

March Madness Analysis

Biased Estimators: Alexander Van Rijen, Molly Clark, Rocco Bavuso

May 14, 2018

March Madness is an annual NCAA Division I Basketball tournament. The tournament occurs in the month of March, thereby earning its name. There are 64 teams in the tournament each year, seeded into four regions that each contain 16 teams. This report will look at how far each team makes it into the tournament, based on their regular season data and prior tournament success.

Introduction

In this report we work with data that was obtained from kaggle.com. We were interested to see what factors most affect a team's success in the March Madness tournament, so we compare teams to each other for every year that we have data. In doing so, we narrow down our predictors to find the best model of a team's success in the tournament for each year.

We were motivated to look into this data in part because the tournament is so hard to predict from year to year. We wondered what statistics and data from a team's season and history could be used to estimate how far the team would make it in the tournament. It is not uncommon for there to be many upsets over the course of the tournament, which can throw off any model, so we had to consider this uncertainty when choosing the best model.

Data Summary

From Kaggle's website, we downloaded a data set that gave us a look at all Division I teams who did or did not qualify for the March Madness tournament in the past 30 or so years. Each team is assigned a four digit code that is consistent from season to season and data set to data set. This allows us to manipulate and analyze the data across the different files.

We had data that was collected during the regular season and data that was collected during the tournament, but in the long run choose to focus our model on regular season data so as to be able to predict the current season's tournament success if need be.

For the years 1985 to 2003, we have data in regards to the wins and losses of each involved team. For the years 2003 to 2016, we have more in depth data that includes each team's statistics from each game all season and throughout the tournament.

We began by looking at the data that has been collected season to season and follow up by looking at the data from previous tournaments and regional and past seed data to see which factors effect a team's chances of winning games in the tournament.

Because this tournament occurs each year, and because our data spans many years, we also saw it fitting to analyze how well teams had performed in the past when trying to predict their success in the future. The expectations and reputation of a team surely have an impact on how well they perform during the season and tournament, so temporal data about past success was essential to our model.

Throughout this report, let the following be universally true:

Field Goals: defined as any shot that is made in the game and is worth 2 points (within the 3 point line, not a free throw)

Three Pointers: defined as any shot that is made in the game and is worth 3 points (outside the 3 point line, from any place)

Free Throws: defined as any shot that is made in the game and is worth 1 point (shot after being fouled in any form, from the free throw line)

Assist: defined as a pass to another player who then immediately scores

Rebound: defined as a play in which a player grabs the ball, which bounced off of either the rim or backboard on an attempted shot. For this paper, we include offensive and defensive rebounds

Turnovers: defined as any action that results in the loss of basketball. (an action that gives the basketball to the other team not including a failed shot attempt)

Steals: defined as a defensive play in which a player steals the basketball from an opposing player

Block: defined as a defensive play in which a player deflects an opposing shot attempt before it reaches the basket

Personal Fouls: defined as an action that results in either a loss of possession or free throws for the other team

Pre-Analysis

We began by looking at our data from a lens that based winning teams against losing teams. This was based on who won and lost each game of each season, so it is important to note that it is likely that teams would fall into both categories on occasion. We hoped to find what factors and variables in a season could predict a team's overall success in the tournament and moving forward.

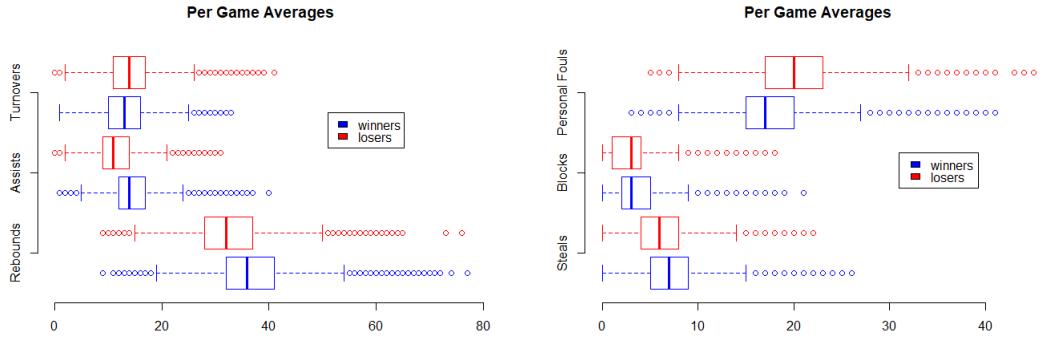
We already had easy access to data that was parsed based on which team had won and which team had lost, so this seemed like a logical first step. We chose to keep regular season data apart from tournament data because the game play is so different in the tournament. In general, it is expected that the involved teams are among the best in the country, and the games have much higher stakes, so statistics may look different.

Regular Season Data

In working with the regular season data, we first looked at some larger scale averages, comparing winning teams to losing teams on a very basic level.

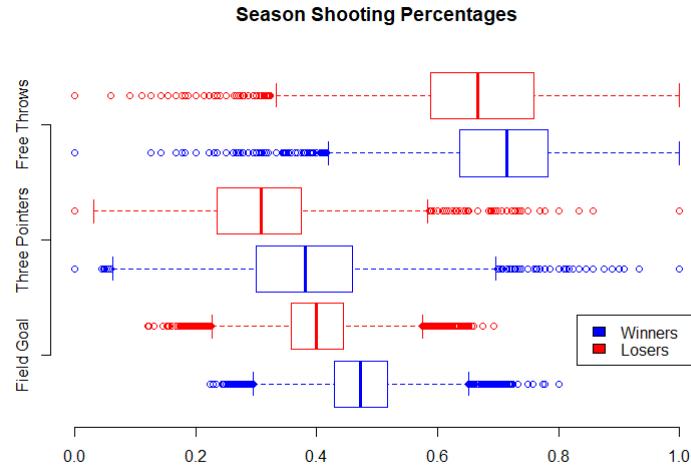
We compared the average statistics of winning teams to the average statistics of losing teams and found what many would expect: on average, winning teams perform better in areas that are considered "good"

statistics, whereas losing teams have higher rates of "bad" statistics.



