



Basketball IV

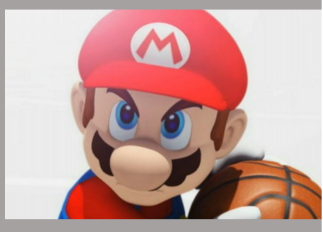
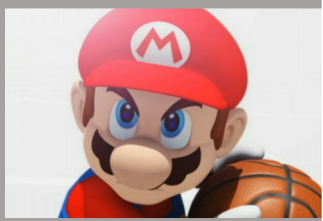


Produced by Dr. Mario
UNC STOR 538





NBA Salaries



- Recall Baseball Salary Estimation

- Based on WAR in Baseball
- Assumed Replacement Player Costs \$500,000
- Team of Replacement Players Cost \$12.5M (48-114 Record)
- Average Team's Salary was \$114M (81-81 Record)
- \$101.5M Needed for Replacement Team to Get to Average

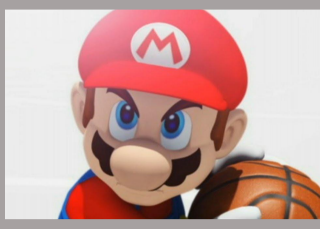
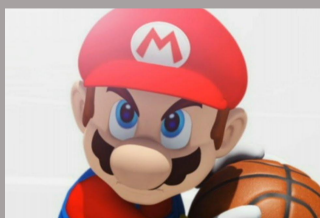
- Real Plus-Minus (RPM)

- Designed by Jermias Engelmann and Steve Ilardi
- Utilized Modified Ridge Regression to Shrink Coefficients Toward the Box Plus-Minus of the Player
- Leaders in 2018-2019

RANK	NAME	TEAM	GP	MPG	ORPM	DRPM	RPM
1	Paul George, SG	OKC	77	36.9	4.55	3.08	7.63
2	James Harden, SG	HOU	78	36.8	7.4	0.02	7.42
3	Stephen Curry, PG	GS	69	33.8	5.99	0.85	6.84
4	Giannis Antetokounmpo, PF	MIL	72	32.8	3.16	3.53	6.69



NBA Salaries



- **Interpretation of RPM**

- Numbers are Per 100 Possessions
- **Giannis RPM = 6.69**
- **If Giannis Replaced an Average Player, then his Team Improves by 6.69 Points Over the Average Opponent Per 100 Possessions**
- **RPM of an Average Player = 0**
- **RPM of a Replacement Player = -3.1 (Equivalent to 10 Percentile)**

- **Team of Replacement Players**

- **Deficit Versus an Average Team**

$$5(-3.1) = -15.5 \text{ Points Per 100 Possessions}$$

- **Average Pace in 2017-2018 = 96 Possessions Per Game**
- **Conversion of Deficit Per 100 Possessions to Per Game**

$$\left(-\frac{15.5}{100}\right) * 96 = -14.88 \text{ Points Per Game}$$



NBA Salaries

- **Replacement Team Versus Average Team**

- Average Team Scored 105.6 Points Per Game
- Expected Final Score: 90.72 to 105.6 (Difference of 14.88)
- Scoring Ratio

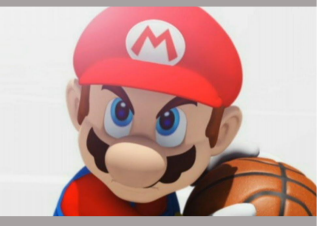
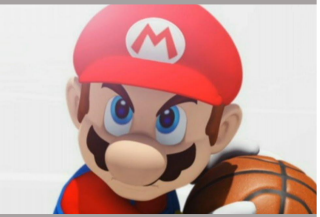
$$\frac{90.72}{105.6} = 0.86$$

