Determinants of NBA Players' Salary

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Abstract

Exploring the relationship between the salary and performance of NBA players in National Basketball Association (NBA) is of great significance for team managers to make reasonable decisions on players' salary. Our project serves to highlight the performance variables, such as points, turnovers, and blocks, that affect players' salary in NBA. The methodology is chosen as not only closely analyze performance of players, but as a further motivation in seeking how the skills of a player is related to his salary. In order to do so, our project involved an exploratory phase referred as Exploratory Data Analysis (EDA) to analyze multiple data sets collected from website 'Basketball Reference' that are dedicated to displaying statistics of NBA players in various seasons. Further, we calculated efficiency (EFF) indices that take into account players' positions by utilizing Principal Components Analysis (PCA). Additionally, we calculated correlations between performance variables and players' salary. In this project, we focused on investigating performance variables of 471 NBA players from 30 teams in the 2015-2016 season. An emergent feature that our group discovered was all performance variables of a player are positively correlated to his salary. To be more specific, total points and field goals gained by a player are the two most correlated performance variables. We presented some of the more meaningful findings and implications of the results in detail in the following demonstration.

Introduction

In the 2013-2014 National Basketball Association (NBA) season, the Los Angeles Laker's Kobe Bryant earned $30.4 million whereas the average NBA player salary is about 5 million. Is Kobe that much better than a player who earns 5 millions a year? Thus the question whether NBA players are overpaid arises. Overpayment in the NBA is problematic.Statistically some players are overpaid based on poor or sub-par performance. These players are highly sought after because they are proficient in one aspect of their game such as three point shooting or they may be a strong defensive force. However, these same specialized players may be a major liability in other areas. For example, the three point shooter may be a poor defender and the defensive force may be a poor free throw shooter. Whatever the issue, overpayment in the NBA is a concern. The reason for payment is to fairly compensate a player for his play.

However, in the NBA it seems as if compensation is a reward for past performance and anticipated or expected future performance. However, past performance and expected performance may not be good indicators of fair compensation. NBA owners and general managers often over spend for a player that they feel will meet and immediate need. Therefore, for managers of different teams in NBA, it is of great significance to understand the relationship between player's performance and salary. The exploratory research question for this project is "In the 2015-2016 season, what is the interpretation of the performance statistics of a player and what is the relastionship between performance variables and player's salary.

To answer this problem, we first used exploratory data analysis to explore individual performance statistic and see the relationship between different performance variables and salary . Then we calculated the efficiency index by position to better evaluate players' performance with different positions.

Data

Introduction of NBA

National Basketball Association (NBA) is one of the four major professional sports leagues in the United States and Canada. It is widely considered to be the premier men's professional basketball league in the world. It has 30 teams including 29 U.S teams and 1 Canada team. Teams belong to either Eastern Conference or Western Conference. NBA regular season is from the last week of October to the mid April. After regular season, follows the NBA Playoffs, which begin in late April, with eight teams in each conference competing for the Championship.

Introduction of data

The primary source of data for this project is from Basketball Reference, which is a website that provides statistics, scores, and history for the National Basketball Association(NBA), American basketball Association (ABA), Women's National Basketball Association(WNBA), and top European competition. In this project, we focused on analyzing statistics of NBA teams in season 2015-2016.

The project starts with data acquisition. Our team scraped three kinds of raw data tables from the website: Roaster, Totals(Player Statistics) and Salaries for each team, and stored those tables in comma separated files(CSV).

The Roster tables contain information about each player's name, position, height, weight, birth date, years of experience and attended college. There are some missing values for attended college in the raw tables. They were all converted to 'NA' values when we started our data acquisition process. The Totals tables contain player's statistics during the entire season: age, games played, games started, minutes played, field goals, field goals attempts, etc. They are all quantitative variables that we would use to find out the conclusion for the central topic: the relationship between salary and performances of NBA players. The salaries table simply contains the salary of the players.

In the Roster table, there's a 'Position' columns that contains five different positions: 'C', 'SF', 'SG', 'PF' and 'PG'. They are abbreviated names of 'Center', 'Small Forward', 'Shooting Guard', 'Power Forward' and 'Point Guard'. Players at the center position are skilled at gathering rebounds and contesting shots. The small forward position is considered to be the most versatile of the main five basketball positions. They are typically skilled at drawing fouls and shooting from long-range. Most shooting guards are good shooters from three-point-range. Lastly, as for point guards, they are the team's best ball handler and passer. They are good at assists and steals. Since players in various positions have various skills, we took their positions into consideration when calculating the efficiency index and the values of players.

Methodology

In analyzing all of the data for this project, we utilized the programming language R. Our main source of data was this website. First of all, we had to scrape three different tables from every team's page in order to gather the roster, salary, and in-game statistics of each player for every team. There were a few issues that we ran into while doing this; some players started out on a certain team but sometime during the course of the season were transferred onto another team. However, most of these players that ended being transferred weren't on the salary or stats tables for the new team, so we were able to avoid dealing with a player appearing on multiple teams by cross-referencing the three different tables for each team. This was achieved by joining all of the tables on the common column "Player" for each team, and then at the very end, once we got rid of duplicates within each team, we simply combined all of the joined tables with each other to get all of the values together.

However, there were still some problems that weren't conducive to our analysis of the data. For example, the mode of several of the columns would make plotting the variable extremely inefficient (e.g. the salary column had a mode of factor, when it really should have had a mode of numeric). As such, after combining the data from all of the different teams together, we had to clean it. Additionally, we changed the names of the columns of the table so that a reader will have a better understanding of what kind of data each variable/column contains. After applying these changes to our dataset, it was written into roster-salary-stats.csv.

Upon having a complete dataset that can be used to form the basis of our analysis, we to get a feel for the data. In doing so, we created a script called eda-script.R, which generates summary statistics for each of the variables within roster-salary-stats.csv, all of which can be seen in data/cleandata/eda-output.txt. Additionally, we also generated box plots, histograms, and bar charts within ed-script.R, all of which can be viewed in the images folder.

In addition to this period of data exploration, we looked at the aggregated salaries for each team, along with their additional statistics. To do this, we created make-salary-stats-script.R, which essentially iterates through all of the teams and creates vectors for each of the values in team-salaries.csv (teams, total_payroll , min_salary, max_salary, first_quartile_salary, median_salary, third_quartile_salary, average_salary, interquartile_range, and standard_deviation). Then, these values are then put into a dataframe and written to team-salaries.csv. To aid with understanding the data and providing a visual representation of our results, we created a web app using shiny that plots a bar chart of a specific statistic relating to salary per team.

After performing an analysis of the salaries of each team, we decided to tackle the heart of the matter: giving each player a statistic that measures how well they perform in their games and how much they contribute to the team. In doing this, we decided to generate the efficiency of each player, which is typically calculated by summing up the total points, rebounds, assists, steals, and blocks, subtracting missed field goals, missed free throws, and turnovers, and then dividing the resulting number by the games the specific player has played. However, the issue with this method is that offense-oriented players are heavily favored; the number of points a player scores per game vastly outweighs the rebounds, assists, steals, and blocks that they can rack up. To solve this issue, we decided to use principal components analysis(PCA) to give a more fair analysis. This way, we can compare apples to apples, so to speak. Ultimately, we wrote the variables used to calculated our efficiency index (position, total points, rebounds, assists, steals, blocks, missed field goals, missed free throws, turnovers, games played, and salary) and the efficiency index to eff-stats-salary.csv.

As with the analysis of salaries per team, we also created a web app using shiny. For this particular app, we wanted the user to be able to compare any two statistics with each other and visually see the correlation between the two. As such, we provided the ability to plot any of the two of total points, rebounds, assists, steals, blocks, missed field goals, missed free throws, turnovers, games played, and salary against each other. To aid in understanding our scatter plot, we gave the option of color-coding the plot by position, as well as an additional option of displaying the linear regression line on the plot.

Finally, we wanted to explore which players had the best “value”, where value was defined to be a player’s efficiency index divided by their salary. This way, we can see how a player’s value is tied to the amount of money that they make. We then found the top 20 most “valuable” players, as well as the 20 least “valuable” players, and saved our findings in best-worst-value-players.txt.

Result

Players Analysis

From the position bar chart we can see that there are roughly equal number of players in each position. However, there are slightly more players who play power forwards(PF) than players who play other positions. This make sense because power forward player’s primary goal is assist, shot blocking and short range shooting. They defend opposite power and stays close to the basket and helps teammates in scoring points.

From histogram of age we can see that most players are in their mid 20’s. The average age of players is 26.6. This make sense because most professional players are about that age after finishing college and start to play NBA. There are little players in later 30’s because many of players retire due to injuries after playing in the NBA for over a decade.