The above figures show the distribution of the winning and losing teams' averages throughout the years. They illustrate the above point that winning teams have higher averages in more beneficial statistics such as Rebounds, Assists, and Steals. This is a trend that we take note of when moving forward.

We then looked at winning and losing teams' average shooting percentages for the regular season. We were hoping to find which shots hold the most weight in the game. For example, three point shots are worth more points than any other shots, but free throws offer up an easy opportunity for a point or two and may be necessary late in the game.

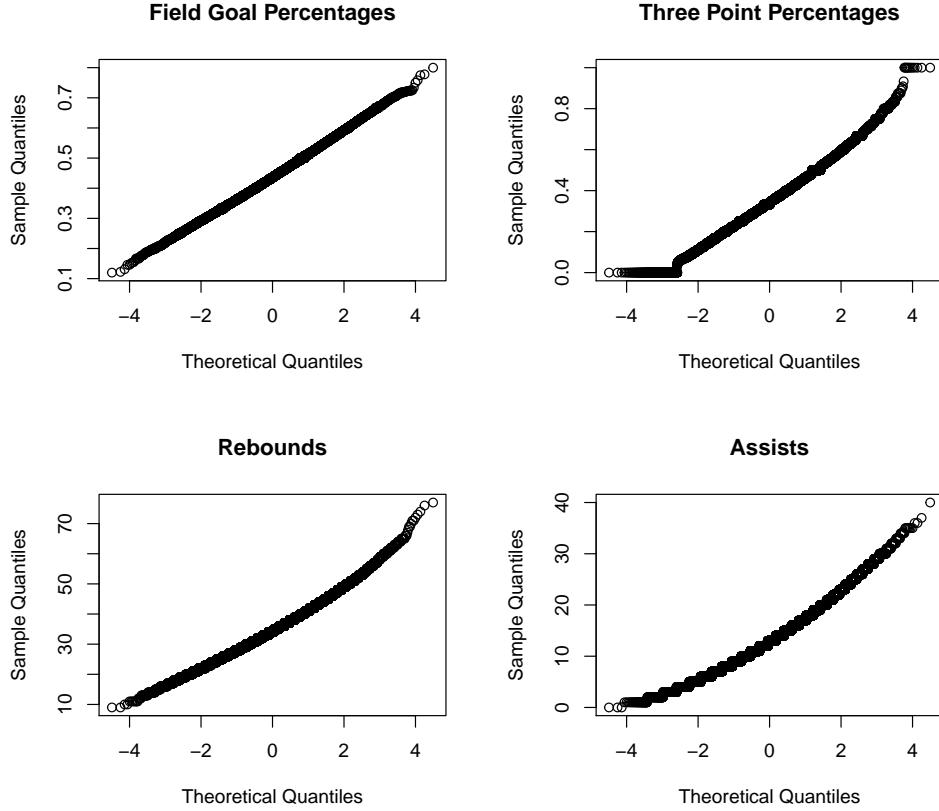


This figure visualizes the differences that exist, on average, in winning and losing teams' shot percentages. There are a large number of outliers in this plot, which should be noted for future analysis. It is also hard to tell which shots look to be more influential in the winning of a game because the data is so wide-spread.

Checking Parameters for Normality

In order to test potential parameters for normality, we look at the QQ-plots. For field goal percentage, three point percentage, rebounds per game, and assists per game. Due to the large sample size, over

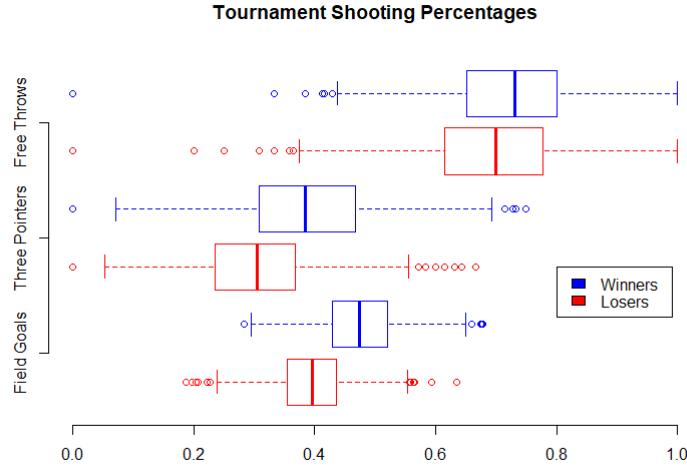
140,000, we do not anticipate having issues due to the Central Limit Theorem.



The only parameter of concern here is the tails of the three point percentage. The minimum and maximum values of this value are 0 and 1, respectively. The issue here lies in the fact that there are several data points with these minimum and maximum values, but there is a gap of values just above the minimum and just below the maximum. For example, for a team to shoot 1 percent on three pointers, the team would have to only hit 1 and attempt 100. This is not plausible. However, a team can only attempt 5 three points and miss all of them, giving them a three point percentage of 0. The same analysis can be made for the maximum value.

Tournament Data

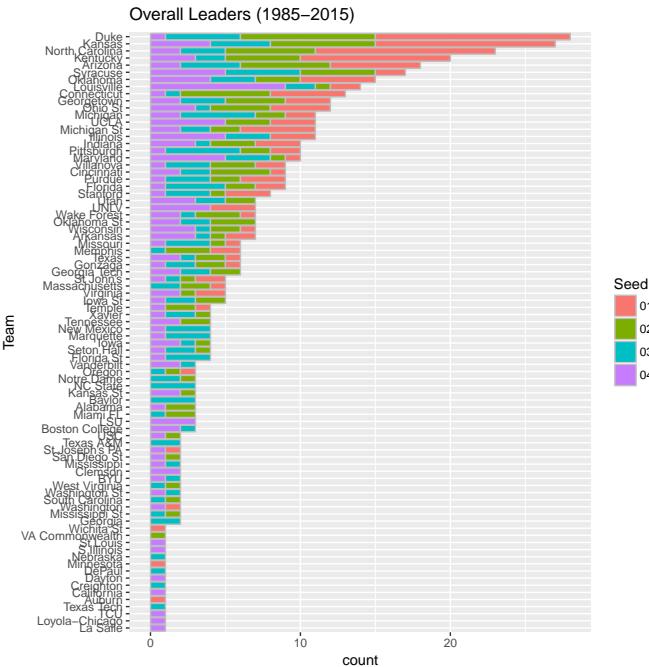
Much the same as when we worked with the regular season data, we analyzed the tournament data at first on a more basic level of winning teams versus losing teams. Much of the data that we had for tournaments was centered on the teams' abilities to score. We analyzed their shooting percentages during the tournaments and compared average winning teams to average losing teams.