- **Basketball Pythagorean Theorem From Chapter 1 ($\alpha = 14$)**

$$\frac{0.86^{14}}{0.86^{14} + 1} = 10.7\%$$

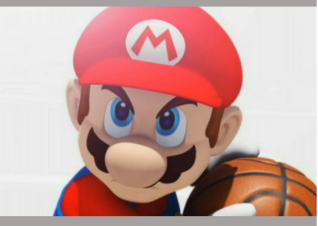
- **Conclusion: Expect Replacement Team to Win 10.7% of Games**

Final Record = 8.7 Wins and 73.3 Losses





NBA Salaries



- Application to NBA Salaries (Based off 2017-2018)
 - Average Team Payroll Was Approximately \$93M
 - Minimum Player Salary Between \$500K and \$1.5M
 - Assume Average Minimum = \$1M
 - Payroll of Replacement Team = \$12M
 - Costs \$93M - \$12M = \$81M to Go From Replacement to Average
 - This is Equivalent to Go From 9 Wins to 41 Wins
 - Equivalent:
$$32 \text{ Wins} = \$81M$$
 - For Simplicity/Laziness, $32 \text{ Wins} = \$80M$
 - Each Win Above Replacement is Worth \$2.5 Million



NBA Salaries

- Calculation of Fair Salary

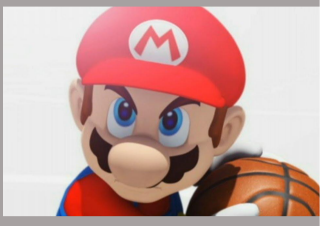
- Suppose Player Generated 20 Wins in 2016-2017

$$\text{Fair Salary} = 20 * 2.5 = \$50M$$

- Descriptive Versus Predictive Metrics

- Book Calculates Fair Salary of a Player in 2018 Based off Generated Wins From Previous Season

- What is the Problem Here?



	Player Wins 2016	Player Wins 2017
Team Salaries 2016	Was Pay Fair in 2016?	Helpful or Not Helpful?
Team Salaries 2017	Fair Salary Next Year	Was Pay Fair in 2017?



NBA Salaries

- NBA Salary Information Across the Years

- Data from Basketball-Reference.com
- Data Preview

```
head(salary)
```

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

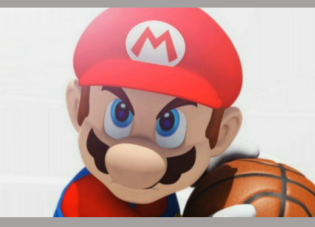
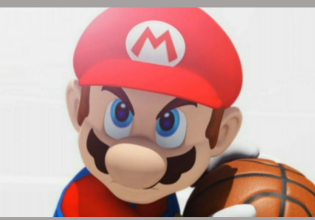
league	player_id	salary	season	season_end	season_start	team
<chr>	<chr>	<int>	<chr>	<int>	<int>	<chr>
NBA	abdelal01	395000	1990-91	1991	1990	Portland Trail Bl~
NBA	abdelal01	494000	1991-92	1992	1991	Portland Trail Bl~
NBA	abdelal01	500000	1992-93	1993	1992	Boston Celtics
NBA	abdelal01	805000	1993-94	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