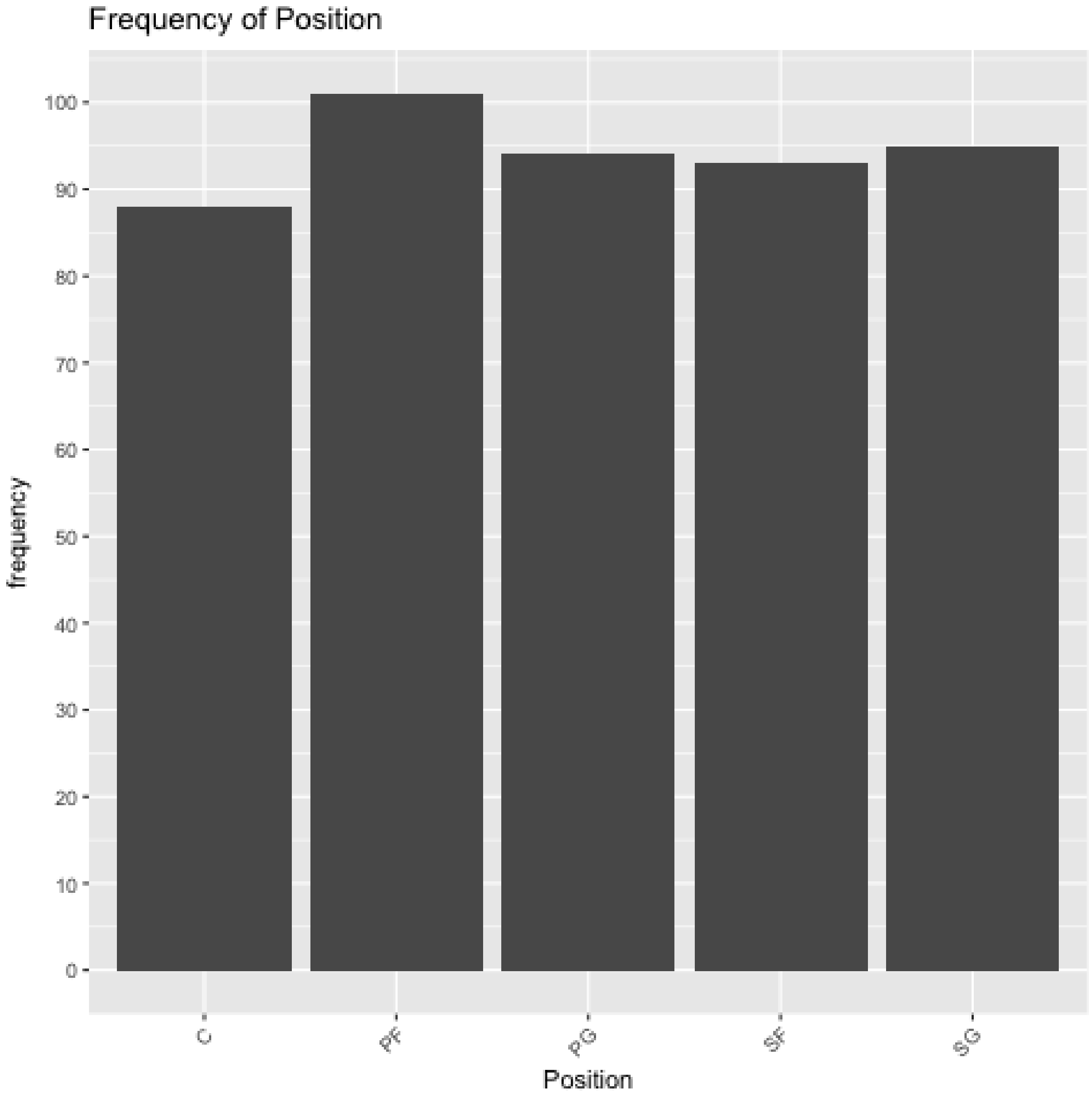


Figure 1: Bar Chart of Players' Position

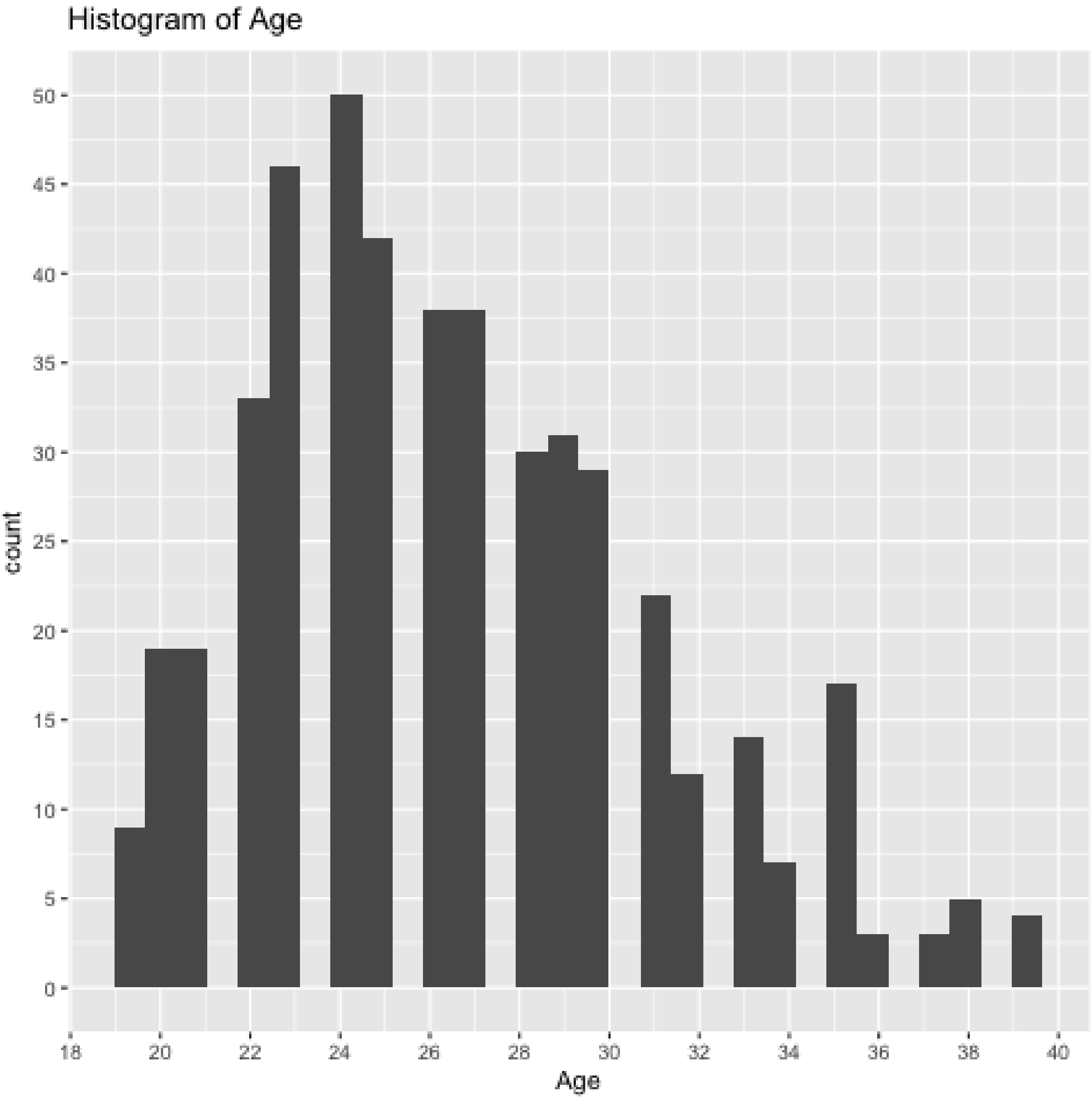


Figure 2: Frequency of Players' Age

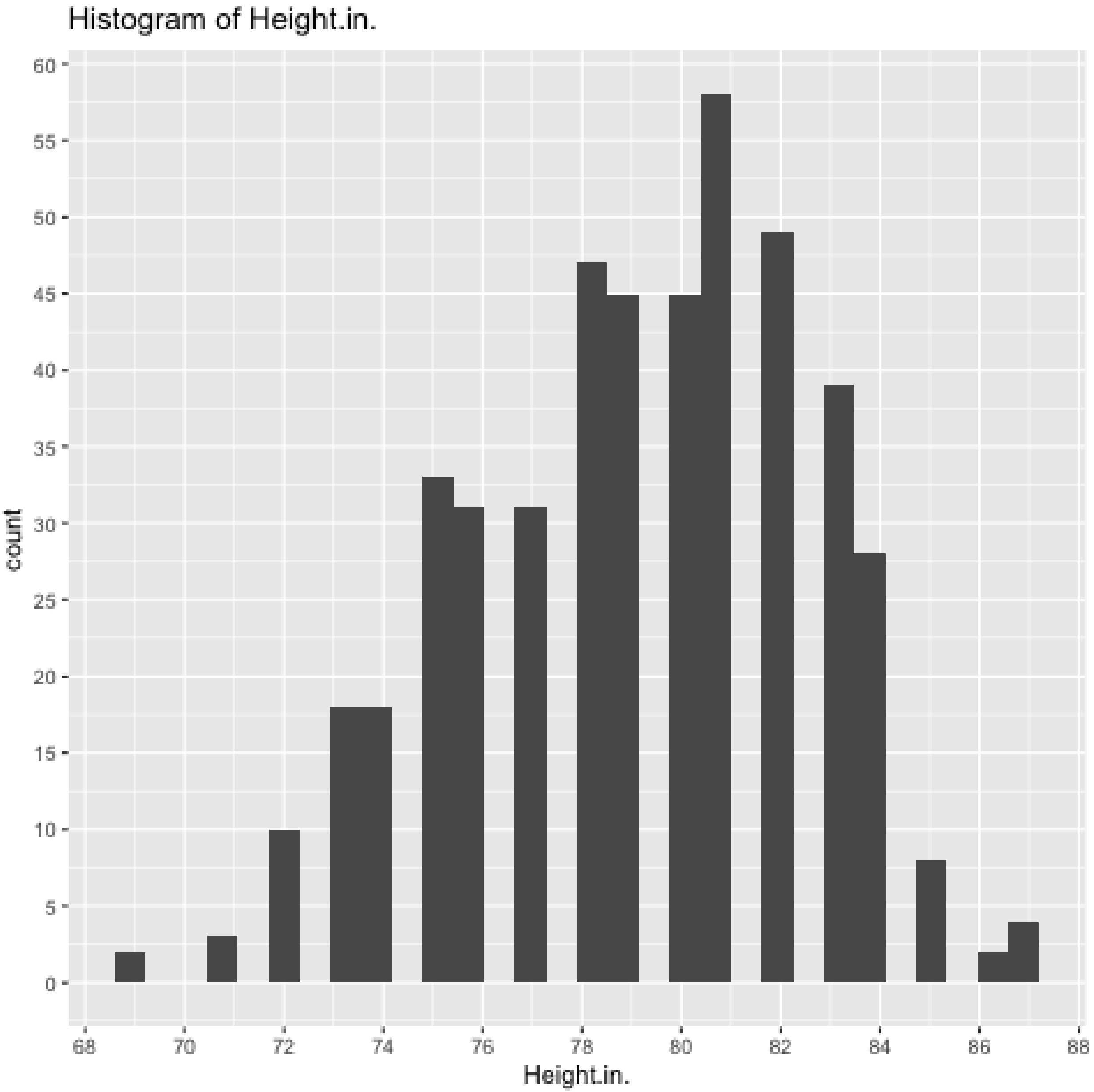


Figure 3: Frequency of Players' Height

From the histogram of height we can see that height of players are roughly normally distributed. Those relatively taller players are in the position of center because they are generally more skilled at gathering rebounds.

Skills and Position analysis

Our used boxplot for exploratory analysis to see the relationship between each skill measurements and position. Boxplots show that player in position power guard focus more on assist and steals. Players in position center focus more on blocks, defensive rebounds, offensive rebounds, free throws, two point field goals. This make sense because center players are positioned close to the basket. Player in position shooting guard focus on making three point field goals because they are always far away from the basket.

Skills and Salary analysis

Multiple regression analysis was conducted to determine which explanatory variables were predictors of NBA player salaries. From the scatterplot of the number of years players have played in NBA and their salary, we observe that there is a weak positive correlation of 0.36 between years played in NBA. About 13.12% of the variations in salaries can be explained by years played in NBA. This makes sense because salaries should be more correlated to player's performance. Although more experience tends to lead to better performance, it is not the cause. Thus the number of years players have played in NBA does not appears to be a main factor that influence the amount of salaries a player gets. Thus we decide to keep investigate the relationship between other factors and salaries.

From the boxplot of points we can see that team Memphis Grizzlies has the lowest average total points score in the season. Also, we can see that there are outliers in several team. There are two person who get the most points in the entire season, one is from Golden State Warriors(GSW) and on from Houston Rockets (HOU). After checking from data, we identified this two person to be Stephen Curry(2375) and James Harden(2376). The person who get the second most point in the entire season is from team Oklahoma City Thunder(OKC). After checking the data, we identified this player to be Kevin Durant. However, those people who contribute large number of points in the season do not get paid significantly more than other players. Thus, we decide to check the relationship between points score in the season by players and their salaries.

From the scatter plot of point scored in the season and salary, we can see that there is a moderately strong positive correlation of 0.64 between point scored in the season and salaries. About 40.84% of the variation in salaries can be explained by point scored in the season. This make sense because the higher points scored in a season indicates better performance. Team managers would be willing to pay more for players that can help them win games. However, we expected to see an even stronger correlation between points scored in the season and salaries. Thus we decide to see what variable are related to points, how these variables are related to salaries and investigate what other factors determines how much a player gets paid.

There are four variables relates to points: field goals, three point goals, two point goals, and free throws. The scatterplot of the number of field goals and salaries appears to have a moderately strong positive correlation of 0.64. About 40.97% of the variation of salaries can be explained by the number of field goals. Thus the number of blocks a player contributes appears to be a main factor that influence salaries the amount of salaries a player get. This make sense because team wins a game by scoring more points than its opponent, and players get points by making field goals. Therefore, a player who is able to contribute more field goals than others will be favored, and team manager will be willing to pay high salaries for these players. However, there are two types of field goals: two points and three points. Thus we further analyze whether three or two point field goal influence salary more.

The scatterplot of the number of three point goals and salaires appears to be very scattered and have a weak positive correlation of 0.34. Only 11.34% of the variation of salaries can be explained by the number three point goals. Thus the number of three point field goals a player contributes does not appears to be a main factor that influence the amount of salaries a player get.