As the above figure illustrates, winning teams, on average, have higher shooting percentages in all categories. It is essential to note how large the differences may be. From this data we can start to decide which types of shots are the most important to tournament success.

History of Success

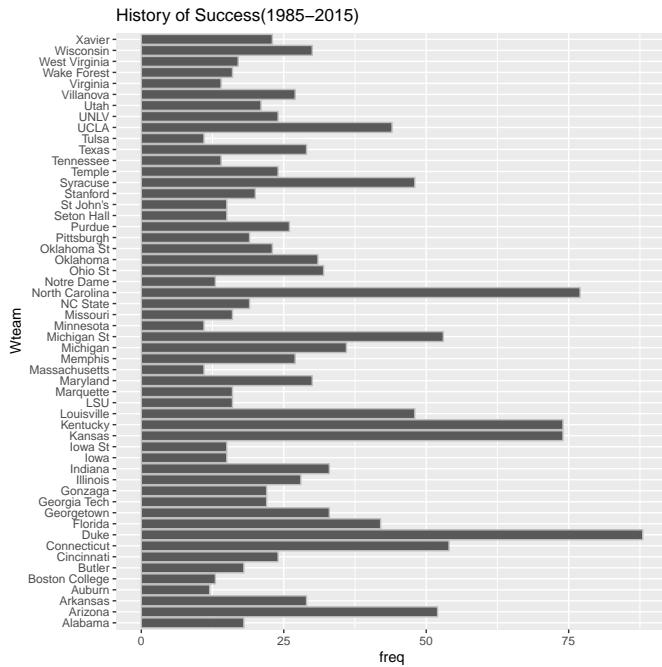
As a result of looking at our data, and through our own personal knowledge of the sport, we decided it was fitting to look into each team's history of success in the tournament and how often they had been seeded near the top.



The above figure maps how often teams have been seeded among the top four, for any region in the tournament. Teams that have been successful in the past are more likely to be seeded near the top again in the future, as is pictured above. The teams near the top of this chart are those that are commonly

discussed amongst basketball fans. They are teams that come from schools that are known for basketball, and they likely draw in more talented players as a result of their reputation, helping them further develop their program.

We continue this analysis of History of Success by looking at teams that are all-around leaders in past tournaments. We look at each team's past appearances in the tournament to compare them to each other.



The figure above shows some of the teams with the most appearances in the March Madness tournament. Higher frequency logically relates to a better team, and this data allows us to see which teams are consistently present and performing in the tournament.

Initial Model

$$Y_{daynum} = \beta_0 + \beta_{conf} + \beta_{fgp} + \beta_{tpp} + \beta_{ass} + \beta_{rb} + \beta_{app} + \epsilon$$

Our original model contained all of the predictors that we felt would be the most important moving forward. These predictors and subscripts are outlined below:

- The response variable, $daynum$, signifies what day of the year the last game is played for each team. This is a good measure of two things: If a team makes the tournament and how far that team advances.
- $conf$: the conference the team plays in - different conferences have vastly different quality of teams
- fgp : refers to field goal percentage
- tpp : three point shooting percentage
- ass : assists

- *rb*: rebounds
- *app*: prior tournament success - indicated by number of previous appearances in the tournament

Seed is not included because seeding is almost entirely determined by conference and record. Record is left out because it is in large part determined by a teams statistics, which we have included in the model.

Processing

In working with our data to develop a model, we realized that there may be a better way to interpret it. We also ran into problems with some predictors and variables because they were quite difficult to quantify or compare.

We found that *daynum* may not be the best measure of a team's success in the tournament because the respective games of a tournament are played on slightly different days each year. This means that the team who won the tournament in 2003 could have a higher daynum than the team who won the tournament in 2004, automatically ranking the 2003 team higher, although they played and won the same number of games.

We also found that *conf* was difficult to quantify because while some conferences are undoubtedly better than others, it is not up to our judgment as to decide how much better they are and which conferences deserve to be credited as the best.

Data Plumbing

Data Reconstruction

Full Model

$$Y_{GP_{year}} = \beta_0 + \beta_{avgScore} + \beta_{avgASS} + \beta_{avgFT} + \beta_{avgPF} + \beta_{avgTP} + \beta_{avgRB} + \beta_{avgTO} \\ + \beta_{avgSTL} + \beta_{avgBL} + \beta_{GP_{year-1}} + \epsilon$$

We fit a full model with all of the possible predictors that we pulled from the data. The full list of predictors includes:

- *GP_{year}*: number of games the team plays in the tournament in a given year
- *avgScore*: average score per team per game in regular season
- *avgASS*: average assists per team per game in regular season
- *avgFT*: average free throws per team per game in regular season
- *avgPF*: average personal fouls per team per game in regular season
- *avgTP*: average three point shots made per team per game in regular season
- *avgRB*: average total rebounds per team per game in regular season
- *avgTO*: average turnovers per team per game in regular season

- $avgSTL$: average steals per team per game in regular season
- $avgBL$: average blocks per team per game in regular season
- GP_{year-1} : number of games the team plays in the tournament in the prior year