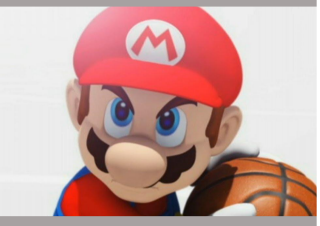
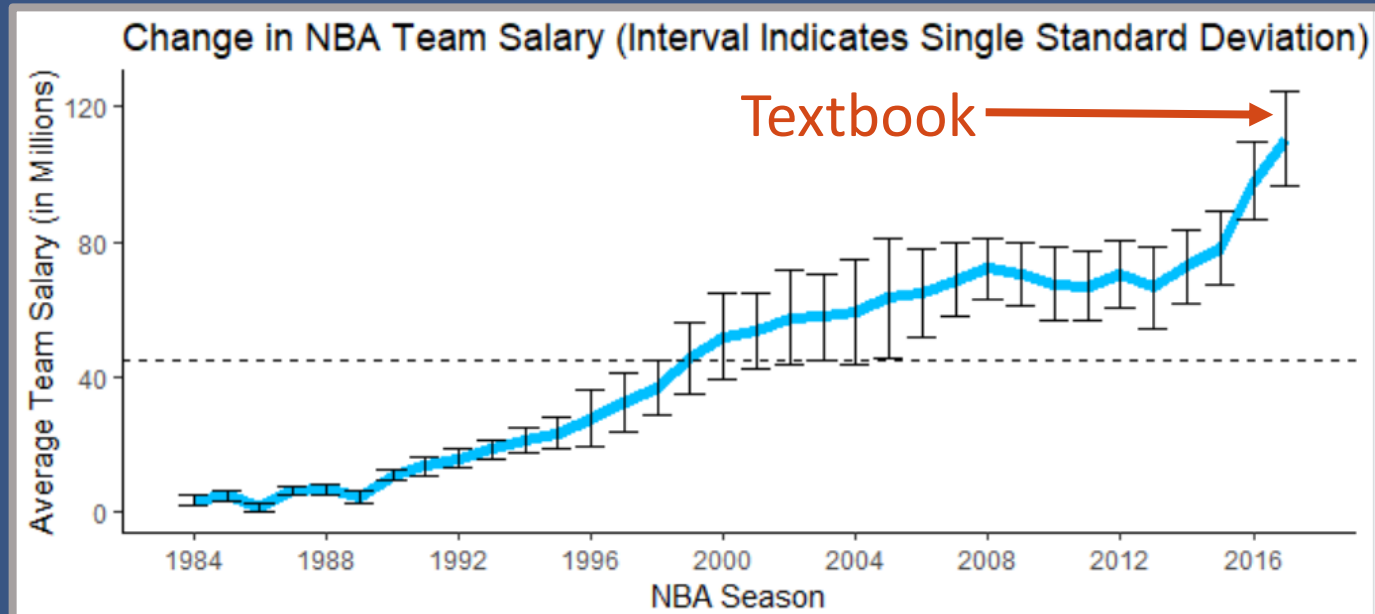
NBA Salaries

- 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

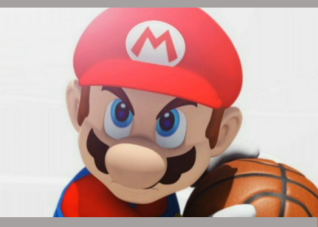
$$Win \% \approx \frac{\left(\frac{Points\ Scored}{Points\ Allowed} \right)^\alpha}{\left(\frac{Points\ Scored}{Points\ Allowed} \right)^\alpha + 1}$$

- From Textbook, $\alpha=14$ Based on Data
- Question: Can We Confirm This?
- 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

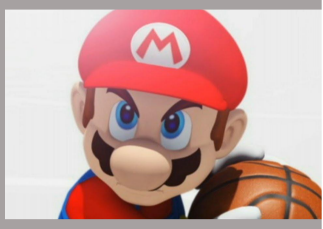
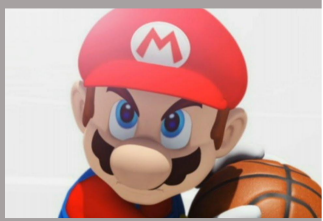
```
Games2 = Games %>%  
  mutate(Season=rep(c(2014,2015,2016,2017),each=82*30)) %>%  
  group_by(Team,Season) %>%  
  summarize(Win.Per=mean(WINorLOSS=="W"),  
            Scored=mean(TeamPoints),  
            Allowed=mean(OpponentPoints))
```

```
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

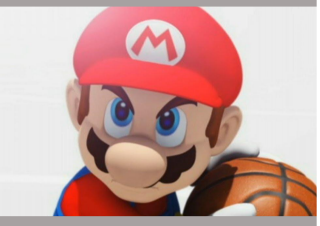
- Pythagorean Theorem For Basketball
 - Minimize Sum of Squares (Predicted Win % Versus Actual Win %)