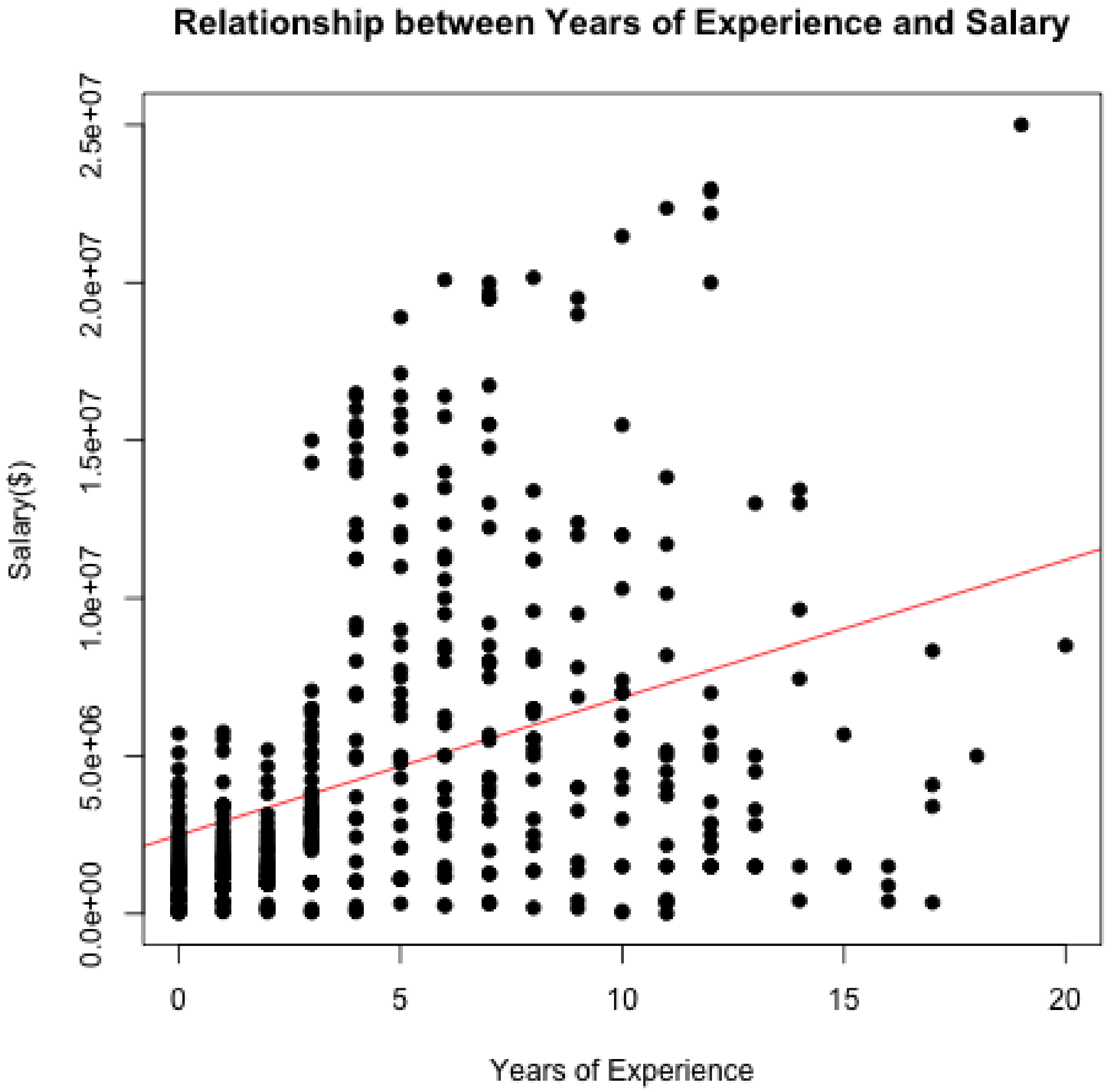


Figure 4: Scatterplot of years of experience and salary

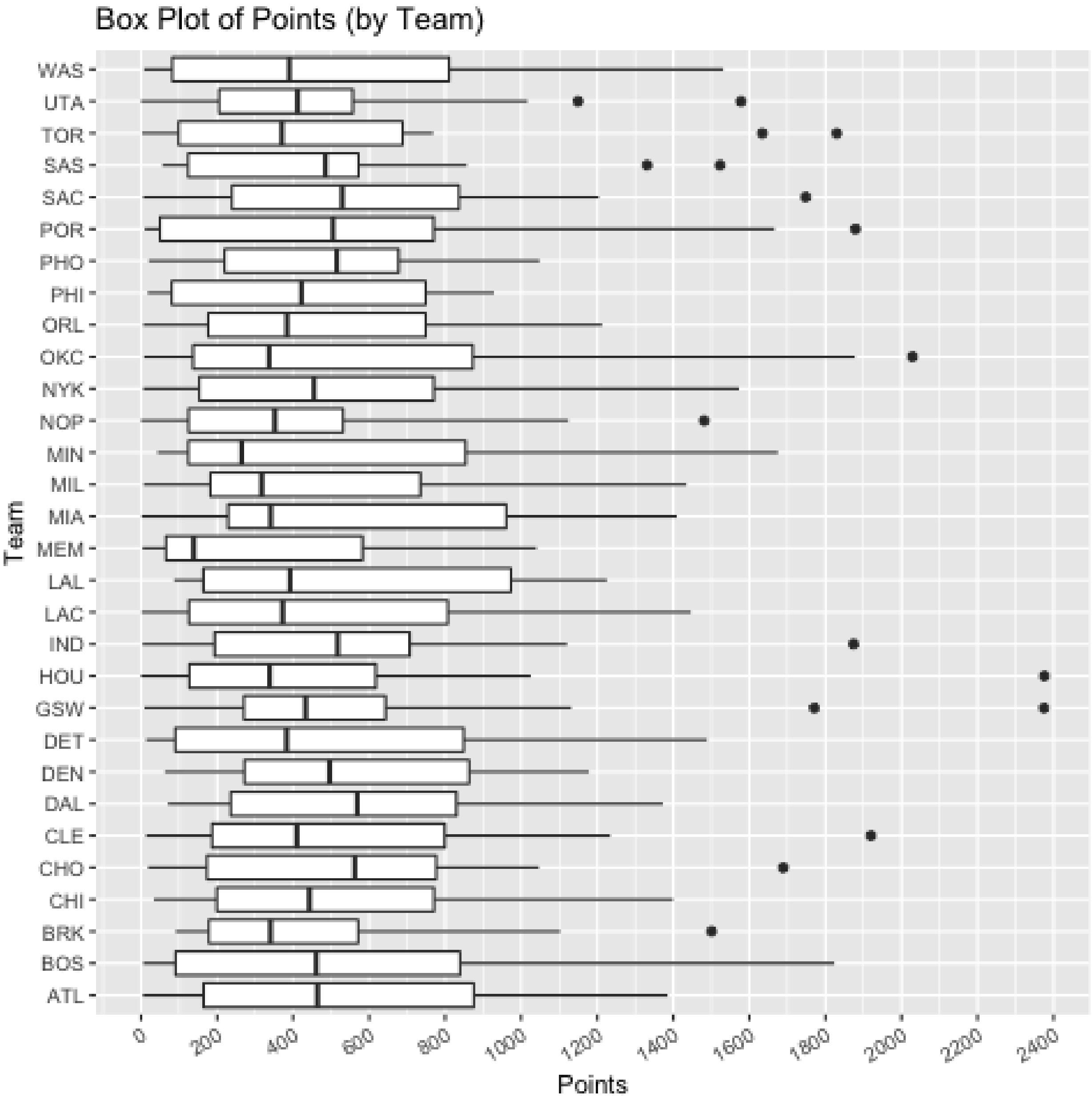
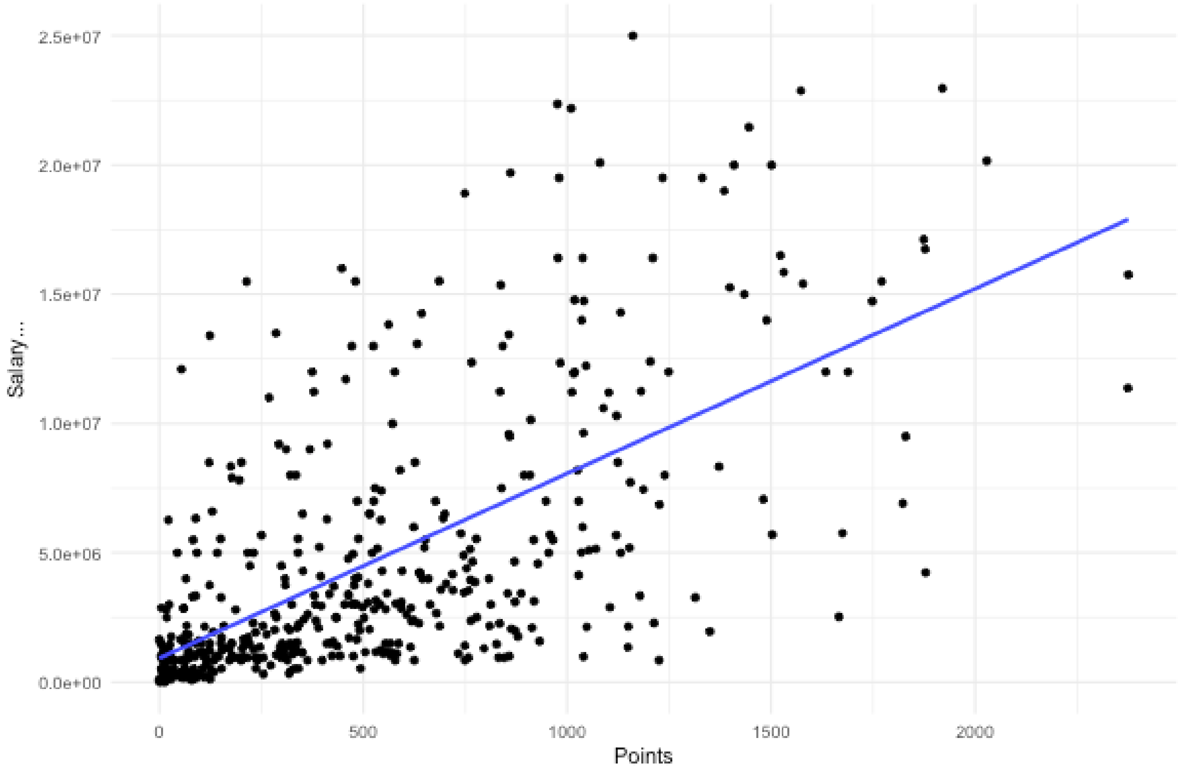


Figure 5: Boxplot of Points by Team



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Correlation Coefficient between Points and Salary...: 0.640033177250208
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Figure 6: Scatterplot of Point and Salary

