	75.0
Philadelphia 76ers	69.1
Minnesota Timberwolves	66.8

Team: New York Knicks
Payroll: \$117M
Record: 33-49
Conclusion: Idiots



NBA Salaries

- Getting Wins and Losses Into Data

- Scraping Team Records From Wikipedia

```
wikipedia="https://en.wikipedia.org/wiki/2006%E2%80%9307_NBA_season"
wins = wikipedia %>%
  read_html() %>%
  html_table(fill=T)

wins2=as.data.frame(rbind(as.matrix(wins[[4]]),as.matrix(wins[[5]]),
                          as.matrix(wins[[6]]),as.matrix(wins[[7]]),
                          as.matrix(wins[[8]]),as.matrix(wins[[9]]))[,1:2])
names(wins2)=c("team","wins")
str_detect(wins2$team,".-")
wins3=mutate(wins2,team=str_replace(team,".-",""))
```

```
head(wins3)
      team wins
Toronto Raptors    47
New Jersey Nets    41
Philadelphia 76ers  35
New York Knicks    33
Boston Celtics     24
Detroit Pistons    53
```

- Merging Datasets

```
salarywins06=inner_join(salary06,wins3)
salarywins06$wins=as.numeric(as.character(salarywins06$wins))
```

```
head(salarywins06)
A tibble: 6 x 3
  team                total.salary wins
  <chr>                <dbl>   <dbl>
1 New York Knicks     117.     33
2 Dallas Mavericks    88.4     67
3 Los Angeles Lakers  77.1     42
4 Portland Trail Blazers 75.0     32
5 Philadelphia 76ers   69.1     35
6 Minnesota Timberwolves 66.8     32
```





NBA Salaries

- Fix Based on Criticism 1
 - Linear Regression Model and Fit

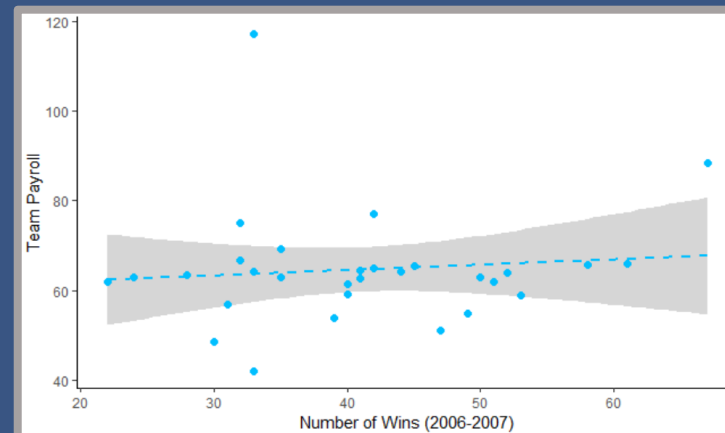
```
call:
lm(formula = total.salary ~ wins, data = salarywins06)
```

Residuals:

Min	1Q	Median	3Q	Max
-21.690	-4.943	-0.927	0.420	53.597

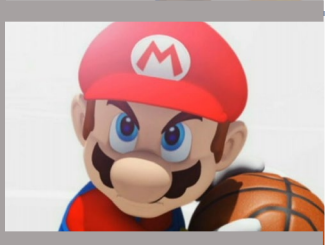
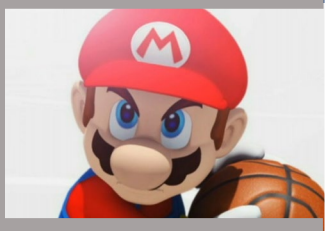
Coefficients:

	Estimate	Std. Error	t value	Pr(> t)
(Intercept)	59.7207	9.6061	6.217	0.00000102 ***
wins	0.1192	0.2268	0.526	0.603



- Prediction Under Linear Model is \$64M for 41 Win Team
- Assumption: Costs \$62M to Be Average
- This Implies:

$$\text{Price Per Win} = \frac{\$62M}{41} = \$1,512,195$$





NBA Salaries

- Fix Based on Criticism 2

- Median is Robust Against Outliers (NY Knicks)
- Motivation: We Don't Want One Stupid Team to Get Us to Overpay
- Assumption: Costs \$61M to Be Average

```
median(salarywins06$total.salary)  
[1] 63.25874
```

- This Implies:

$$\text{Price Per Win} = \frac{\$61M}{41} = \$1,487,805$$

- Points Over Replacement Player (PORP)

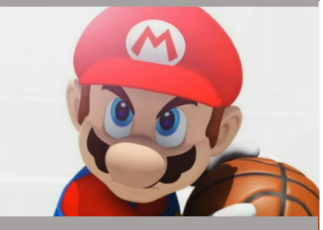
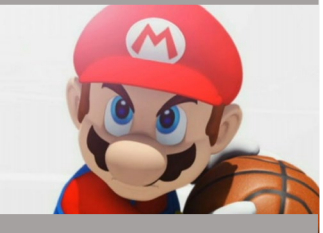
$$PORP = (\text{Adjusted } +/ -) - (-6) = (\text{Adjusted } +/ -) + 6$$



Individual Player



Replacement Player





NBA Salaries

- PORP for Average Team
 - For Average Player, PORP = $0+6 = +6$ Points Per 48 Minutes
 - In a Season, There are 3,936 Minutes
 - For Team 5 Players, This Equates to 19,680 Minutes
 - For Team of 5 Average Players,

$$PORP \times Minutes = 6 \times 19,680 = 118,080$$

- Scaled to Number of Wins

$$\frac{118,080}{41} = 2,880 \text{ Per Win}$$





NBA Salaries

- Determining Fair Salary Based on PORP

- Wins Generated by a Player (W)

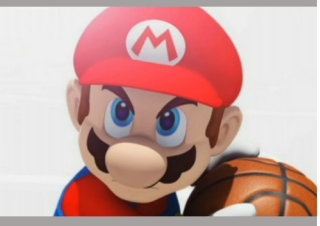
$$W = \frac{PORP \times Minutes Played}{2,880}$$

- Fair Salary (SAL)

$$SAL = W \times Dollars Per Win$$

- We Found 3 Different Choices for Dollars Per Win

- \$1,560,976
- \$1,512,195
- \$1,487,805





NBA Salaries

- **Example: King James in 2006-2007**
 - Played 3,190 Minutes and Had an Adjusted +/- of 14.412 Per 48 Minutes
 - Therefore LeBron James Had a PORP of 20.412
 - Wins Generated by LeBron James

$$W = \frac{20.412 \times 3,190}{2,880} = 22.6$$

- **Fair Salary for LeBron James**

Method	Wins	Price Per Win	Fair Salary
Book	22.6 Wins	\$1,560,976	\$35.3M
Regression	22.6 Wins	\$1,512,195	\$34.2M
Median	22.6 Wins	\$1,487,805	\$33.6M





Final Inspiration

There is no “I” in team,
but there is in win.

- Michael Jordan