```
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
```



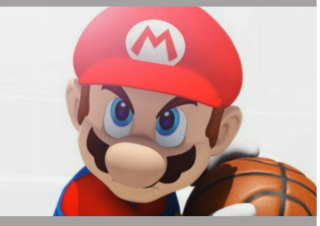


NBA Salaries

- Cost of Winning (Based on Book)
 - Cost \$12M to Get 9 Wins Over 82 Games
 - \$12M is \$81M Less Than the Average Salary (2017-2018)
 - Assumption: Costs \$81M to Be Average
 - This Implies:

$$\text{Price Per Win} = \frac{\$81M}{41 - 9} = \$2.5M$$

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

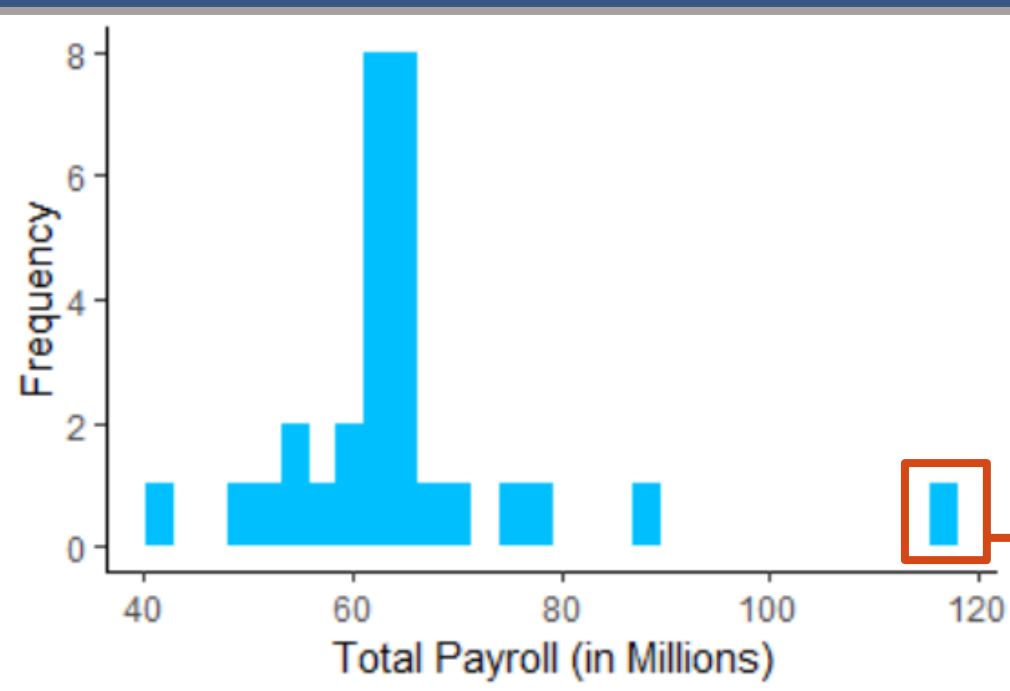
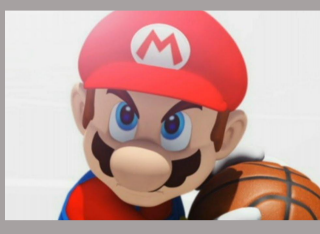
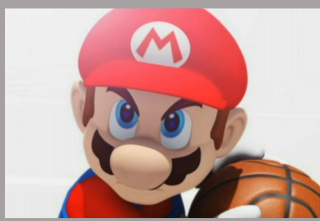




NBA Salaries

- Observe Interesting Data From 2006