We formed this model for each year from 2004 to 2015 because those are the years that we have the most data for, and we seek out the model with the highest R^2 value because it accounts for the most variation in the response. The coefficients and summary of some of the models are shown below:

```

> prev4 = addPriorYear(2, avgstl, TRUE)
> fit04 = lm(GP04 ~ ., prev4[, -1])
> summary(fit04)

Call:
lm(formula = GP04 ~ ., data = prev4[, -1])

Residuals:
    Min      1Q  Median      3Q     Max 
-1.7484 -0.6289 -0.1841  0.5283  3.5693 

Coefficients: (1 not defined because of singularities)
Estimate Std. Error t value Pr(>|t|)    
(Intercept) -2.476693   2.445436  -1.013   0.3157  
avgScore04 -0.003557   0.084844  -0.042   0.9667  
avgFG04     0.208241   0.238282   0.874   0.3860  
avgTP04     0.111249   0.147521   0.754   0.4541  
avgFT04      NA        NA        NA        NA      
avgRB04     0.011671   0.018473   0.632   0.5302  
avgASS04    -0.128551  0.119710  -1.074   0.2877  
avgTO04     -0.239030  0.112035  -2.134   0.0374 *  
avgSTL04    -0.124997  0.123520  -1.012   0.3161  
avgBL04     0.328675   0.133100   2.469   0.0167 *  
avgPF04     0.162716   0.105641   1.540   0.1293  
GP03       0.076130   0.112047   0.679   0.4998  
---
Signif. codes:  0 *** 0.001 ** 0.01 * 0.05 . 0.1    1

Residual standard error: 1.125 on 54 degrees of freedom
Multiple R-squared:  0.3546, Adjusted R-squared:  0.2351 
F-statistic: 2.967 on 10 and 54 DF,  p-value: 0.004799

>
> prev9 = addPriorYear(7, avgstl, TRUE)
> fit09 = lm(GP09 ~ ., prev9[, -1])
> summary(fit09)

Call:
lm(formula = GP09 ~ ., data = prev9[, -1])

Residuals:
    Min      1Q  Median      3Q     Max 
-1.6153 -0.6350 -0.1082  0.5441  2.6755 

Coefficients: (1 not defined because of singularities)
Estimate Std. Error t value Pr(>|t|)    
(Intercept) -0.17350   2.63262  -0.066  0.947699  
avgScore09  0.22102   0.06561   3.369  0.001400 ** 
avgFG09    -0.59909   0.19117  -3.134  0.002789 ** 
avgTP09    -0.39458   0.12390  -3.185  0.002407 ** 
avgFT09      NA        NA        NA        NA      
avgRB09     0.01778   0.01539   1.155  0.253025  
avgASS09    0.34903   0.10525   3.316  0.001636 ** 
```

```

avgTO09      -0.03090   0.10399  -0.297  0.767497
avgSTL09     0.19539   0.12018   1.626  0.109797
avgBL09     -0.08933   0.11806  -0.757  0.452553
avgPF09     -0.15114   0.10048  -1.504  0.138351
GP08        0.28387   0.07955   3.568  0.000763 ***
---
Signif. codes:  0 *** 0.001 ** 0.01 * 0.05 . 0.1    1

Residual standard error: 0.9419 on 54 degrees of freedom
Multiple R-squared:  0.5478, Adjusted R-squared:  0.4641
F-statistic: 6.542 on 10 and 54 DF,  p-value: 1.58e-06

>
> prev15 = addPriorYear(13, avgSZ, TRUE)
> fit15 = lm(GP15 ~ ., prev15[, -1])
> summary(fit15)

Call:
lm(formula = GP15 ~ ., data = prev15[, -1])

Residuals:
    Min      1Q  Median      3Q      Max 
-2.13475 -0.74144 -0.07461  0.59031  2.93999 

Coefficients: (1 not defined because of singularities)
Estimate Std. Error t value Pr(>|t|)    
(Intercept) -1.137942  2.505740  -0.454  0.65146
avgScore15   0.009128  0.087329   0.105  0.91712
avgFG15      0.222098  0.204176   1.088  0.28127
avgTP15     -0.161144  0.132683  -1.215  0.22956
avgFT15      NA       NA       NA       NA      
avgRB15      0.018762  0.013055   1.437  0.15615
avgASS15     -0.062710  0.100166  -0.626  0.53378
avgTO15      -0.156939  0.122918  -1.277  0.20686
avgSTL15     0.055784  0.118423   0.471  0.63940
avgBL15      -0.035234  0.118800  -0.297  0.76787
avgPF15      -0.042033  0.082793  -0.508  0.61363
GP14        0.372234  0.099741   3.732  0.00044 ***
---
Signif. codes:  0 *** 0.001 ** 0.01 * 0.05 . 0.1    1

Residual standard error: 1.011 on 57 degrees of freedom
Multiple R-squared:  0.4606, Adjusted R-squared:  0.366
F-statistic: 4.868 on 10 and 57 DF,  p-value: 4.65e-05

```

The above code output shows the coefficients for three models, from years 2004, 2009, and 2015. Clearly, the R^2 values vary from model to model, but we found that the model from 2009 had the highest R^2 value and the most significant figures when compared to the other full models.

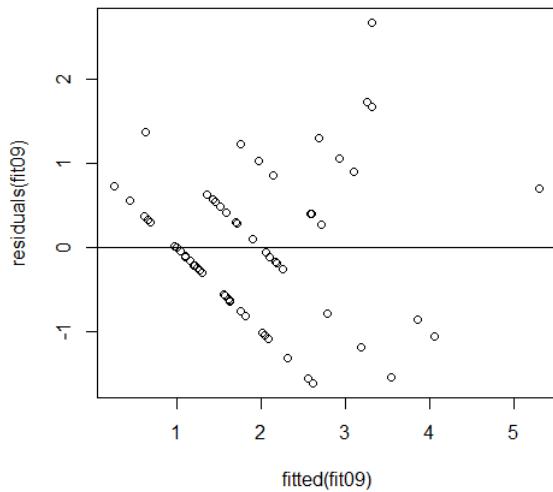
Full Model Analysis

We were clearly working with too many predictors in the full model, so we ran diagnostic tests on the full 2009 model and then used the stepwise function, both forward and backward, to reduce the number of predictors. We decided to start by working with the 2009 model because it had a high R^2 value and many significant predictors.

```

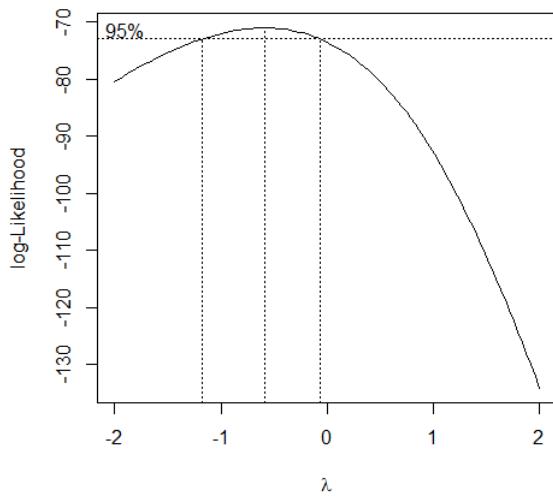
plot(fitted(fit09), residuals(fit09))
abline(h=0)

