The Valuation of Shots in the NBA

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1 Introduction

The NBA, according to their marketing slogan, is "Where amazing happens." Whether it's Michael Jordan sinking the 2-point jumper that wins him his final championship, or Lebron James carrying his team into the NBA Finals by scoring his team's last 29 points, the NBA thrives on improbable moments. Both of these examples featured an individual largely ignoring his other four teammates and taking inefficient, well-defended shots that happened to go in. However, regression to the mean is real, and neither player can expect to make those plays every night. Thus, the question for NBA teams has always been how to make their "average" game better than everyone else's.

During the 2000s, baseball began to see a proliferation of teams combining advanced statistical analysis with traditional qualitative scouting to help build their teams. By favoring advanced statistics such as on-base percentage (percentage of at-bats that lead to a player getting to base) over batting average (percentage of at-bats that lead to a hit), mathematically inclined general managers (GMs) such as Billy Beane of the Oakland A's were able to find success despite having one of the lowest payrolls in the league [1]. What was once considered taboo was quickly embraced, as other teams began setting up their own analytics department in an attempt to emulate Beane's success.

Copying a successful tactic is common throughout sports, and like the transformation of baseball due to analytics, advanced statistics is beginning to change the way basketball is played. Led by Daryl Morey, the GM of the Houston Rockets, some teams have began using advanced statistics to inform their in-game strategy. By considering the field goal percentages of different zones, not just overall field goal percentage, Morey realized that certain shots are more valuable than others. For example, making a shot just behind the 3-point line is essentially just as difficult as making a shot just inside the 3-point line, yet the former earns a whole extra point. The Rockets transformed their offense completely, taking only 3-pointers and shots close to the basket, while largely avoiding long-range two pointers.

Although the Rockets have yet to win the NBA championship under Morey, they have been quite successful, with a winning percentage of .568 since Morey joined the team in 2007, and more impressively, never going below .500. This came despite having to rebuild the team due to the departures of Hall-of-Fame level talents in Yao Ming and Tracy McGrady in 2010, losses that would have devastated most teams.

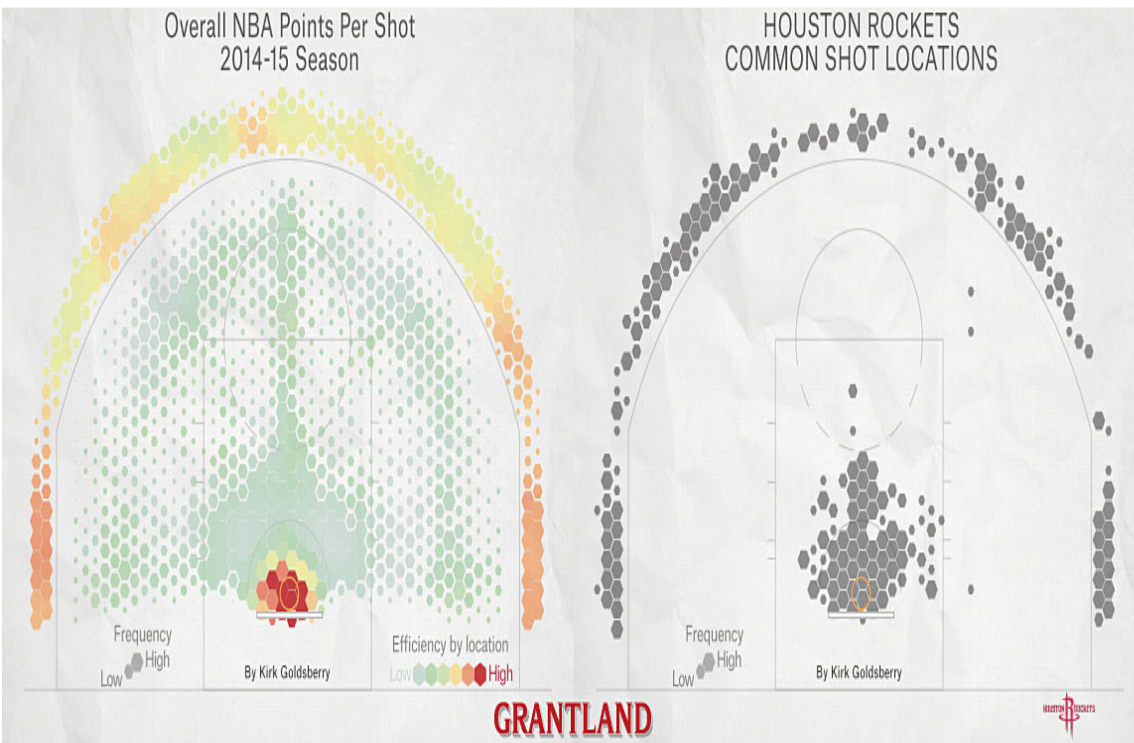

Figure 1: NBA Points per Shot vs. Rockets Shot Chart

The left side of Figure 1 provides a nice look at what shots are most valuable in the NBA. The hexagon sizes represent shot frequency, so the more shots taken in a particular region, the larger the hexagons. Hexagons are colored such that the most efficient shots relative to each region in terms of percentage made are colored red, while the least efficient are colored green. It is clear that interior close-range shots and 3-pointers have the highest expected points per shot in the NBA, but it seems that NBA teams still do not take enough 3 point shots. Figure 2 shows that only 25.5% of shots taken are 3-point shots, compared to 33.2% for mid-range[1] 2-point shots.