```
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

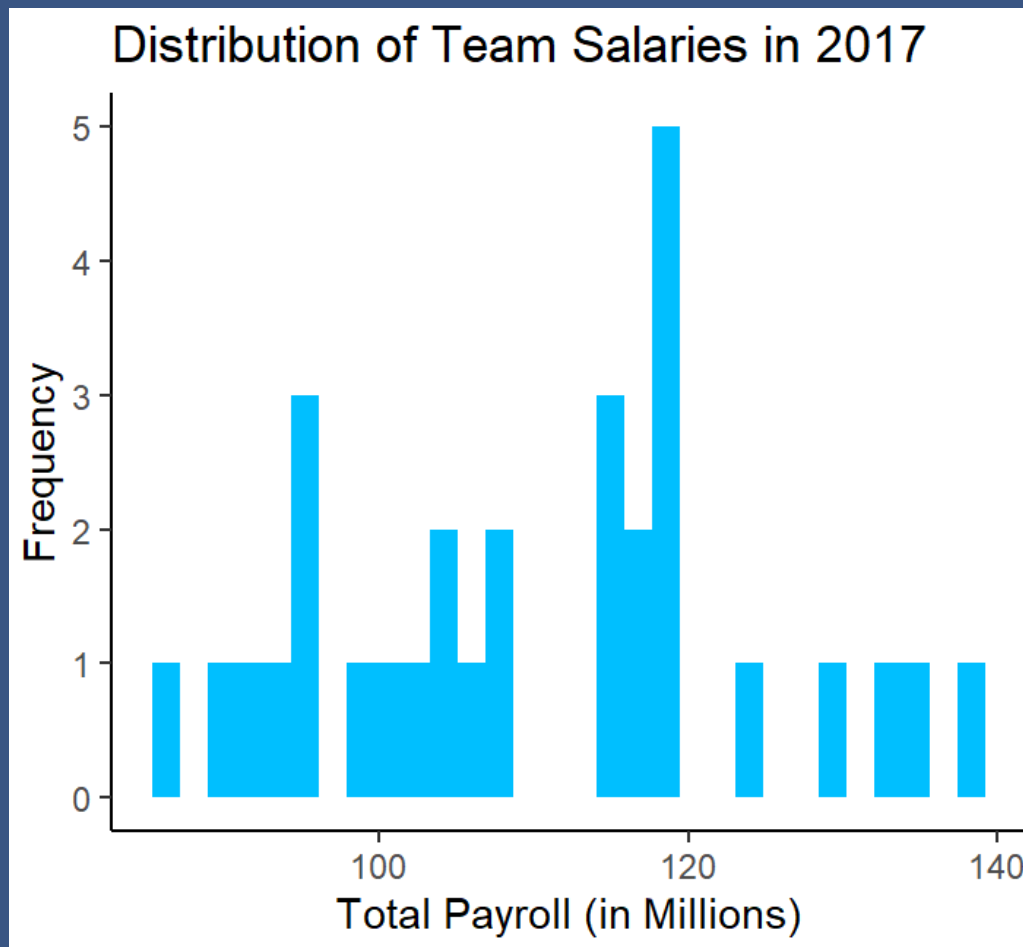
team	total.salary
<chr>	<dbl>
New York Knicks	117.
Dallas Mavericks	88.4
Los Angeles Lakers	77.1
Portland Trail Blazers	75.0
Philadelphia 76ers	69.1
Minnesota Timberwolves	66.8

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



NBA Salaries

- Fix Based on Criticism 1

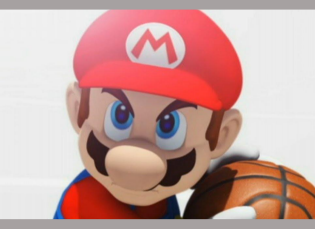


2017-2018 Season

Average Salary: \$110M

Fix

Median Salary: \$111M





NBA Salaries

- Getting Wins and Losses Into Data

- Scraping Team Records From Wikipedia

```
wikipedia="https://en.wikipedia.org/wiki/2017%E2%80%9318_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,"..\\p{Pd}..")
wins3=mutate(wins2,team=str_replace(team,"..\\p{Pd}..",""))
```

```
head(wins3)
```