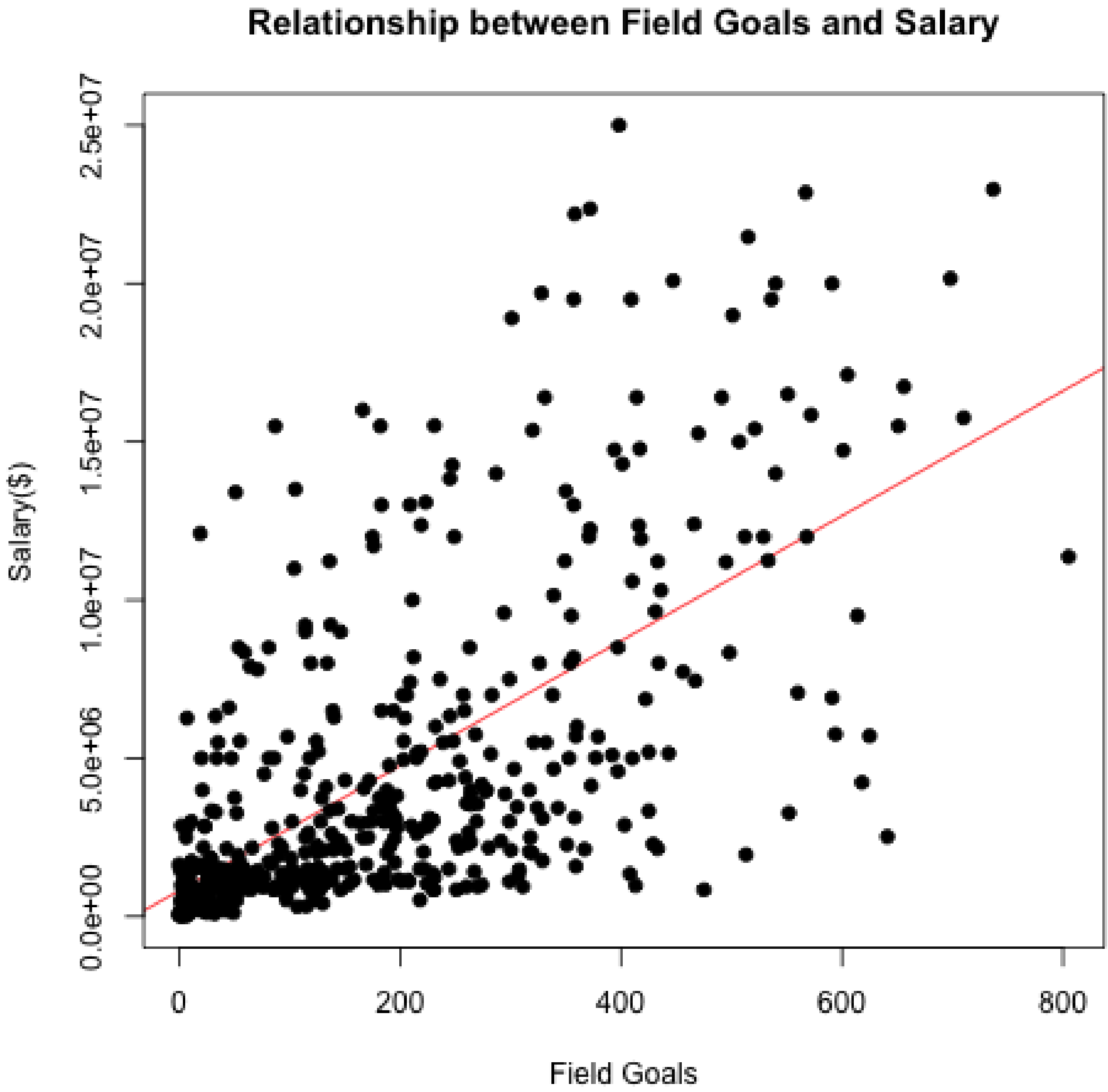


Figure 7: Scatterplot of Field Goals and Salary

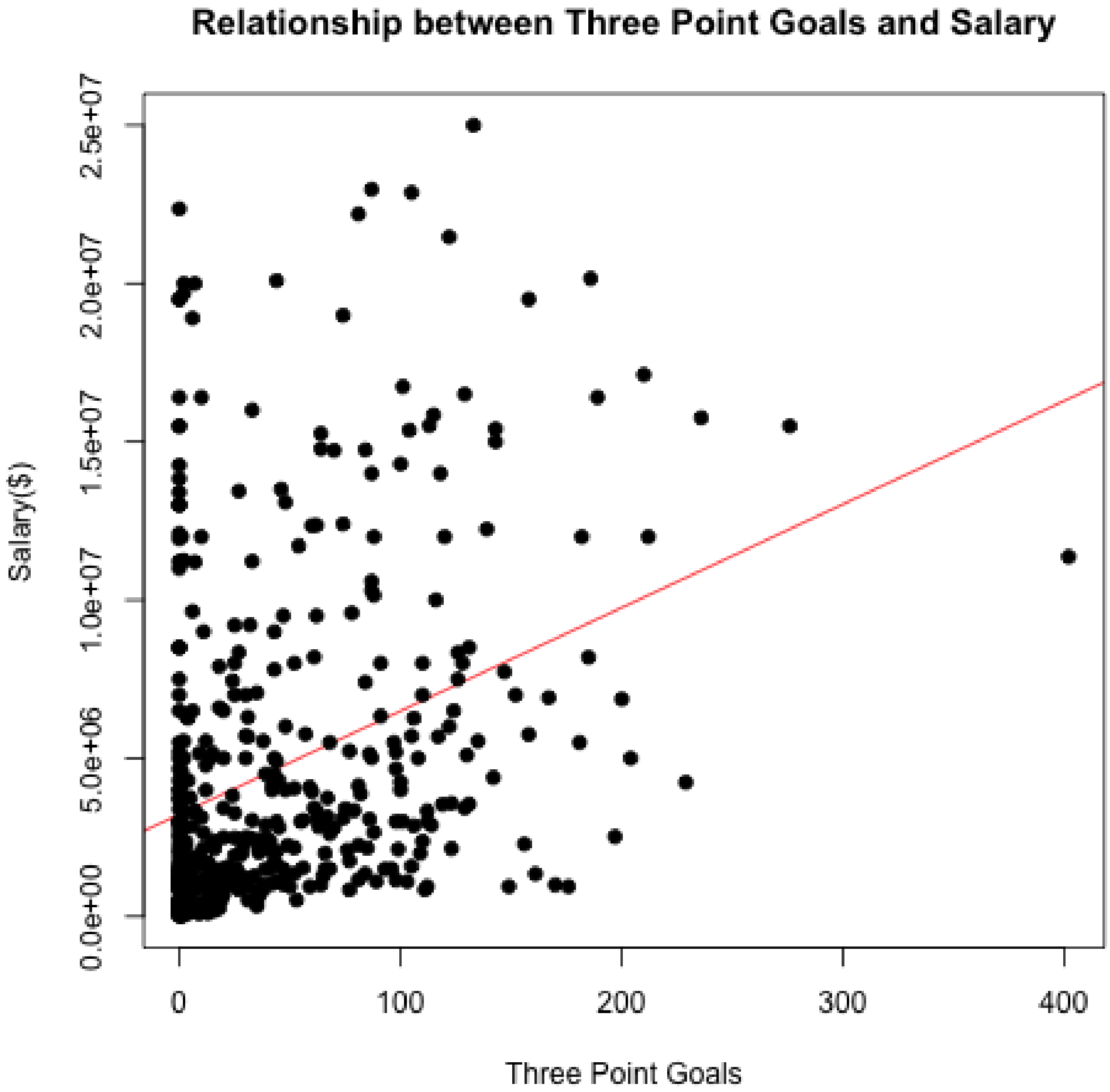


Figure 8: Scatterplot of Three Point Goals and Salary

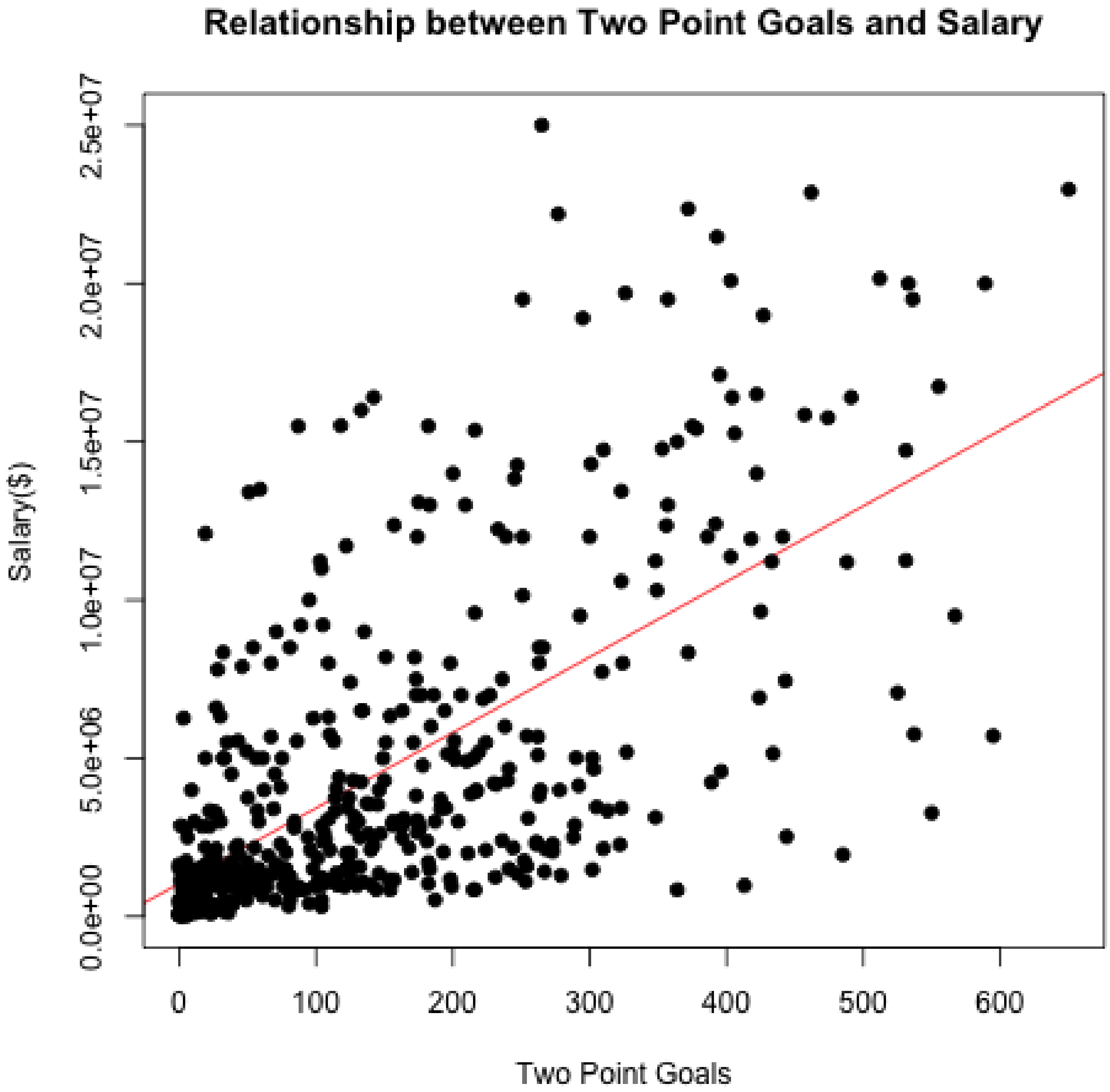


Figure 9: Scatterplot of Two Point Goals and Salary

Checking the scatterplot of the number of two point goals and salaries, we found it to be less scattered than the three point field goals and have a moderately strong positive correlation of 0.64. About 41.14% of the variation of salaries can be explained by the number two point goals. Thus the number of two point goals a player contributes appears to be a main factor that influence the amount of salary a player gets.

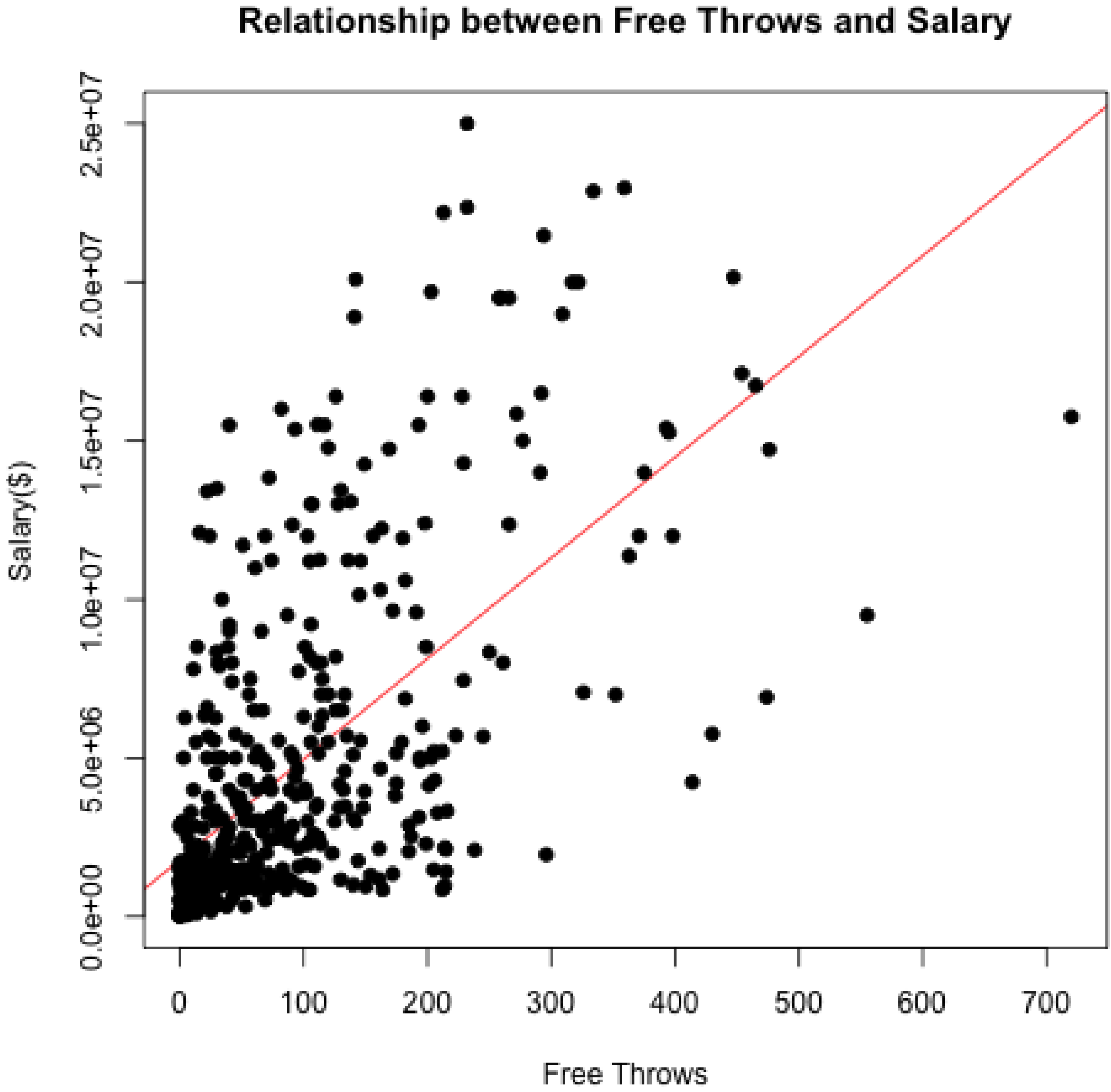


Figure 10: Scatterplot of Free Throws and Salary

Another way a player contributes points is by making successful free throws. The scatterplot of the number of free throws and salaires appears to have a moderately strong positive correlation of 0.6213. About 38.47% of the variation of salaries can be explained by the number of free throws. Thus the number of free throws a player contributes appears to be a main factor that influence salaries the amount of salaries a player get.