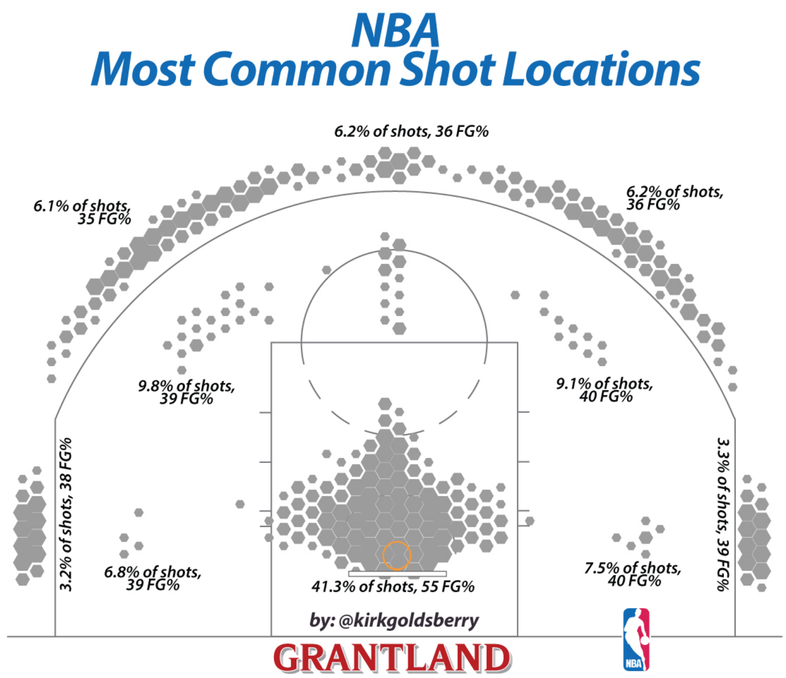

Figure 2: NBA Shot Chart

Judging from Figures 1 and 2[2], it appears that the average NBA team might be undervaluing the 3-point shot. A cursory glance at the past two NBA champions seems to support the value of good 3-point shooting[4]. The Miami Heat and the San Antonio Spurs played each other in both the 2012-2013 Finals and the 2013-2014 Finals, with the Heat winning the former and the Spurs winning the latter. There are numerous similarities between the two teams. Both have payrolls heavily invested in three star players: Lebron James, Dwayne Wade, and Chris Bosh for the Heat, and Tim Duncan, Tony Parker, and Manu Ginobli for the Spurs. Yet despite the large investment in only 3 of the max 15 players a team can have under contract, both teams were able to fill in the remaining roster spots with productive players

[1]Mid-range jumpers are considered those that are taken in the region between the rectangular area surrounding the basketball, known as the "paint" or "post", and the 3 point line.

[2]Figures 1,2 are pulled from [2] and [3] respectively

while remaining under the league-mandated salary cap. Both teams also happen to embrace the 3-point shot, surrounding their star players (who focus on close-range shots), with inexpensive yet accurate 3-point marksmen. These sharpshooters have led to another trend in the NBA: the emergence of the "3 and D" player. As the name suggests, these players' main role is to be able to shoot 3 pointers and play strong defense. Is it a coincidence that these two teams both seem to be constructed in similar fashion? Or is this evidence of two teams taking advantage of an undervalued asset, the three pointer, to achieve consistent success?

This paper aims to test the hypothesis that the 3-point shot has been undervalued in the NBA. To test this hypothesis, we will use Kirk Goldsberry's ShotScore statistic[5], a statistic that measures how many more points a team or player produced compared to an average NBA team or player based on their shot selection. By using ShotScore for each of the three ranges (close-range, mid-range, and 3-point), we can see how being effective from each of the ranges affects a team's win total as well as a player's salary. The paper will be structured as follows: Section 2 will explain the ShotScore statistic in greater detail. Section 3 will be an overview of the data set used as well as the methodology of the regressions. Section 4 will present the results of the regressions.

2 NBA Shooting Overview

On the surface, the value of a 3 pointer comes from the fact that it is 1.5 times more valuable than a 2 pointer. However, tactically, just the threat of a potential 3 point shot creates value for a team. As we saw in the introduction, the most effective shots in basketball are those close to the rim, such as a slam dunk. However, professional defenses are well aware of this, and focus on preventing such close-range shots. If a team lacks shooters, a defense can congregate closer to the hoop, denying the offense any space to get to the basket, and daring the offense to take long-range shots. Thus, having the threat of being able to make 3 point shots allows an offense an easier path to the rim by forcing defenses to spread out.