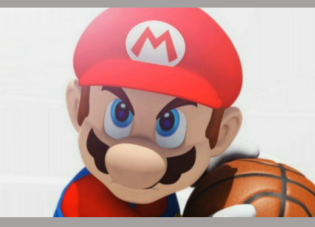
team	wins
Toronto Raptors	59
Boston Celtics	55
Philadelphia 76ers	52
New York Knicks	29
Brooklyn Nets	28
Cleveland Cavaliers	50

- Merging Datasets

```
salarywins17=inner_join(salary17,wins3)
# Joining, by = "team"
salarywins17$wins=as.numeric(as.character(salarywins17$wins))
head(salarywins17)
```

A tibble: 6 × 3

team	total.salary	wins
<chr>	<dbl>	<dbl>
Cleveland Cavaliers	138.	50
Golden State Warriors	135.	58
Oklahoma City Thunder	134.	48
Miami Heat	129.	44
Washington Wizards	124.	43
Portland Trail Blazers	119.	49





NBA Salaries

- Fix Based on Criticism 2
 - Linear Regression Model and Fit

```
lm(formula = total.salary ~ wins, data = salarywins17)
```

Residuals:

Min	1Q	Median	3Q	Max
-21.930	-7.004	-1.433	9.382	20.911

Coefficients:

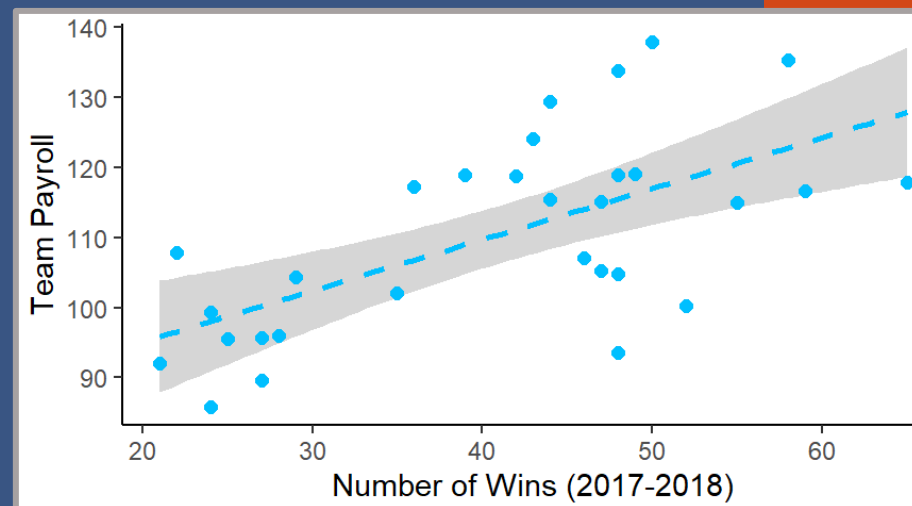
	Estimate	Std. Error	t value	Pr(> t)
(Intercept)	80.5493	7.1444	11.274	0.000000000000639 ***
wins	0.7281	0.1672	4.354	0.000161 ***

```
predict(linearwts,newdata=data.frame(wins=41),interval="confidence")
```

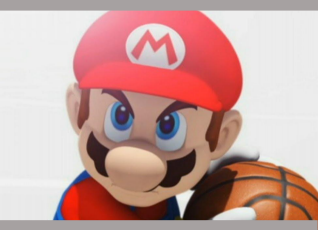
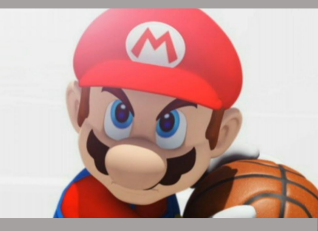
fit	lwr	upr
110.4022	106.2861	114.5183

```
predict(linearwts,newdata=data.frame(wins=41),interval="prediction")
```

fit	lwr	upr
110.4022	87.48456	133.3198



- Prediction for 41 Wins is Almost Identical to Actual Average Salary
- What is the Value of Knowing the Lower and Upper Limits?





Final Inspiration

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

- Michael Jordan