Since basketball is a team game, besides measurements for individual performance such as points and fields goals, other skills that help the team such as rebounds, blocks, assist and steals are also critical. The scatterplot of the number of total rebounds and salary appears to have a moderate positive correlation of

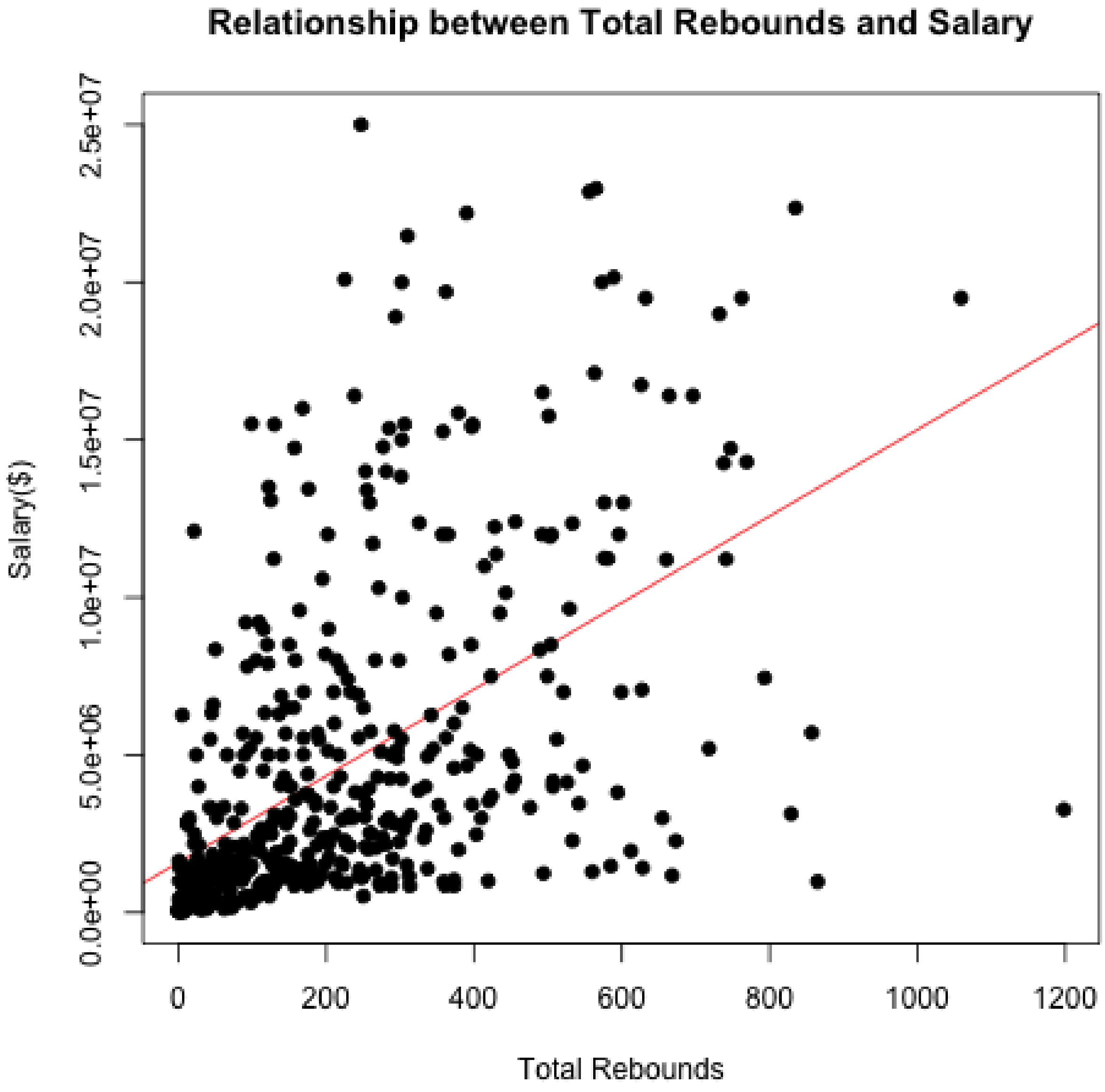


Figure 11: Scatterplot of Total Rebounds and Salary

0.5299. About 27.92% of the variation of salaried can be explained by the number of total rebounds. Thus the number of total rebounds a player contributes may be a main factor that influence the amount of salaries a player gets. We further investigated two types of rebounds: offensive and defensive.

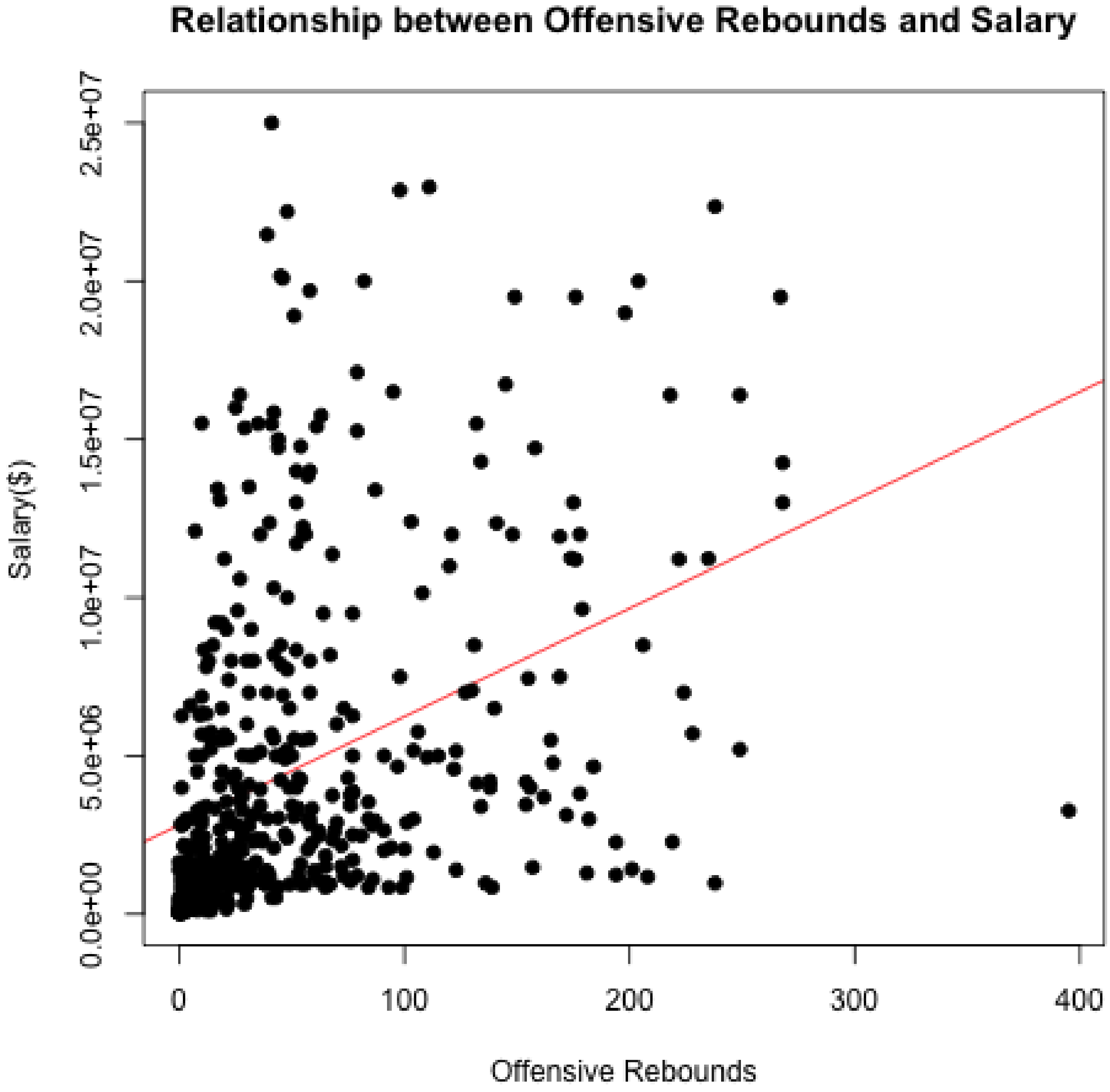


Figure 12: Scatterplot of Offensive Rebounds and Salary

The scatterplot of the number of offensive rebounds and salaires appears to have a weak positive correlation of 0.3935. Only 15.31% of the variation of salaries can be explained by the number of offensive rebounds. Thus the number of offensive rebounds a player contributes does not appears to be a main factor that influence the amount of salary a player gets.

The scatterplot of the number of defensive rebounds and salaires appears to have a moderate positive correlation of 0.5592. About 31.12% of the variation of salaried can be explained by the number of offensive rebounds. Thus the number of offensive rebounds a player contributes appears to be a main factor that influence the amount of salaries a player gets.