There is a further wrinkle in 3 point shooting: not all 3 pointers are the same. As we see from the court shape seen in figure **??**, the NBA 3 point line is not a semi-circle. It straightens out at the edges. Thus, the curved portion of the 3 point line is almost 24 feet from the basket while the straight portion is only 22 feet from the basket. Because of their location, these shorter 3 point shots are labelled as corner 3 pointers. Thus, there is the possibility of taking a shot 23 feet from the basket and earning only 2 points while a corner 3 is closer to the basket and earns 1.5 times more points. Thus, even a player who struggles with the longer 3 point shot but can consistently make the corner 3 would provide great value for an offense's strategy. As we will see in later, the Miami Heat had great success exploiting the corners, as they were the best team at shooting corner 3 pointers but mediocre at other 3 point locations.

2.1 ShotScore Overview

When it comes to measuring shooting efficiency in basketball, traditionally there has been a trade-off between accuracy versus volume. Ideally, a good statistic for shooting proficiency would reward taking a large number of shots with high accuracy. However, most shooting stats solely focus on accuracy. DeAndre Jordan led the league during 2013-2014 in effective field goal percentage with an eFG[3] of .676 based largely on dunking the ball 4 or 5 times a game. Meanwhile, Kevin Durant, the 2013-2014 league NBA MVP, had an eFG of .560, but with a much larger number of shots and arguably higher degree of difficulty. So while Jordan led the league in the statistic most commonly used to measure shooting accuracy, it's hard to convince any casual fan of the game that Jordan is a better shooter, even close to the basket, than Durant.

In fact, looking at Figures 3 and 4[4], if Durant solely focused on taking shots right next to the basket, he would probably have an eFG much higher than .676. The figures here are very similar to the ones previously seen. The larger the squares, the more shots taken in a particular area. Red shots are made at an above average rate, while blue shots are below average.

While eFG does a decent job of measuring shooting proficiency since it measures how accurate you are, its weakness is the inability to account for shooting volume. To account for shooting volume, Harvard professor Goldsberry came up with the ShotScore statistic. The ShotScore statistic essentially compares the points scored by a player to the points a league average player would have scored taking the same shots.

[3]eFG accounts for the fact that a 3 point shot is 1.5 times more valuable than a 2 point shot. $\text{eFG\%} = \dfrac{\text{Field Goals Made} + 0.5 \cdot 3 \text{ Pointers Made}}{\text{Field Goals Attempted}}$

[4]Courtesy of [6]

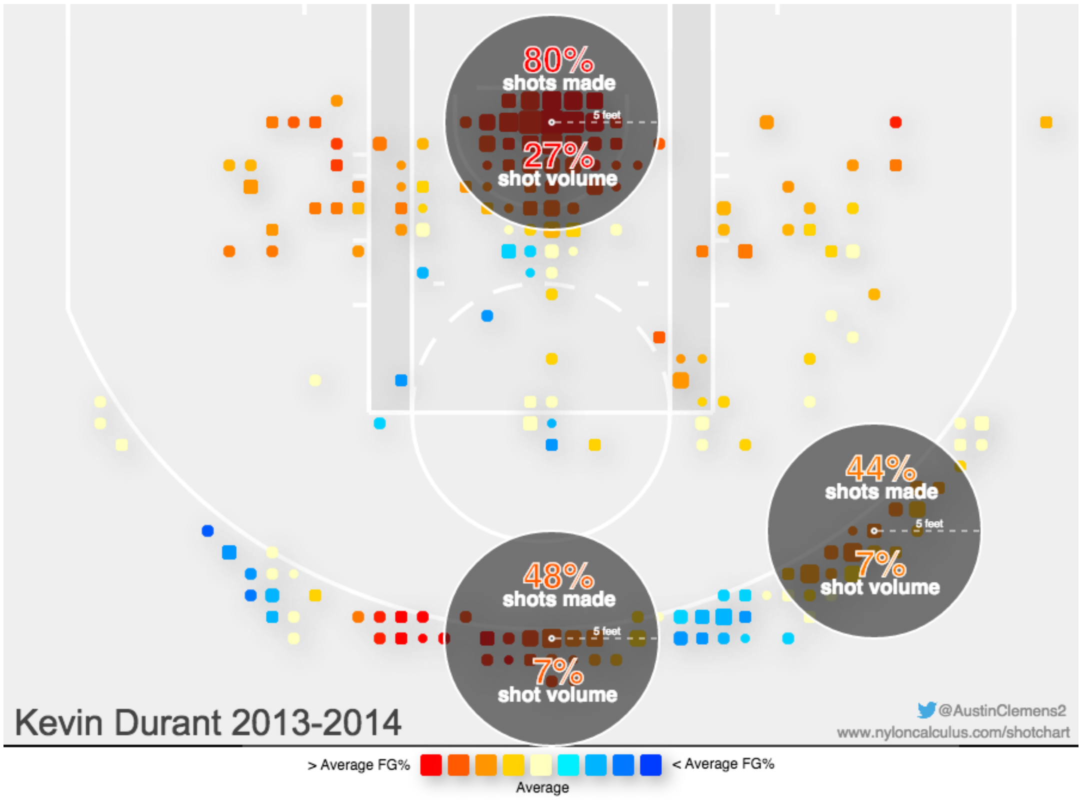

Figure 3: Kevin Durant Shot Chart

$$\text{ShotScore} = p \cdot \text{FGA}_{region}(\text{FG\%}_{region} - \text{FG\%}_{region,\text{NBA}}) \tag{1}$$