```



Clearly, there is a distinct fan shape to our residual plot, so we ran a boxcox function to see what type of transformation we should perform on the data.

```
boxcox(fit09, plotit = TRUE)
```



The boxcox graph shows that we should raise the response to the $-\frac{1}{2}$, so we adjust the model and replot the residuals.

```
fit09Adj <- lm(I(GP09^(-1/2)) ~ ., prev9[, -1])
plot(fitted(fit09Adj), residuals(fit09Adj))
abline(h=0)
summary(fit09Adj)

Output:
Call:
lm(formula = I(GP09^(-1/2)) ~ ., data = prev9[, -1])
```

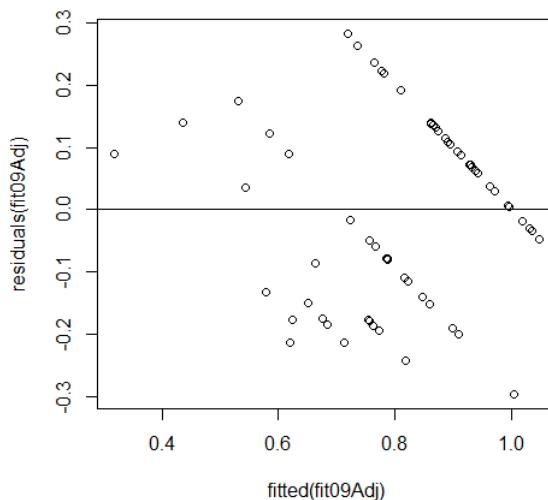
```

Residuals:
Min      1Q   Median      3Q     Max
-0.295461 -0.131892  0.006337  0.113975  0.282223

Coefficients: (1 not defined because of singularities)
Estimate Std. Error t value Pr(>|t|)
(Intercept) 0.623708  0.440643  1.415 0.162678
avgScore09 -0.033851  0.010982 -3.082 0.003231 ** 
avgFG09    0.091291  0.031998  2.853 0.006127 ** 
avgTP09    0.066538  0.020738  3.208 0.002246 ** 
avgFT09     NA       NA       NA       NA
avgRB09    -0.001131  0.002575 -0.439 0.662340
avgASS09   -0.038591  0.017616 -2.191 0.032810 *
avgTO09    0.016290  0.017406  0.936 0.353500
avgSTL09   -0.046625  0.020115 -2.318 0.024271 *
avgBL09    0.020326  0.019761  1.029 0.308254
avgPF09    0.031443  0.016818  1.870 0.066959 .
GP08      -0.051046  0.013315 -3.834 0.000332 *** 
---
Signif. codes:  0 *** 0.001 ** 0.01 * 0.05 . 0.1     1

```

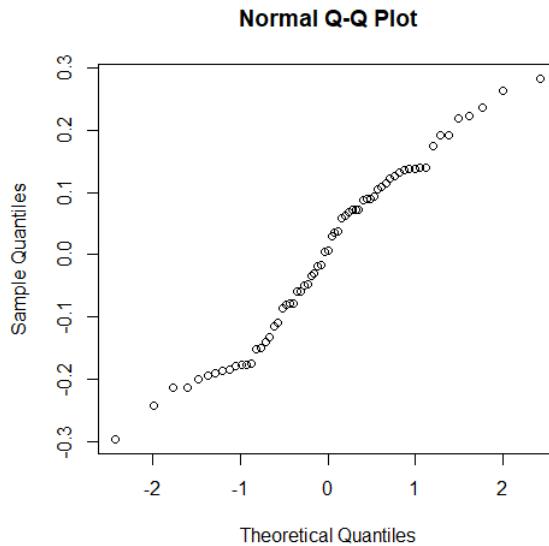
Residual standard error: 0.1576 on 54 degrees of freedom
Multiple R-squared: 0.5097, Adjusted R-squared: 0.4189
F-statistic: 5.614 on 10 and 54 DF, p-value: 1.074e-05



The residual plot is not perfect, but they are more evenly spaced from 0, so we move forward with the adjusted model.

We continue by testing the normality of the residuals.

```
qqnorm(fit09Adj$residuals)
```



The residuals seem to follow a fairly Normal pattern, so we continue to move forward.

Final Model

$$Y_{GP_{year}}^{-0.5} = \beta_0 + \beta_{avgASS} + \beta_{avgFT} + \beta_{avgPF} + \beta_{avgFG} + \beta_{avgTO} + \beta_{GP_{year-1}} + \epsilon$$

Final Model Analysis

Each predictor in the final model carries significant meaning with valuable interpretation. Average assists, free throws and field goals measure overall offensive power, while turnovers measures how careful the offense is. Assist to turnover ratio was found to be ineffective as this data variable was not distinguishable enough from team to team. Generally, the more assists a team has the more ball movement they have, the more prone they are to turning the ball over. Amongst march madness bracket teams, the individual number of assists and turnovers proved to be more of a relevant statistic than assist to turnover ratio. Furthermore, the assist to turnover ratio is more precise and valuable in measuring a particular players effectiveness, for example a team's point guard. The remaining predictors are personal fouls and prior year success. Personal fouls is a measure of a team's defensive ability. This is not the best statistic for measuring a teams defensive capability, but it is for this data set. Prior year tournament success is the last predictor and is the most straight forward. There is tremendous correlation across time for teams making the tournament one year if they made it the previous year.