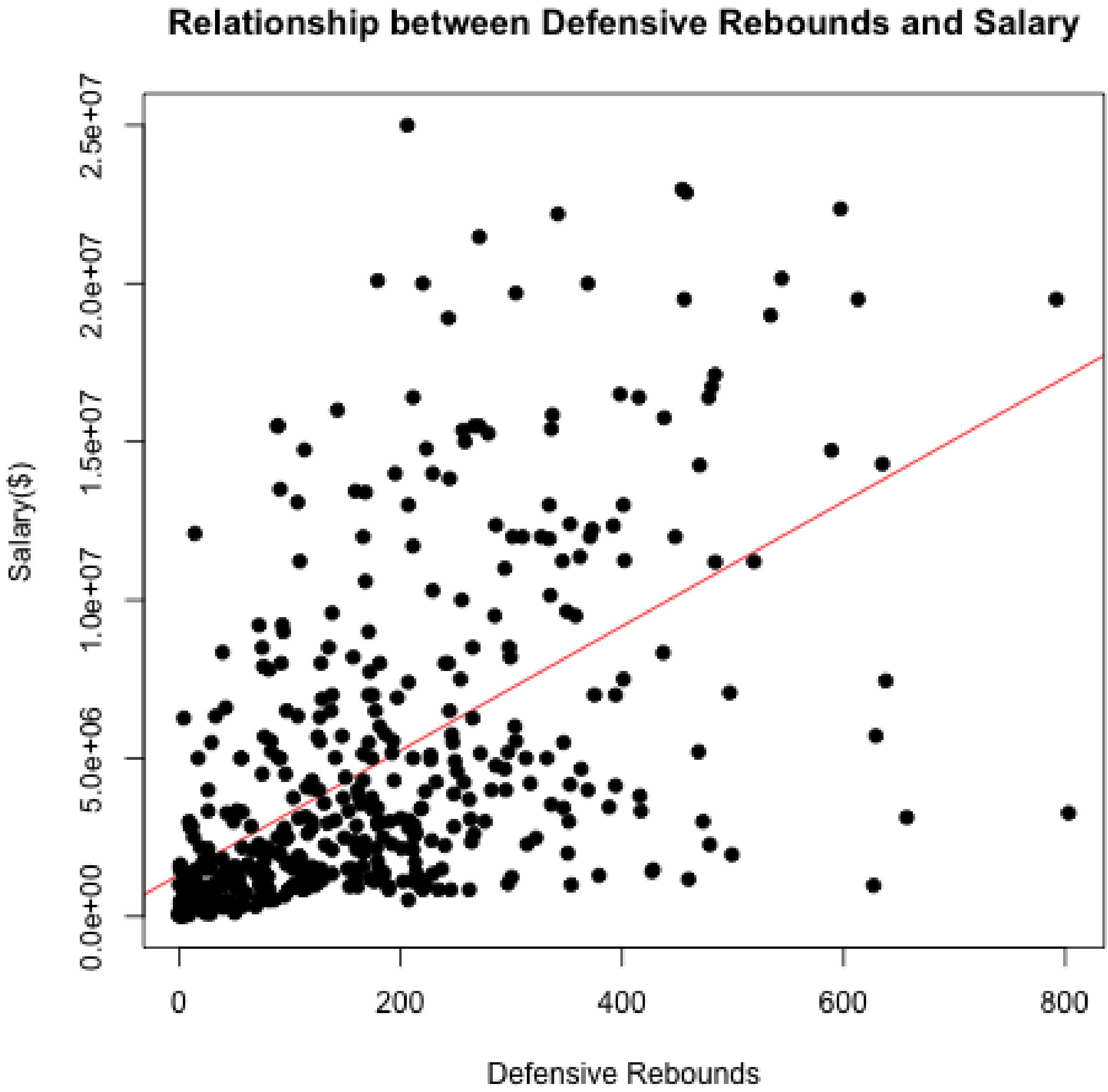


Figure 13: Scatterplot of Defensive Rebounds and Salary

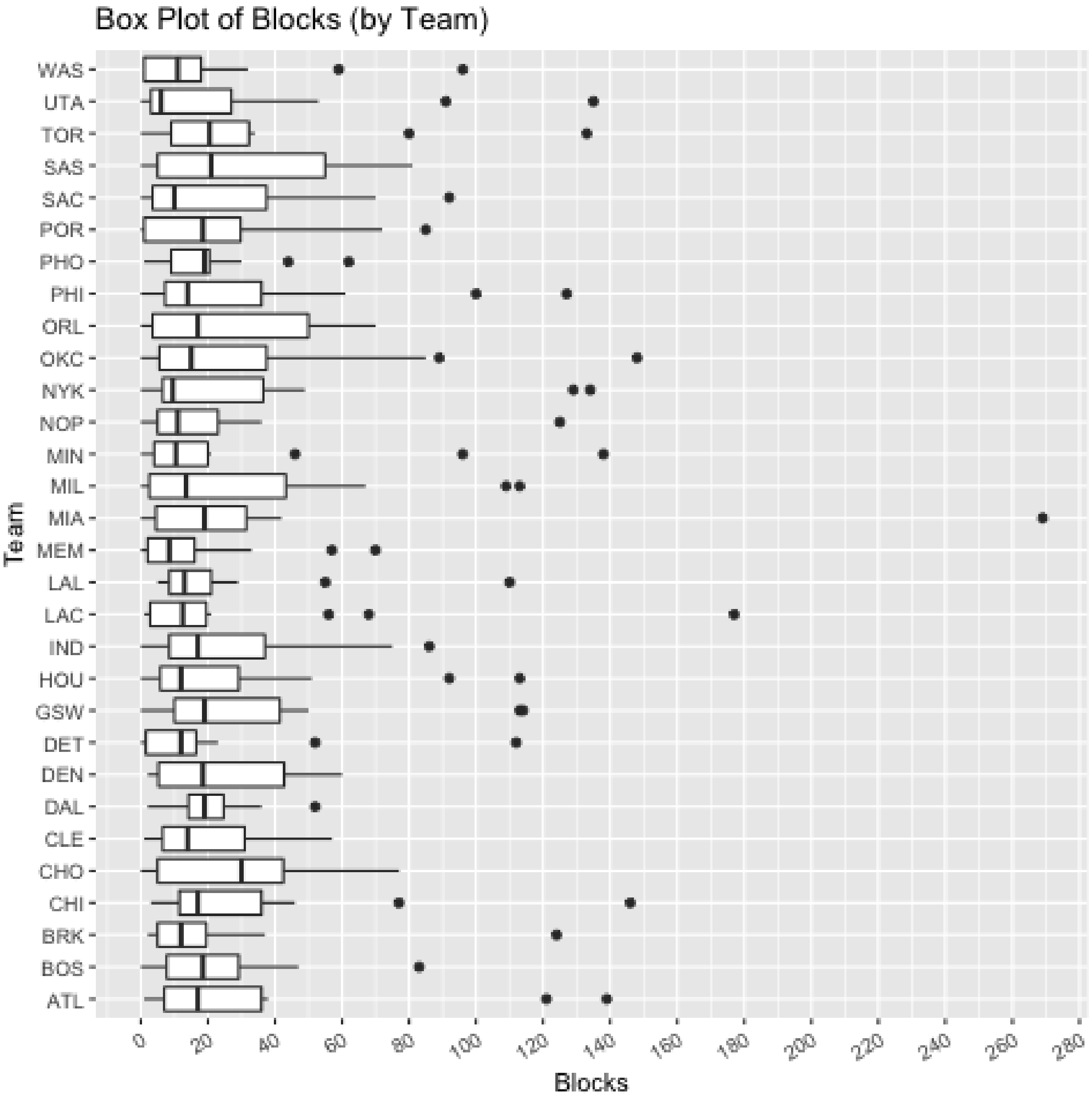


Figure 14: Boxplot of Blocks and Salary

Beside rebounds, a player can also help the team by blocking its opponents shoots. From the boxplot of blocks we can see that most team have average blocks around 20. Team CHO has the highest number of blocks in the season. Many teams have a player that contributes a lot more block than other players in the team that appears to be an outlier in the boxplot. The player who generates the most number of block is Hassan Whiteside (269 blocks) from team Miami Heat (MIA). However, after checking the data, this person does not have a high salary compare to players who scored many points in the season. Thus we decide to check the correlation between blocks and salaries.

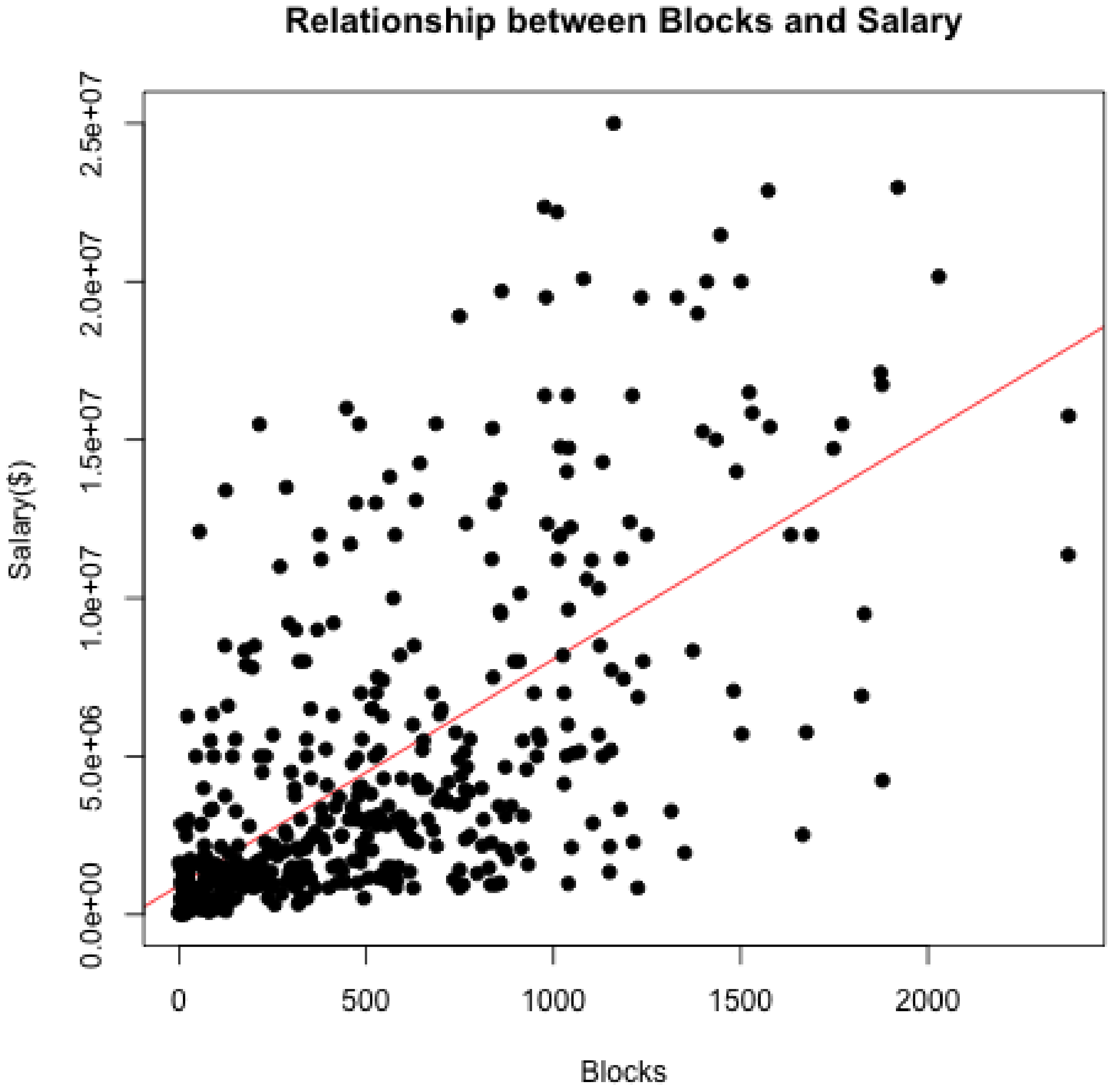
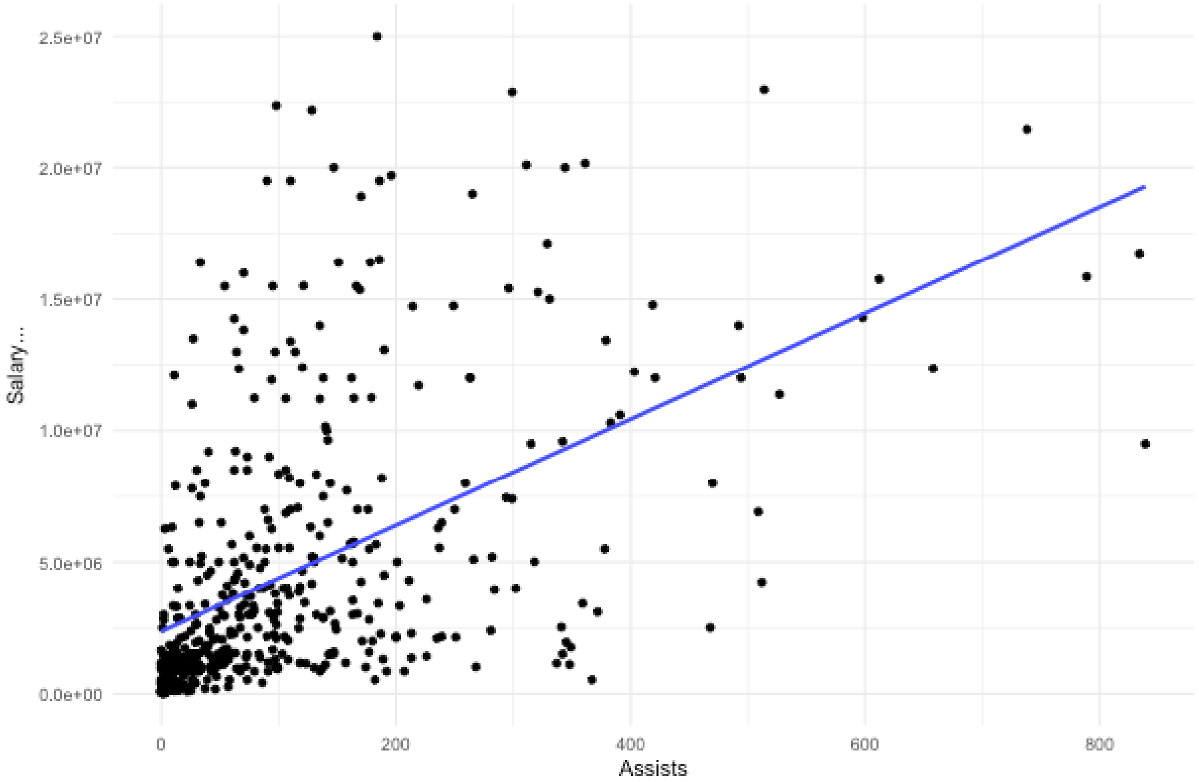


Figure 15: Scatterplot of Number of Blocks and Salary

The scatterplot of the number of blocks and salaires appears to have a weak positive correlation of 0.3589. Only 12.69% of the variation of salaried can be explained by the number blocks. Thus the number of blocks a player contributes does not appears to be a main factor that influence salaries the amount of salaries a player get.