In the equation, the NBA subscript indicates the statistic is the league average value. $FG\%$ denotes the field goal percentage, while FGA denotes the number of field goals attempted. p is equal to 2 if the region is within the 3 point line, and is equal to 3 if outside the line. To get a positive ShotScore, you just to have to be more efficient than the league average. However, to get a high ShotScore, you would need to have both a high FGA and a high $FG\%$ relative to the league average. This is exactly what we were looking for in a statistic to measure shooting proficiency, as it deals with the trade-off between volume and efficiency. Consider Kyle Korver, perhaps the best 3-point shooter in the game. Kyle Korver made 185 3 pointers in the 2013-2014 season with a percentage of .472. His 3 point ShotScore is 131.712. Now consider a hypothetical NBA player who never misses a 3 pointer. Such a player would have to

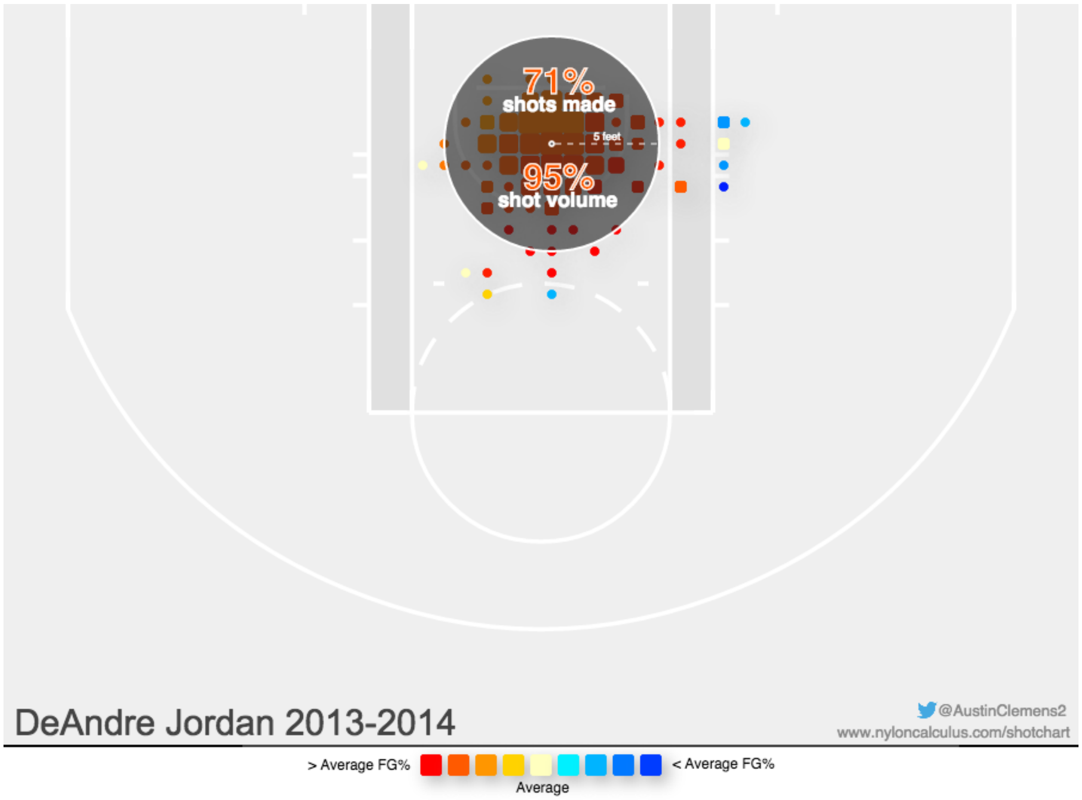

Figure 4: DeAndre Jordan Shot Chart

take 69 3 Pointers and never miss in order to match Korver. Only 4 players in the 2013-2014 season made all of their 3 pointers last season, and for each of them, that was their only 3 point attempt. With ShotScore, we can truly see how mind-boggling Korver's[5] blend of accuracy and volume is.

We calculate ShotScores for each region of the court: shots taken $0-3$ feet from the rim, $3-10$ feet, and so on. We then add up the component ShotScores to get an aggregate total. With ShotScore, we not only have a good idea of who the most efficient and proficient shooters overall are, but also for each region of the court. Let's go back to our comparison between Jordan and Durant and their shooting proficiency close to the basket. Kevin Durant took 367 shots in the region 0-3 ft. from the basket. He had a FG% of .798 in this region. The league average was .636. Therefore we calculate:

[5]For the record, Korver had the highest 3 point ShotScore in 2013-2014.

$$2 \cdot 367(.798 - .636) = 121.8$$

For comparison, Jordan had a ShotScore of 68.2 for the same region, a region that is responsible for his league-leading shooting accuracy. Jordan took 421 shots in this region, which is not that much higher than Durant's number of attempts considering the standard deviation for FGA in the 0-3 ft. region is 114.21.