Predictions

Further Research

Further research that would likely have more prediction power would incorporate advanced sports statistics. The most important improvement in the model could be defensive metrics. As far as stat sheet

statistics go for defense, the only measureable statistics are blocks, steals, and personal fouls. Blocks and steals do not occur many times in a game, the player that leads the league in either category typically does not average more than four per game. In the past ten years, a great deal of advancements in statistical analysis have paved the way for new defensive metrics for a basketball team. A common statistic is points allowed per 100 possessions. The team with the fewest points allowed per 100 possessions would be classified as the team with the lowest scoring defense. Unfortunately, in our data set, we could not formulate any advanced defensive statistics.

Another predictor we would like to have in the future is a measure of conference. This was expressed in our initial, hypothetical model but not in our final model. In NCAA basketball, specific conferences have more high quality teams. These teams are more likely to make the tournament even if their record is inferior to other teams in other conferences. There are a total of 32 conferences for the 2017-2018 season, but only 7 of them make up the majority of NCAA tournament teams: Big 12, ACC, Big East, Big Ten, SEC, The American, and the Pac-12. Every year multiple teams from these conferences make the tournament. This cannot be said for all conferences. For example, Binghamton's basketball team lies in the American East conference. Only the winner of this conference typically makes the tournament. Future models should incorporate some kind of dummy variable to account for this variation. A predictor variable "conference" could be added. Teams in these conferences would be assigned a value of 1 while other teams would be assigned a value of zero. This would help the prediction of the model, due to the fact that two teams in different conferences can have very similar statistics on paper, but one will make the tournament and one will not. A good example of this was this year's Vermont team in the American East conference. Vermont had a 27-8 overall record, but failed to make the NCAA tournament due to their loss in the American East tournament. Teams with this record in the 7 conferences previously mentioned would make the NCAA tournament every year.

Appendix

Summary output for full model:

```
> prev14 = addPriorYear(12, avgS2, TRUE)
> fit14 = lm(GP14 ~ ., prev14[, -1])
> summary(fit14)

Call:
lm(formula = GP14 ~ ., data = prev14[, -1])

Residuals:
    Min      1Q  Median      3Q     Max 
-1.6535 -0.6375 -0.1490  0.3945  3.7843 

Coefficients: (1 not defined because of singularities)
Estimate Std. Error t value Pr(>|t|)    
(Intercept) 5.301180   2.745766   1.931   0.0585 .
avgScore14 -0.104674   0.083860  -1.248   0.2171
avgFG14     0.309636   0.239501   1.293   0.2013
avgTP14     0.156841   0.153644   1.021   0.3117
avgFT14      NA        NA        NA        NA      
avgRB14     0.009232   0.018780   0.492   0.6249
avgASS14    -0.053165   0.107422  -0.495   0.6226
avgTO14     -0.209756   0.127291  -1.648   0.1049
avgSTL14    -0.145048   0.133040  -1.090   0.2802
avgBL14     0.275043   0.145680   1.888   0.0641 .
avgPF14     -0.106358   0.110073  -0.966   0.3380
GP13        0.082681   0.126693   0.653   0.5166
---
Signif. codes:  0 *** 0.001 ** 0.01 * 0.05 . 0.1     1
```

Residual standard error: 1.208 on 57 degrees of freedom
Multiple R-squared: 0.2437, Adjusted R-squared: 0.1111
F-statistic: 1.837 on 10 and 57 DF, p-value: 0.07443

```
>
> prev13 = addPriorYear(11, avgsZ, TRUE)
> fit13 = lm(GP13 ~ ., prev13[, -1])
> summary(fit13)
```

Call:
lm(formula = GP13 ~ ., data = prev13[, -1])

Residuals:

Min	1Q	Median	3Q	Max
-1.8786	-0.6606	-0.1628	0.5599	3.1439

Coefficients: (1 not defined because of singularities)

Estimate	Std. Error	t value	Pr(> t)
(Intercept)	3.30169	3.04878	1.083 0.2834
avgScore13	-0.06515	0.09446	-0.690 0.4932
avgFG13	0.20597	0.23302	0.884 0.3805
avgTP13	0.08966	0.15024	0.597 0.5530
avgFT13	NA	NA	NA
avgRB13	0.01222	0.02041	0.599 0.5516
avgASS13	-0.14487	0.11411	-1.270 0.2094
avgTO13	-0.04789	0.12670	-0.378 0.7068
avgSTL13	0.29211	0.13630	2.143 0.0364 *
avgBL13	0.01784	0.14977	0.119 0.9056
avgPF13	-0.16485	0.12234	-1.347 0.1832
GP12	0.25061	0.11103	2.257 0.0279 *

Signif. codes: 0 *** 0.001 ** 0.01 * 0.05 . 0.1 1

Residual standard error: 1.154 on 57 degrees of freedom
Multiple R-squared: 0.3101, Adjusted R-squared: 0.1891
F-statistic: 2.562 on 10 and 57 DF, p-value: 0.01243

```
>
> prev12 = addPriorYear(10, avgsZ, TRUE)
> fit12 = lm(GP12 ~ ., prev12[, -1])
> summary(fit12)
```

Call:
lm(formula = GP12 ~ ., data = prev12[, -1])

Residuals:

Min	1Q	Median	3Q	Max
-2.3717	-0.6724	-0.1912	0.4705	2.8825

Coefficients: (1 not defined because of singularities)