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Correlation Coefficient between Assists and Salary...: 0.513387169472171
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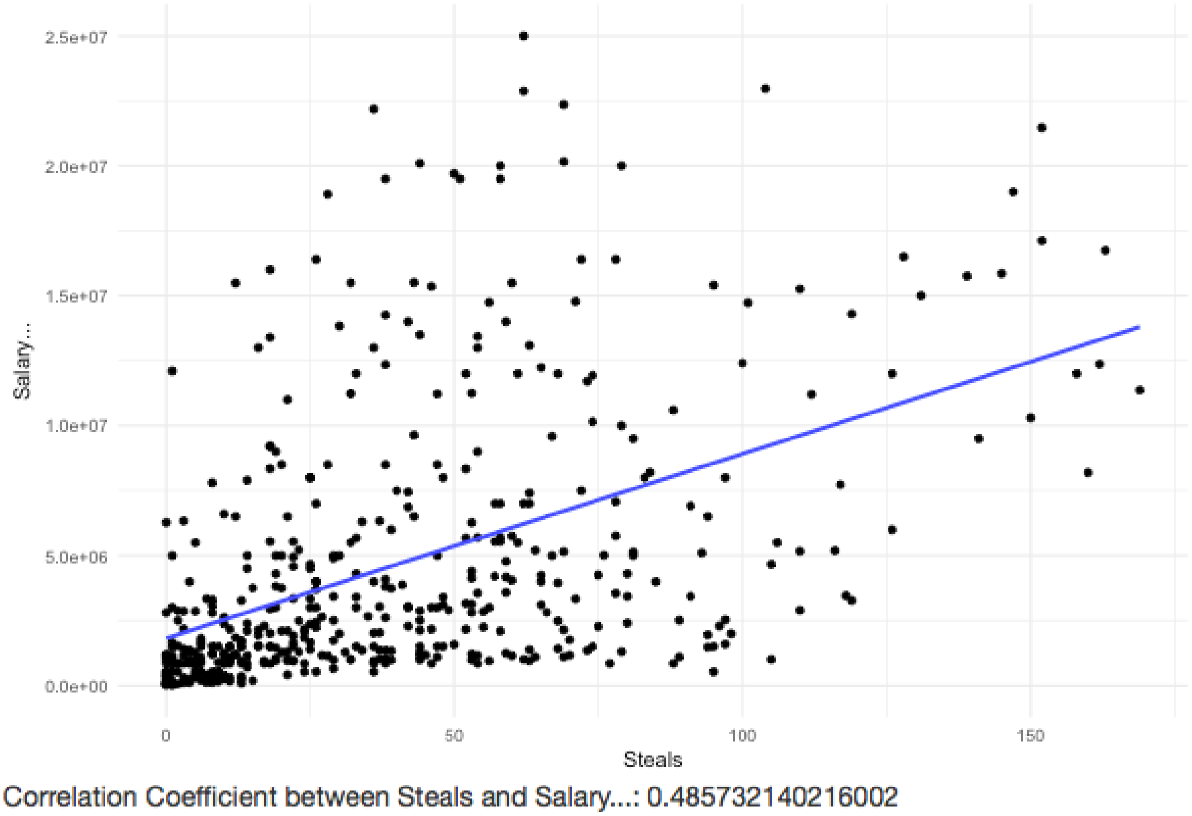
Figure 16: Scatterplot of Number of Assists and Salary

The scatterplot of the number of assists and salary appears to have a moderate positive correlation of 0.5134. Only 26.20% of the variation of salaried can be explained by the number of total assist. Thus the number of assists a player contributes appears to be a main factor that influence the amount of salaries a player gets.



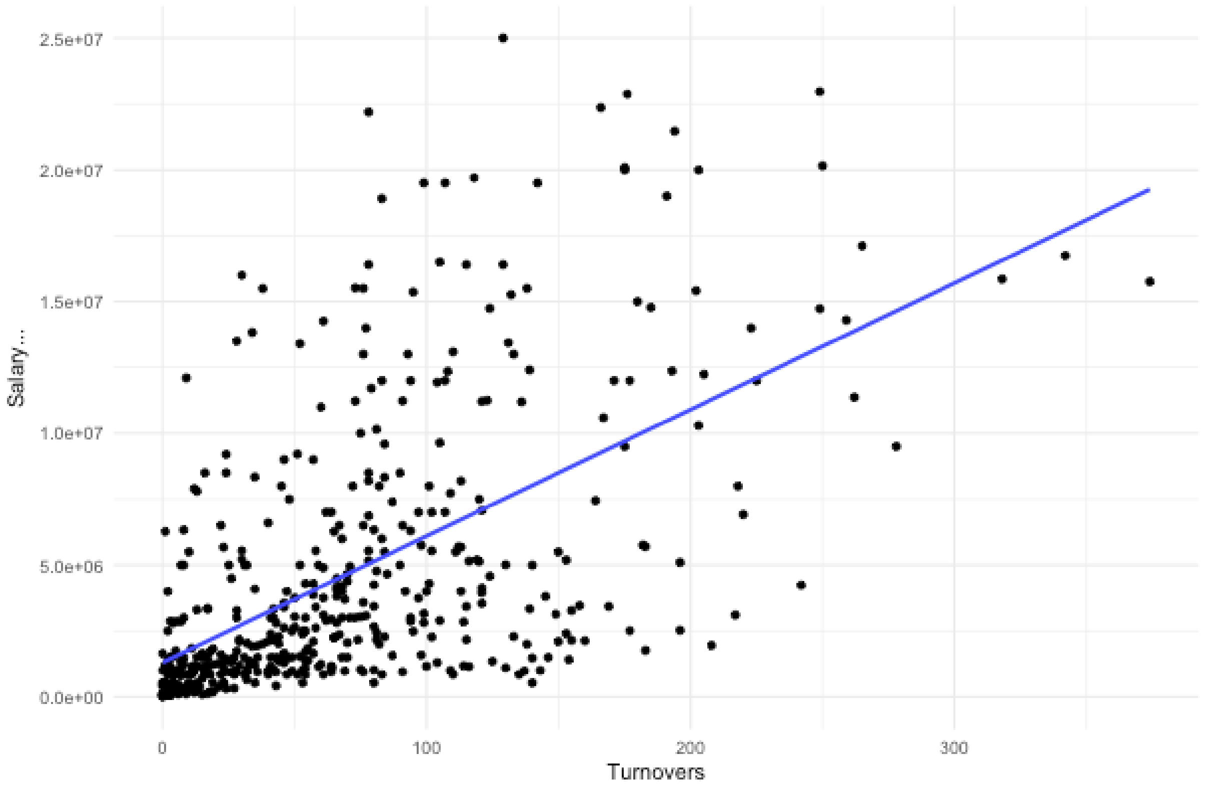
Correlation Coefficient between Steals and Salary...: 0.485732140216002

Figure 17: Scatterplot of Number of Steals and Salary

The scatterplot of the number of steals and salary appears to have a moderate positive correlation of 0.4857. About 23.43% of the variation of salaried can be explained by the number of steals . Thus the number of steals a player contributes may be a main factor that influence the amount of salaries a player gets.

Besides scoring and assistant skills, mistakes players made have surprising relationship with salary. Measurements for mistakes are turnovers and personal fouls. The scatterplot of the number of turnovers and salary appears to have a moderately strong positive correlation of 0.5828. About 33.83% of the variation of salaried can be explained by the number of turnovers. This result is surprising at first because normally people would think the more turnovers player has, the worst his basketball skills is, and thus lower salaries. However, if we think in a different way, it makes sense. Higher turnovers means that the player have more possession of ball, and thus better skills and higher salary. The relatively high correlation means that the number of turnovers a player contributes appears to be a factor that influence salaries the amount of salaries a player get.

The scatterplot of the number of personal fouls and salary appears to have a moderate positive correlation of 0.4451. About 19.64% of the variation of salaried can be explained by the number of total rebounds. Similar as turnovers, this result doesn't make sense at first. However, larger number of personal fouls may also means that the player is aggressive and will probably contributes more points. Teams would want to pay higher salaries for these players. Thus the number of personal fouls a player makes may be a factor that influence salaries the amount of salaries a player get.



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Correlation Coefficient between Turnovers and Salary...: 0.582806909101476
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Figure 18: Scatterplot of Number of Turnovers and Salary