It is easy to calculate team ShotScore as well. Instead of player FGA and $FG\%$, we can just use the same statistics but for the team instead. Thus, we can calculate how proficient each team is at shots in each region of the court.

3 Data & Methodology

3.1 Data

For the analysis we have taken team data from the 2006-2007 NBA season through the 2013-2014 NBA season. The website basketball-reference.com [7] provides all in-game statistics such as relevant shooting percentages, as well as assists, rebounds, and other performance statistics. We have also compiled individual data for this time range of players who made more than 200 field goals in a given season. The reason 200 was chosen as the cutoff was because the minimum requirement to qualify for the leaderboard for field goal percentage is 300, but this excluded many players who played enough minutes to qualify for the league minutes leaderboard. On the otherhand, there are some players who played just enough minutes to qualify for the minutes leaderboard, but there is no salary information on these players. Thus, as a compromise, 200 field goals was chosen.

Tables 1 and 2 provide an interesting look at the league under the frame of ShotScore. In 2006, the top 3 teams in ShotScore were also the 3 winningest teams in the league, while the top 3 teams in 2014 all made the playoffs, with the top 2 playing in the NBA Finals as mentioned previously. Likewise, generally teams with a low total ShotScore seem to be pretty bad, with the exception of the 2014 Chicago Bulls, who made the playoffs despite terrible shooting numbers. The Bulls however were the second best team that year in terms of defensive rating, so it appears their defensive prowess allowed them to get away with awful offense. Although being good at shooting obviously helps a team win games, the Bulls show that there are plenty of other ways

Team Name	Corner 3 SS	Other 3 SS	Total SS	Wins	League Rank	Payroll
Phoenix Suns	118.99	37.91	541.7	61.00	2	65399240
San Antonio Spurs	39.61	16.45	265.5	58.00	3	65327646
Dallas Mavericks	-9.67	32.67	204.2	67.00	1	88531846
New York Knicks	-21.50	-8.82	-221.5	33.00	22	117024192
Charlotte Bobcats	0.00	-4.99	-247.3	33.00	21	41689161
Atlanta Hawks	-8.67	-26.56	-296.6	30.00	27	48456234

Table 1: 2006 Top 3 and Bottom 3 Teams by ShotScore

Team Name	Corner 3 SS	Other 3 SS	Total ShotScore	Wins	League Rank	Payroll
San Antonio Spurs	31.56	148.84	474.6	62.00	1	63810698
Miami Heat	79.68	-87.84	438.8	54.00	7	80707960
Dallas Mavericks	24.68	120.69	398.2	49.00	10	67285965
Chicago Bulls	-6.74	-43.27	-361.4	48.00	13	71043080
Detroit Pistons	7.15	-193.66	-431.4	29.00	23	61897253
Philadelphia 76ers	-63.01	-192.5	-593.11	19.00	29	53308029

Table 2: 2014 Top 3 and Bottom 3 Teams by ShotScore

to win a game. Still, the correlation between Total ShotScore and win percentage is .646, indicating a potential strong positive relationship between ShotScore and team success.

The 3 point ShotScore statistics also lend to some interesting observations. Again, the top teams in ShotScore were generally very good at the 3 point shot. This is supported by the correlation of .440 between aggregate 3 point ShotScore and win percentage. As discussed previously, the 2014 Spurs and Heat were built to surround their talented stars with excellent shooters. For the Heat, their shooters were not very good at shots outside the corners, and the negative ShotScore shows that the Heat's offensive system encouraged players to take these shots even though they weren't very good at them. However, this was almost offset by just how good they were at making those corner threes. Meanwhile, the bad teams in both seasons were not very good at 3 point shooting, but even more so in 2014. This suggests in 2014 more teams were encouraging 3 point shots even though their team wasn't great at making those shots. For example, 25.8% of the 76ers' field goal attempts were 3 pointers, which ranks just below the league average of 25.9%. However, the 76ers finished dead last in percent 3 point goals made, making 31.2% of their 3 point attempts, compared to the league average of 36%.

3.2 Methodology

For the analysis, we performed two regressions, one for player salary and one for win-loss percentage. Win-loss percentage is the percentage of games that a team won.

3.2.1 Wins Regression

$$\text{W/L\%} = \beta X + \beta_1 \text{ss}_r \tag{2}$$

X is a vector of performance variables. It includes assists per game, rebounds per game, defensive rating, pace, turnover percentage, and free thow factor. These account for the measurable statistics that help a team win besides scoring. These statistics try to measure team performance adjusted for pace. Pace is a pretty important statistic describing the number of possessions a team has per game. Pace can heavily influence a team's traditional statistics such as points scored. For example, a team playing at a high pace can score a lot of points purely because it has more chances to make a basket. To measure a team's defensive capabilities, we use defensive rating, which measures the average number of points a team gives up in 100 possessions. Turnover percentage measures the percentage of possessions that result in turnovers. Finally, free throw factor is the average free throws made per field goal attempt. This measures how often a team can get to the free throw line and then make the free throws.

ss_r refers to the respective ShotScore for region r. We will be looking at 6 different regions: shots taken 0-3 feet, 3-10 feet,10-16 feet , and 16-23 feet within the basket, as well as corner 3 point shots and all other 3 point shots. We will check for heteroskedasticity and linearity of the regressors with a Breusch-Pagan test and a Ramsay RESET test respectively.

