Basketball IV

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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

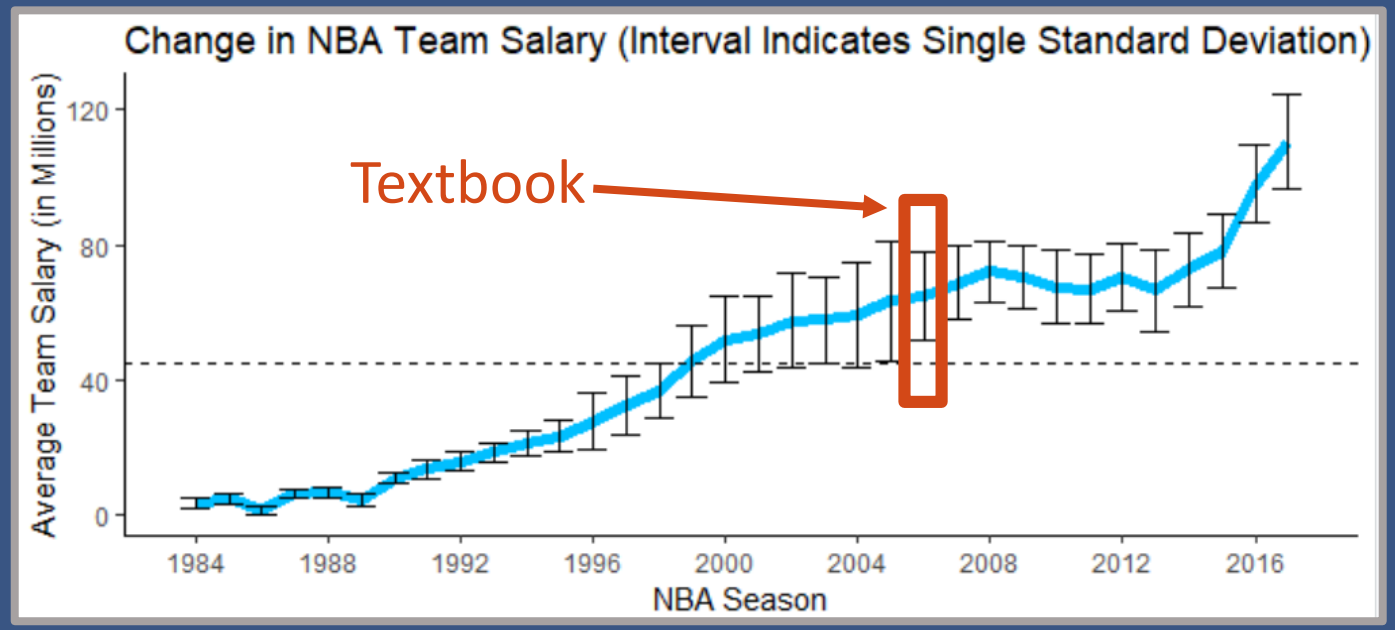
```
head(Salary.Data)
A tibble: 6 x 4
season_start     n mean.salary sd.salary
       <int> <int>       <dbl>     <dbl>
        1984    24        3.49      1.62
        1985    23        4.76      1.41
        1986    16        1.36      1.26
        1987    23        6.05      1.26
        1988    25        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, α=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

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

  - 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:

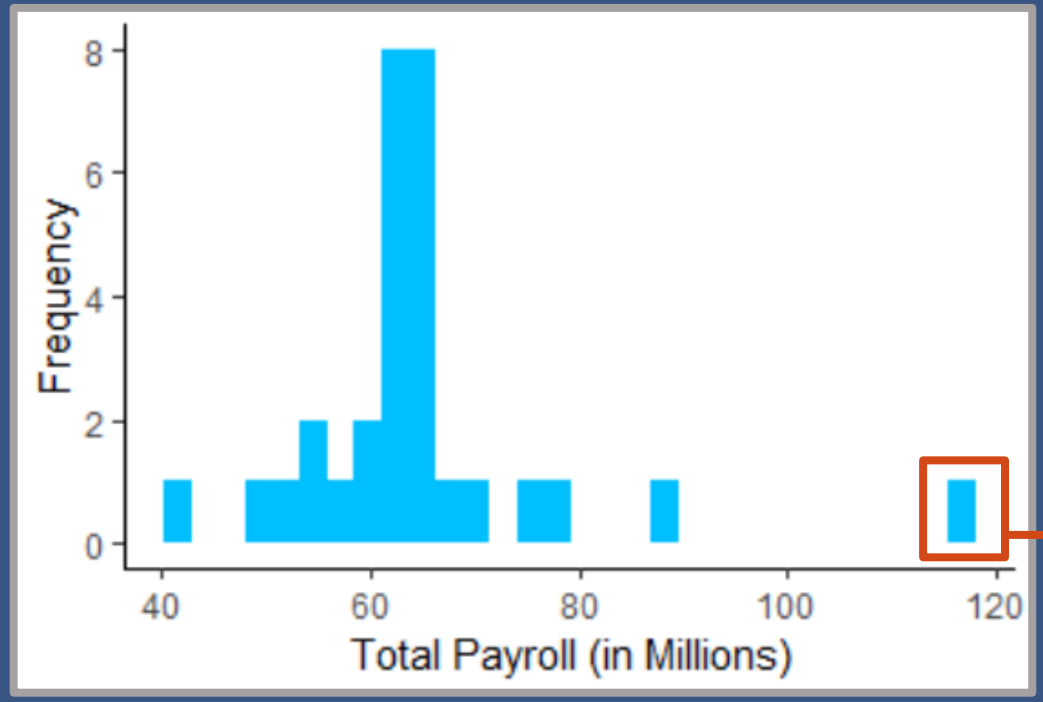
$$Price\ Per\ Win = \frac{\$64M}{41} = \$1{,}560{,}976$$

- **Criticism 1**
  - Average Salary is not 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>
New York Knicks                117.     33
Dallas Mavericks                88.4    67
Los Angeles Lakers              77.1    42
Portland Trail Blazers          75.0    32
Philadelphia 76ers              69.1    35
Minnesota Timberwolves          66.8    32
```

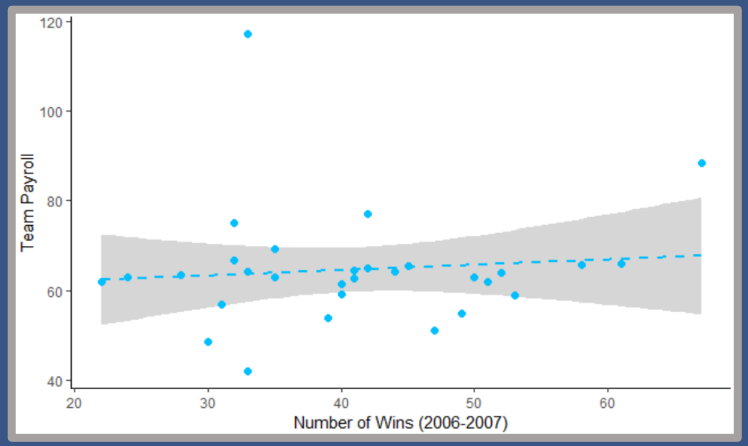
NBA Salaries

- 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:

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




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:

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

- Points Over Replacement Player (PORP)

$$PORP = (Adjusted\ +/-) - (-6) = (Adjusted\ +/-) + 6$$

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 Games

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

  - Indicates the Following Conversion

$$2{,}880\ PORP \times Minutes\ Played = 1\ Win$$

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