Estimate	Std. Error	t value	Pr(> t)
(Intercept)	3.58332	2.81280	1.274 0.20786
avgScore12	-0.17995	0.08624	-2.087 0.04141 *
avgFG12	0.36211	0.25401	1.426 0.15945
avgTP12	0.01410	0.13270	0.106 0.91576
avgFT12	NA	NA	NA
avgRB12	0.06054	0.02019	2.999 0.00402 **
avgASS12	-0.06248	0.13882	-0.450 0.65437
avgTO12	-0.01225	0.11686	-0.105 0.91686
avgSTL12	0.10954	0.12354	0.887 0.37899
avgBL12	0.07202	0.15598	0.462 0.64602
avgPF12	-0.04097	0.10304	-0.398 0.69239

```

GP11          0.22083    0.10731   2.058  0.04419 *
---
Signif. codes:  0 *** 0.001 ** 0.01 * 0.05 . 0.1    1

Residual standard error: 1.075 on 57 degrees of freedom
Multiple R-squared:  0.3898, Adjusted R-squared:  0.2827
F-statistic: 3.641 on 10 and 57 DF,  p-value: 0.0008516

>
> prev11 = addPriorYear(9, avgScoreZ, TRUE)
> fit11 = lm(GP11 ~ ., prev11[, -1])
> summary(fit11)

Call:
lm(formula = GP11 ~ ., data = prev11[, -1])

Residuals:
    Min      1Q  Median      3Q     Max 
-1.5599 -0.7117 -0.3055  0.4825  4.0113 

Coefficients: (1 not defined because of singularities)
Estimate Std. Error t value Pr(>|t|)    
(Intercept) 2.261465  2.888834  0.783   0.4370  
avgScore11 -0.007744  0.092958 -0.083   0.9339  
avgFG11     0.256092  0.263395  0.972   0.3350  
avgTP11     0.162204  0.166759  0.973   0.3348  
avgFT11     NA        NA        NA      NA      
avgRB11     0.013038  0.018242  0.715   0.4777  
avgASS11    -0.293256  0.135765 -2.160   0.0350 *  
avgTO11     -0.046868  0.145977 -0.321   0.7493  
avgSTL11    0.108027  0.140027  0.771   0.4436  
avgBL11     0.014608  0.162108  0.090   0.9285  
avgPF11     -0.223840  0.124075 -1.804   0.0765 .  
GP10        0.151927  0.102938  1.476   0.1455  
---
Signif. codes:  0 *** 0.001 ** 0.01 * 0.05 . 0.1    1

Residual standard error: 1.201 on 57 degrees of freedom
Multiple R-squared:  0.2788, Adjusted R-squared:  0.1523 
F-statistic: 2.204 on 10 and 57 DF,  p-value: 0.03038

>
> prev10 = addPriorYear(8, avgScoreZ, TRUE)
> fit10 = lm(GP10 ~ ., prev10[, -1])
> summary(fit10)

Call:
lm(formula = GP10 ~ ., data = prev10[, -1])

Residuals:
    Min      1Q  Median      3Q     Max 
-1.6940 -0.7676 -0.3351  0.5501  3.7452 

Coefficients: (1 not defined because of singularities)
Estimate Std. Error t value Pr(>|t|)    
(Intercept) 1.40279   3.22112   0.435   0.6649  
avgScore10  0.07318   0.09513   0.769   0.4451  
avgFG10    -0.26524   0.25676  -1.033   0.3062  
avgTP10    0.01756   0.19928   0.088   0.9301  
avgFT10     NA        NA        NA      NA      
avgRB10    0.01787   0.01944   0.919   0.3620  
avgASS10   0.05366   0.12805   0.419   0.6768  
avgTO10    -0.07381   0.14292  -0.516   0.6077 

```

```

avgSTL10    -0.10435    0.13868   -0.752    0.4551
avgBL10     0.28555    0.17057    1.674    0.0999 .
avgPF10     0.03564    0.11033    0.323    0.7479
GP09        0.26721    0.11937    2.239    0.0293 *
---
Signif. codes:  0 *** 0.001 ** 0.01 * 0.05 . 0.1   1

Residual standard error: 1.257 on 54 degrees of freedom
Multiple R-squared:  0.1949, Adjusted R-squared:  0.04579
F-statistic: 1.307 on 10 and 54 DF,  p-value: 0.2504

>
> prev8 = addPriorYear(6, avgZ, TRUE)
> fit08 = lm(GP08 ~ ., prev8[, -1])
> summary(fit08)

Call:
lm(formula = GP08 ~ ., data = prev8[, -1])

Residuals:
    Min      1Q      Median      3Q      Max
-1.42411 -0.62107 -0.08825  0.63471  1.95409

Coefficients: (1 not defined because of singularities)
Estimate Std. Error t value Pr(>|t|)
(Intercept) -1.38585  2.00584 -0.691  0.49258
avgScore08 -0.02949  0.07537 -0.391  0.69716
avgFG08     0.16887  0.18739  0.901  0.37152
avgTP08     -0.24737  0.12896 -1.918  0.06039 .
avgFT08     NA       NA       NA       NA
avgRB08     0.03838  0.01563  2.456  0.01730 *
avgASS08    0.03256  0.09736  0.334  0.73936
avgTO08     -0.23483  0.09382 -2.503  0.01537 *
avgSTL08    0.09159  0.10375  0.883  0.38123
avgBL08     0.06124  0.10269  0.596  0.55342
avgPF08     0.14675  0.09236  1.589  0.11792
GP07        0.33183  0.08974  3.698  0.00051 ***
---
Signif. codes:  0 *** 0.001 ** 0.01 * 0.05 . 0.1   1

Residual standard error: 0.9184 on 54 degrees of freedom
Multiple R-squared:  0.5701, Adjusted R-squared:  0.4905
F-statistic: 7.16 on 10 and 54 DF,  p-value: 4.689e-07

>
> prev7 = addPriorYear(5, avgZ, TRUE)
> fit07 = lm(GP07 ~ ., prev7[, -1])
> summary(fit07)

Call:
lm(formula = GP07 ~ ., data = prev7[, -1])

Residuals:
    Min      1Q      Median      3Q      Max
-1.7748 -0.7216 -0.2807  0.6634  2.4802

Coefficients: (1 not defined because of singularities)
Estimate Std. Error t value Pr(>|t|)
(Intercept) 2.6029631  2.4564810  1.060  0.29403
avgScore07 -0.0651920  0.0718252 -0.908  0.36810
avgFG07     0.2446843  0.1938464  1.262  0.21228
avgTP07     0.1423438  0.1418684  1.003  0.32017
avgFT07     NA       NA       NA       NA