X and ss_r were both standardized within seasons. This would allow us to make true comparisons between different statistics and their impact on win percentage. For example, it's hard to compare increasing rebounds per game by one with increasing ShotScore by one, but normalizing these variables would allow us to compare how improvements in the two relative to the league average would affect win percentage. Standardizing also accounts for variation between seasons, as a statistic considered high in one season might be average in another.

Finally, we treat each season as independent. This follows the methodology used by Hakes and Sauer[8] in their analysis of the undervaluation of on-base percentage. In that paper, Hakes and Sauer examined the effect that on-base percentage had on team's winning percentage. They aggregated data from the 1999-2003 seasons, and ignored the time component. The argument is that there is so much variability across seasons that the seasons can be seen as independent. For example your team can have arguably the greatest basketball player of all time in Michael Jordan retire from basketball in his prime to play minor league baseball for two years. Losing a player of that caliber would completely change a team. Likewise, any combination of injuries, retirement, new acquisitions, coaching changes, etc. means that a team is unlikely to be the same as the previous season's version.

3.2.2 Salary Regression

$$log(\text{Salary}) = \beta X + \beta_1 \text{ss}_r + \beta_2 \text{Year} + \beta_3 \text{Post} + \beta_{textFA} \tag{3}$$

For this regression, we get the salary for year t, and then all other data comes from year $t-1$. This is because a salary is given as a result of prior performance, and therefore more indicative of how a team valued a player. X is once again a set of performance variables, but slightly different from team data. X includes assist, rebound, and turnover percentages, free throw factor, minutes played, and defensive win shares. Because players themselves don't have pace statistics to control for how quickly a player's team plays, we use player assists, rebound, and turnover percentages. These percentages are estimates of the percent of total opportunities to collect a relevant statistic accumulated by a player while he was playing. For example, assist percentage would be the percent of field goals made assisted by the player during the minutes he was on the floor. Also, because defensive rating does not accurately reflect an individual player's contribution on defense, we have to use a different metric for defense. Measuring a player's impact on defense is still one of the biggest questions in basketball analytics. Here we use the current widely used advanced metric for defense: defensive win shares. Defensive win shares is an estimate of the number of wins a player contributed to his team due to his defensive play[6]. Finally free throw factor is calculated the same way as it was for team data.

We have also added a number of dummies to account for variation in salary. The most important dummy is the dummy for whether a player is eligible for free agency or not. A player's salary is capped during his first four years, After the fourth year, the player is eligible for restricted free agency, where teams can offer the player a new contract, but the player's original team can choose whether or not to match it and keep the player. If a player doesn't sign a new contract during this year, the player is eligible for unrestricted free agency, and can choose to sign for any team. For simplicity, a player that is in his fifth year or higher will be classified as eligible to be a free agent, since the salaries for the restricted and unrestricted free agency are both significantly higher than salary during the first four years.

In the NBA, a taller player tends to be valued higher than a shorter player simply because height can not be controlled, and rarely improves. Thus, we also include a dummy for players considered power forwards and centers, also known as post players, because these players tend to be the tallest players on the team. In our data set, the mean salary for a post player was $8.5 million, while on average non-post players earned $6.8 million.

Finally, following the methodology used by Hakes and Sauer, we include dummies for each season of the data set to account for time effects.

4 Results

4.1 Wins Regressions

Table 3 examines the effect of Total ShotScore on win percentage. Because the variables were standardized, the interpretation of the coefficients is as follows: an increase in the variable by one standard deviation is associated with a change of β

[6]See the appendix for information on how to actually calculate the player-specific metrics

	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	0.5000	0.0048	104.63	0.0000
Total ShotScore	0.0724	0.0059	12.30	0.0000
Rebounds per game	0.0342	0.0056	6.16	0.0000
Assists per game	0.0158	0.0058	2.70	0.0073
Defensive Rating	-0.0647	0.0060	-10.82	0.0000
Pace	-0.0214	0.0058	-3.67	0.0003
Turnover %	-0.0309	0.0051	-6.03	0.0000
Free Throw Factor	0.0404	0.0051	7.95	0.0000

Table 3: Wins Regression with Aggregate ShotScore

	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	0.5000	0.0047	107.17	0.0000
0-3 Ft. ShotScore	0.0377	0.0055	6.80	0.0000
3-10 Ft. ShotScore	0.0161	0.0053	3.04	0.0027
10-16 Ft. ShotScore	0.0065	0.0057	1.14	0.2575
16-23 Ft. ShotScore	0.0163	0.0058	2.80	0.0055
Corner 3 ShotScore	0.0122	0.0053	2.32	0.0213
Other 3 ShotScore	0.0287	0.0055	5.23	0.0000
Rebounds per game	0.0332	0.0055	5.99	0.0000
Assists per game	0.0162	0.0057	2.83	0.0050
Defensive Rating	-0.0635	0.0059	-10.71	0.0000
Pace	-0.0244	0.0060	-4.07	0.0001
Turnover %	-0.0310	0.0051	-6.12	0.0000
Free Throw Factor	0.0408	0.0050	8.13	0.0000