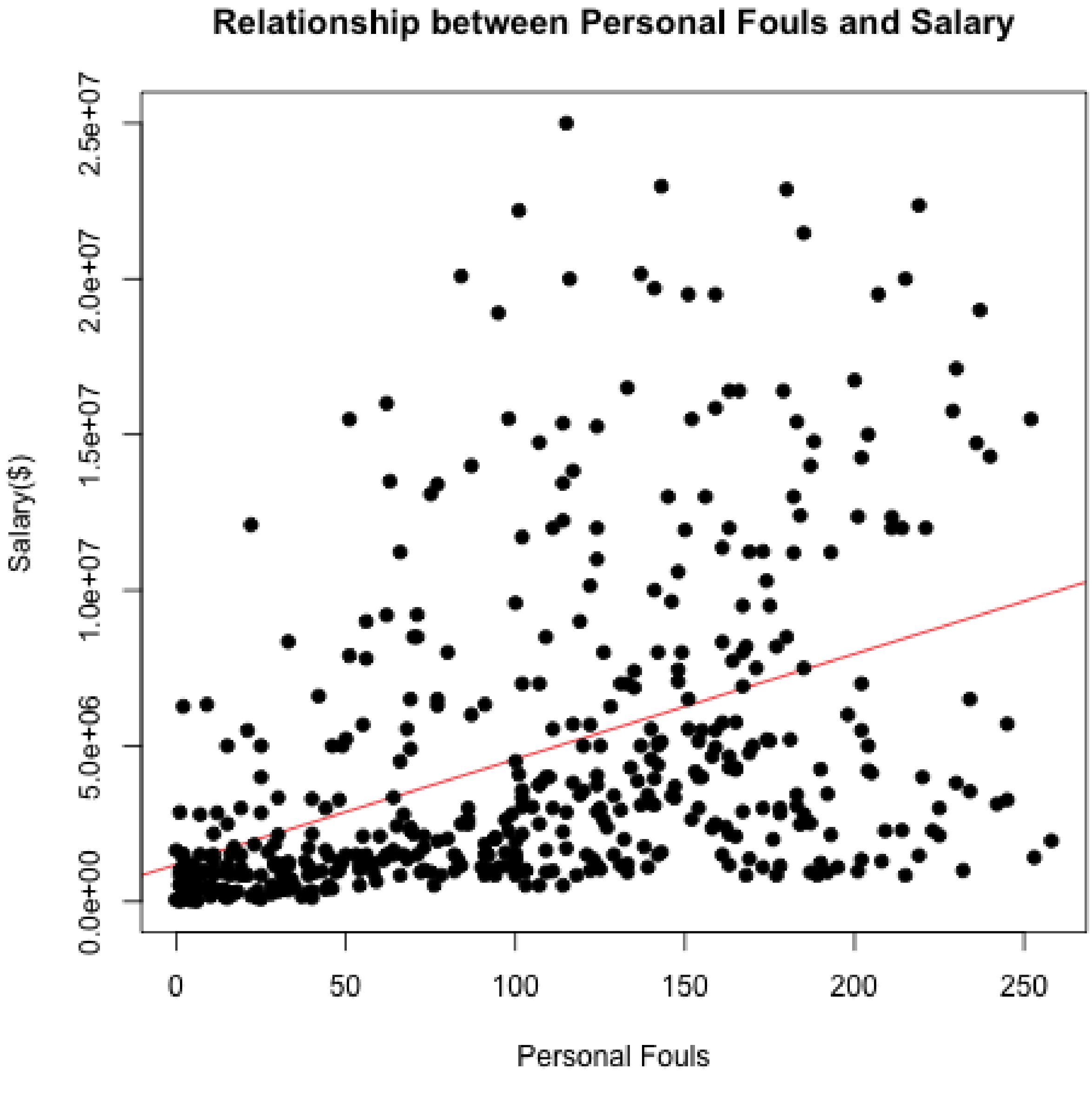
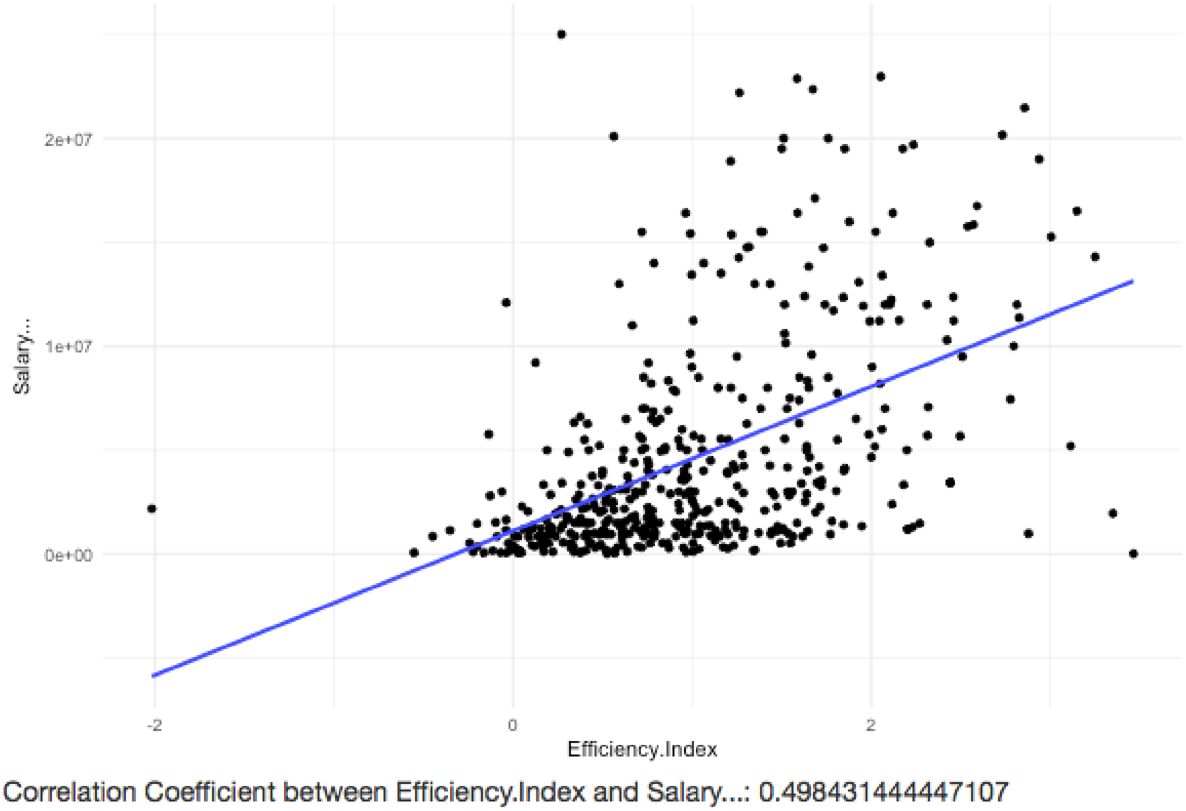


Figure 19: Scatterplot of Number of Personal Fouls and Salary

Efficiency and Value Analysis

Exploratory data analysis of measurements for skills shows that total points, field goals, especially two point goals, and free throws were the three main contributors to player's salary. Moreover, rebounds, especially defensive rebounds, assists, turnovers, and personal fouls are also correlated with player's salary. However, players in different positions have different skill focus. For example, a player who plays in the shooting guard position will have much more number of field points recorded than a player who play in power forward. Thus we further calculated weighted efficiency by position to account the different role each position has. Then we graphed a scatter plot between efficiency and salary to see the relationship between efficiency a player and his salary.



Correlation Coefficient between Efficiency.Index and Salary...: 0.498431444447107

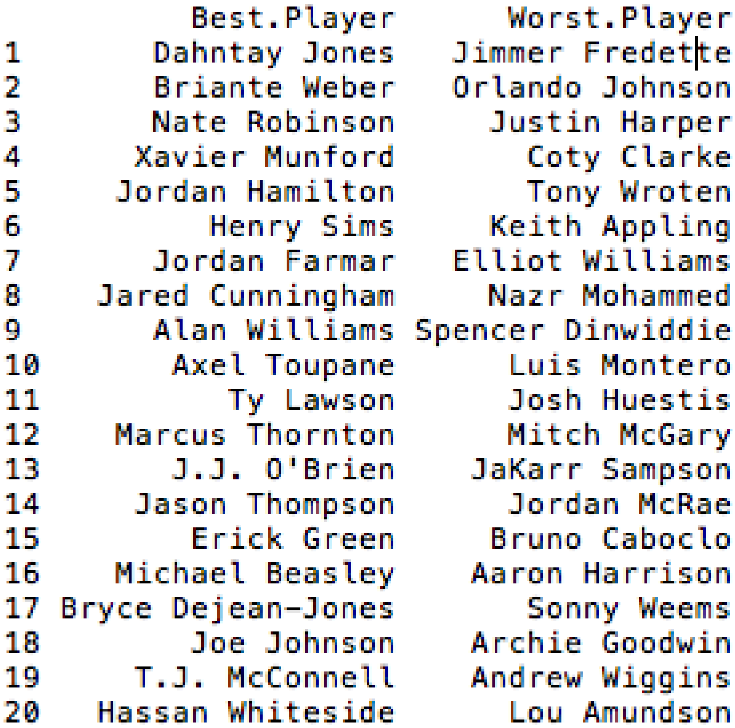
Figure 20: Scatterplot of EFF Indices and Salary

The graph above illustrates the relationship between efficiency of a player and his salary. Each point represents a player and is colored by his position. Hence there are total 471 points across the x axis. The line on the scatterplot is the regression line, which represents the "standard salary" a player should get with different efficiency. Dots above the regression line represents players who receive higher salary than the average salary a player gets with the same efficiency, which may indicates an overpayment. Similarly, dots below the regression line presents players who receive less salary than the average salary earned by players with the same efficiency, which may indicates an underpayment. The further a dot is from the regression line, the more differentiation is the player's salary from the "standard salary".

At the first glance, we observe that dots are pretty spread and there is an positive correlation of 0.498 between efficiency and salary. This means that there is an positive relationship between efficiency and salary, however, efficiency cannot account for all the variations in salaries. In fact, efficiency can only account for about 25% of variations in salaries. After taking a closer look, we can see that the majority of players have salaries below

1 millions. In addition, there are also couple outliers. The most obvious one is a blue dot on top of the graph that represents a player in position small forward who have efficiency less than 0.5 but receives the highest salary. After checking the data set, we found this player to be Kobe Bryant. Another outlier we spotted is a green dot which represents a player in position power guard that has the lowest efficiency but not the lowest salary. After checking the data, we found this person to be Tony Wroten. This two outliers are possible players that get over paid. As for players that might be underpaid, there is a blue dot on the rightmost of graph which represents a play in position small forward that has the highest efficiency (3.464) but gets a extremely low salary ($8819). This player turns out to be Dahntay Jones. However, this player could be an outlier since he only played one games, but out performed a lot of NBA players in the season 2015-2016. After research online, we found that Dahntay Jones has over 10 years of NBA experience and is actually one of the highest paid NBA player, who received 1.5 million salary in year 2015. A possible explanation is that the data on Basketball Reference is wrong. Another player that might be underpaid is Giannis Antetokounmpo who is represented by the green dot on the leftmost of the graph under the regression line. He has the second highest efficiency (3.350) but receive a salary much below the "standard salary". One possible reason is that as a 21 years old player, he is new to NBA. Although people start to see him to shine as the primary player for team Milwaukee Bucks, Giannis still need to play more games to gain attention and show how valuable he is.

Best and Worst Value Players



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            Best.Player      Worst.Player
1         Dahntay Jones   Jimmer Fredette
2         Briante Weber   Orlando Johnson
3         Nate Robinson     Justin Harper
4        Xavier Munford       Coty Clarke
5       Jordan Hamilton       Tony Wroten
6            Henry Sims     Keith Appling
7         Jordan Farmar   Elliot Williams
8      Jared Cunningham     Nazr Mohammed
9         Alan Williams Spencer Dinwiddie
10         Axel Toupane      Luis Montero
11            Ty Lawson      Josh Huestis
12      Marcus Thornton      Mitch McGary
13         J.J. O'Brien    JaKarr Sampson
14       Jason Thompson      Jordan McRae
15          Erick Green     Bruno Caboclo
16      Michael Beasley    Aaron Harrison
17  Bryce Dejean-Jones       Sonny Weems
18          Joe Johnson    Archie Goodwin
19       T.J. McConnell    Andrew Wiggins
20     Hassan Whiteside      Lou Amundson
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Figure 21: List of Best and Worst Value Players

From the list of 20 best and worst players, we can see that the best values player is Dahntay Jones. This make sense because we calculate values using the formula value = efficiency/ salary. Dahntay has the highest efficiency and an extremely low salary. There is no doubt that he will be the best valued player. But as mentioned above, he could is an outlier.

Conclusion

The purpose of this project is to analyze the performance of a player and investigate the relationship between skills and salaries. We found that total points, field goals, especially two point goals, and free throws were the three main contributors to player's salary. Moreover, rebounds, especially defensive rebounds, assists, turnovers, and personal fouls were statistically significant. In regards to assists, teams may be focusing on a player's ability to contribute to scoring. Additionally, in the case of rebounds, a player's value can be enhanced if he is able to either prevent the opponent from another scoring chance by grabbing defensive rebounds and conversely, providing additional scoring chances for his team by grabbing offensive rebounds. Turnovers were also found to be a significant contributor in this study. The reason that a player who has a large number of turnover is that he has more possession of the ball. As for personal fouls, larger number of fouls means this player plays aggressively and maybe able to contribute more points. Thus, a player who does not accumulate fouls is definitely an asset to his team.

Overpaid and Underpaid Players

We further calculated weighted efficiency that accounts for role difference in different positions as a representation of a player's skills. We found a positive relationship between efficiency and salaries and also spotted outliers that represents players who got overpaid and was underpaid. Namely, Kobe Bryant and Tony Wroten may be overpaid since dots represented them are way higher than the regression line. Dahntay Jones appears to be underpaid since he has the highest efficiency but a extremely low salary, however, this could be result from an data error. We believe that Giannis Antetokounmpo is underpaid because he have high second high efficiency but much lower salary than players with even lower efficiency.

Application and Further Analysis

With the burgeoning field of basketball analytics, teams are focusing on a multitude of metrics and developing formulas to determine player efficiency. This practice in theory should influence NBA team management decisions when it comes to determining player salary. This may signal a change in thinking among NBA front office personnel. Further possible analysis is calculating long term efficiency of a player to see his potential and consistency of his performance. Other possible analysis includes relationship between college and efficiency and region and efficiency.