```

```

avgRB07      -0.0005477  0.0172239  -0.032  0.97475
avgASS07     0.0260457  0.1167849   0.223  0.82436
avgTO07      -0.2402723  0.0966838  -2.485  0.01608 *
avgSTL07     -0.0466975  0.1167059  -0.400  0.69064
avgBL07      0.1657333  0.1212501   1.367  0.17733
avgPF07      -0.0462716  0.0882245  -0.524  0.60209
GP06         0.3212087  0.1051509   3.055  0.00349 **
---
Signif. codes:  0 *** 0.001 ** 0.01 * 0.05 . 0.1    1

Residual standard error: 1.056 on 54 degrees of freedom
Multiple R-squared:  0.4317, Adjusted R-squared:  0.3265
F-statistic: 4.102 on 10 and 54 DF,  p-value: 0.0003138

>
> prev6 = addPriorYear(4, avgsZ, TRUE)
> fit06 = lm(GP06 ~ ., prev6[, -1])
> summary(fit06)

Call:
lm(formula = GP06 ~ ., data = prev6[, -1])

Residuals:
    Min      1Q  Median      3Q      Max 
-1.6347 -0.8841 -0.2856  0.5480  4.1550 

Coefficients: (1 not defined because of singularities)
Estimate Std. Error t value Pr(>|t|)    
(Intercept) 0.205358   2.752568   0.075  0.9408
avgScore06  0.076930   0.095801   0.803  0.4255
avgFG06    0.017233   0.261605   0.066  0.9477
avgTP06    -0.005185  0.164894  -0.031  0.9750
avgFT06    NA        NA        NA        NA      
avgRB06    -0.014477  0.017667  -0.819  0.4161
avgASS06   -0.055950  0.131938  -0.424  0.6732
avgTO06    0.030397  0.141820   0.214  0.8311
avgSTL06   0.046671  0.123428   0.378  0.7068
avgBL06    0.133624  0.139198   0.960  0.3414
avgPF06    -0.232631  0.114706  -2.028  0.0475 *
GP05       0.017416  0.106412   0.164  0.8706
---
Signif. codes:  0 *** 0.001 ** 0.01 * 0.05 . 0.1    1

Residual standard error: 1.235 on 54 degrees of freedom
Multiple R-squared:  0.2222, Adjusted R-squared:  0.07813
F-statistic: 1.542 on 10 and 54 DF,  p-value: 0.15

>
> prev5 = addPriorYear(3, avgsZ, TRUE)
> fit05 = lm(GP05 ~ ., prev5[, -1])
> summary(fit05)

Call:
lm(formula = GP05 ~ ., data = prev5[, -1])

Residuals:
    Min      1Q  Median      3Q      Max 
-1.6795 -0.7748 -0.1379  0.6690  2.4834 

Coefficients: (1 not defined because of singularities)
Estimate Std. Error t value Pr(>|t|)    
(Intercept) -1.66958   2.56583  -0.651  0.5180
avgScore05  -0.05241   0.08522  -0.615  0.5412

```

```

avgFG05      0.06125   0.23014   0.266   0.7911 *
avgTP05      0.29683   0.14053   2.112   0.0393 *
avgFT05        NA       NA       NA       NA
avgRB05      0.02712   0.01794   1.512   0.1364
avgASS05     0.23750   0.12278   1.934   0.0583 .
avgTO05      -0.01358   0.11565  -0.117   0.9070
avgSTL05     0.24432   0.10904   2.241   0.0292 *
avgBL05      -0.14186   0.12764  -1.111   0.2713
avgPF05      -0.12144   0.10890  -1.115   0.2697
GP04         0.17571   0.10590   1.659   0.1029
---
Signif. codes:  0 *** 0.001 ** 0.01 * 0.05 . 0.1    1

```

Residual standard error: 1.09 on 54 degrees of freedom
Multiple R-squared: 0.3948, Adjusted R-squared: 0.2827
F-statistic: 3.523 on 10 and 54 DF, p-value: 0.001242

AIC/BIC Selection Output:

```

>prev7 = addPriorYear(5,avgsZ,TRUE)
>fit07 = lm(GP07~,prev7[,-1])
>fit07Adj <- lm(I(GP07^(-1/2))~,prev7[,-1])
>stepwise(fit07Adj,criterion = c("AIC"),direction=c("forward"))

Call:
lm(formula = I(GP07^(-1/2)) ~ avgTO07 + GP06 + avgBL07 + avgFG07,
data = prev7[, -1])

Coefficients:
(Intercept)      avgTO07          GP06          avgBL07          avgFG07
0.63417       0.05928      -0.03359      -0.03413      -0.01854

>prev6 = addPriorYear(4,avgsZ,TRUE)
>fit06 = lm(GP06~,prev6[,-1])
>fit06Adj <- lm(I(GP06^(-1/2))~,prev6[,-1])
stepwise(fit06Adj,criterion = c("AIC"),direction=c("forward"))

Call:
lm(formula = I(GP06^(-1/2)) ~ avgFG06 + avgPF06, data = prev6[, -1])

Coefficients:
(Intercept)      avgFG06          avgPF06
1.26121      -0.03868       0.03074

>prev5 = addPriorYear(3,avgsZ,TRUE)
>fit05 = lm(GP05~,prev5[,-1])
>fit05Adj <- lm(I(GP05^(-1/2))~,prev5[,-1])
>stepwise(fit05Adj,criterion = c("AIC"),direction=c("forward"))

Call:
lm(formula = I(GP05^(-1/2)) ~ avgASS05 + avgRB05 + avgTO05 +
GP04 + avgSTL05, data = prev5[, -1])

Coefficients:
(Intercept)      avgASS05          avgRB05          avgTO05          GP04
1.235432      -0.027876     -0.003836      0.028163      -0.027761
avgSTL05
-0.026225

>prev4 = addPriorYear(2,avgsZ,TRUE)
>fit04 = lm(GP04~,prev4[,-1])

```

```
>fit04Adj <- lm(I(GP04^(-1/2)) ~ ., prev4[,-1])
>stepwise(fit04Adj, criterion = c("AIC"), direction=c("forward"))

Call:
lm(formula = I(GP04^(-1/2)) ~ GP03 + avgFG04 + avgTO04 + avgASS04 +
avgBL04, data = prev4[, -1])

Coefficients:
(Intercept)          GP03        avgFG04        avgTO04        avgASS04
0.99228      -0.02435      -0.03831       0.03943      0.02559
avgBL04
-0.02695
```