Table 4: Wins Regression with Shot Score by Region

on the mean win percentage of the team. Thus an increase in Total ShotScore by one standard deviation is significantly associated with a .0724 increase in a team's mean win percentage. It appears that Total ShotScore has a strong effect on winning percentage, and it has the largest absolute effect of any variable in our regression. The other variables behave like we expect. Rebounding and assists should make positive impacts on winning percentage because the more rebounds you have the more possessions you get, while assists are passes that led to made shots. Meanwhile, the higher defensive rating you have, the more points you are giving up to the other team, so the negative association between defensive rating and win percentage is also expected. Turnovers result in a wasted possession for your team and a new possession for the opponent, so once again it's not surprising that it has a negative association with win percentage. Finally, free throw factor describes how often a team gets to the free throw line and makes its free throws, so a high free throw factor means a higher number of a team's possessions end in uncontested shots from the free throw line. Since free throws for most NBA players are easier than shots taken while being guarded by a player, it's not surprising that free throw factor has a positive association with win percentage. The big surprise is pace having a negative association with win percentage. Conventional thinking would have talented teams trying to play at a high pace, because having more possessions would allow them to exploit their skill advantage more often. Perhaps the negative association is due to the difficulty in maintaining a high pace considering the endurance required, as well as the possibility that only a few elite teams can properly exploit the advantage that more possessions give them.

In table 4, we break up Total ShotScore into regional ShotScores. The results indicate that the efficiency in shots taken 0-3 feet from the basket have the largest positive association with mean win percentage. An increase by one standard deviation in the ShotScore of these types of shots is associated with a .0377 increase in the mean win percentage of the team. As we've discussed earlier, close-range shots are the most effective shots in the game, and the ShotScore coefficient for this region reflects this. The region with the second largest positive association is 3 point shots not taken from the corner. Increasing ShotScore from this region by one standard deviation is associated with a .0287 increase in the mean win percentage. This supports the thinking that 3 point shots are the second most effective shots in the game. However, it is surprising that it is this region, and not corner 3 pointers, that is the second most impactful region. This is because as figure 1 showed, the corner 3 generates the second most expected points per shot. Furthermore, not only does the corner 3 ShotScore not have the second largest association with mean win percentage, it is actually second to last. Perhaps even though corner 3 point shots are very effective, teams have yet to figure out how to generate more of these shots. After all, the corners are a tiny portion of the court, and a high ShotScore also requires a high volume of shots taken. Finally, 3-10 Ft. ShotScore has no significant association with mean win percentage, which suggests that these proficiency in shots from this region is not too helpful for a team.

	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	14.74	0.06	262.51	0.00
Post	0.24	0.06	4.03	0.00
Minutes Played	0.16	0.02	8.06	0.00
Free Throw Factor	0.15	0.02	9.17	0.00
Total Rebound %.	0.12	0.03	3.81	0.00
Assist %.	0.24	0.02	11.43	0.00
Turnover %	-0.11	0.02	-5.69	0.00
Defensive Win Share	0.05	0.02	2.56	0.01
Free Agent	0.91	0.04	24.31	0.00
Total ShotScore	0.08	0.01	5.30	0.00

Table 5: Salary Regression with Aggregate ShotScore

4.2 Salary Regressions

Table 5 shows the results for the salary regression with the aggregate ShotScore. The interpretation of the non-dummy coefficients is very similar to that of regression 2. An increase by one standard deviation from the mean of a particular statistic is associated with a β percentage increase in the player's salary. Here much of the performance statistics and dummies perform as we expected. We see that the statistics that had a positive relationship with win percentage also have a positive relationship with salary, and vice versa. Furthermore, the dummies that we included, the Free Agent dummy and the Post dummy, also behaved as expected. Since players eligible for free agency don't have capped salaries, they should have higher salaries, and the regression results reflect this. In fact, being a free agent appears to be significantly associated with an increase of 91% in player salary, or almost doubling the player's value. Meanwhile, the premium commanded by post players is also reflected, as being one is significantly associated with an increase of 21% in player salary. Finally, the seasons dummies were all insignificant on the 5% level, and really were irrelevant for our analysis. Following Hakes and Sauer's lead, we omit the coefficients for the seasons dummies.

It is interesting to note that the two metrics that have the smallest effect on player salary, defensive win share and ShotScore, have the largest effect on win percentage. How effective a player is at scoring and how good a player is defensively are the two biggest remaining questions in basketball analytics, and it appears that NBA teams are still not good at properly valuing these two skills simply because they have less

	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	14.75	0.06	258.77	0.00
Post	0.21	0.06	3.31	0.00
Minutes Played	0.16	0.02	7.89	0.00
Free Throw Factor	0.15	0.02	9.21	0.00
Total Rebound %.	0.13	0.03	3.93	0.00
Assist %	0.22	0.02	9.19	0.00
Turnover %	-0.11	0.02	-5.31	0.00
Defensive Win Shares	0.06	0.02	2.77	0.01
Free Agent	0.91	0.04	24.26	0.00
0-3 Ft. ShotScore	0.01	0.01	0.38	0.71
3-10 Ft. ShotScore	0.03	0.02	2.16	0.03
10-16 Ft. ShotScore	0.03	0.01	2.26	0.02
16-23 Ft. ShotScore	0.02	0.02	1.53	0.13
Corner 3 ShotScore	0.00	0.02	0.05	0.96
Other 3 ShotScore	0.06	0.02	3.80	0.00

Table 6: Salary Regression with Regional ShotScore

information about them, even though these appear to be the two most important skills in the game. Alternatively, perhaps NBA teams take it for granted that players will contribute in terms of shooting and defense, and pay a premium for the other skills.

Table 6 gives the results after we break up ShotScore by region. Of the 6 regions, 3 are significant on the 5% level, and 3 are not. Of the 3 significant variables, it seems that NBA teams are doing a decent job valuing these regions. Increasing the ShotScores in the 3-10 ft. region and the 10-16 ft. region by one standard deviation from their respective means is each significantly associated with a 3% increase in player salary. We saw in our wins regression that out of all the regions, non-corner 3 point ShotScore has a larger positive association with win percentage than these other two regions, and it also appears to have a larger effect on salary. An increase by one standard deviation in non-corner 3 pointer ShotScore is significantly associated with a 6% increase in player salary. Thus, it appears that NBA teams are not undervaluing other 3 point shooting relative to ShotScore in the 3-16 ft. region. Still, we saw that proficiency in shots from 3-10 ft. don't seem to impact wins, so teams appear to be overvaluing this region. It is also strange to see that there are no significant relationships between ShotScores in the 0-3 ft. region and corner 3 region, and a player's salary. These two types of shots have the two highest expected points per shot, and we have seen that they both have a positive association with win percentage, especially shots in the 0-3 ft. region. Yet the lack of signficance suggests that NBA teams have not had a consistent valuation of shooting proficiency in two important areas of the court. Furthermore, the insignificance of the 16-23 ft. ShotScore variable indicates that perhaps teams don't appreciate the long 2 point jumper either, even though we saw that the same variable had a positive association with win percentage.

5 Conclusion

We have found that there is a strong relationship between ShotScore and win percentage, and especially for the 0-3 ft. region and the other 3 pointers region. We also saw a significant positive association for the corner 3 region, supporting our hypothesis and trending NBA tactics that the 3 point shot and close-range shots are the two most effective shots to take in the NBA. However, because corner 3 point shots have the second highest expected points per shot, we were surprised that the ShotScore for this region didn't have a higher positive association with win percentage. We hypothesize that perhaps NBA teams haven't been able to generate these shots because the corners are a small region of the court, and opponents might be geared towards preventing corner 3s.

We then analyzed the relationship between ShotScore and salary, and found that relative to other factors that contribute to success in the NBA, ShotScore is undervalued. We also found that defensive win share appears to be undervalued. Shooting and defense are perhaps the two hardest aspects of basketball to measure individually, and the results are especially interesting considering the rise of a certain type of NBA player: the "3 and D" player, who's main role is to shoot 3 pointers accurately and play strong defense.

When ShotScore is broken down either further, we find that NBA teams don't appear to be valuing 0-3 ft., 16-23 ft., and corner 3 ShotScores consistently, but that they do seem to be valuing the other 3 regions correctly relative to their contribution to win percentage. This is surprising because it appears that NBA teams are basically ignoring a player's proficiency in the most effective shot in the game, close-range shot, when trying to value a player. Thus, although it doesn't appear that NBA teams are undervaluing 3 point shooting as a whole, it appears there are perhaps areas that NBA teams are not valuing correctly.

6 Appendix

For simplicity we will abbreviate assists as AST, total rebounds as TRB, minutes played as MP, field goals as FG, turnovers as TOV, and free throws attempted as FTA.

- Assists % : $\dfrac{AST}{((MP/(MP_{team}/5)) \cdot FG_{team}) - FG}$
- Total Rebound %: $\dfrac{TRB \cdot (MP_{team}/5)}{MP * (TRB_{team} + TRB_{opponent})}$
- Turnover %: $\dfrac{TOV \cdot (MP_{team}/5)}{MP * (FGA_{team} + 0.44 \cdot FTA_{team} + TOV_{team})}$

Defensive win shares is a little more complicated to calculate. It requires calculating the defensive rating of a player, which is the points given up by a player in 100 possessions. Once this is done, do the following:

1. Marginal Defense $= \dfrac{MP_{team}}{MP_{team}} \cdot (\text{Defensive Possessions}_{team}) \cdot (1.08 \cdot (PPP_{league}) - (\dfrac{\text{Defensive Rating}}{100})$
2. Marginal Points per Win $= 0.32 * PPG_{league} \cdot \dfrac{\text{Pace}_{team}}{\text{Pace}_{league}}$
3. Defensive Win Shares $= \dfrac{\text{Marginal Defense}}{\text{Marginal Points per Win}}$

In the above, PPP stands for points per possesion, and PPG stands for points per game.

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