# Beware Thin Air: Altitude's Influence on NBA Game Outcomes

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**Introduction**

Few can dispute the effects altitude has in sports. When one examines the statistics released from Major League Baseball, it is easy to see why Denver, Colorado's Coors Field is a sought-after destination for offensive production. At an elevation of 5,280 feet, a baseball hit in the mile-high city will travel an additional 9-10% further than it would in sea level Yankee Stadium.[1] The cause of this dramatic effect is found in the less-dense air of the high altitude environment when compared to the density of air particles at sea level—deemed the "Coors Field Effect."[1]

Aside from the physics of altitude, there is much evidence that demonstrates the influence that the density of air has on athletes' performance as well. Observations at the 1968 Mexico City (elev. 7350) Summer Olympics showed those athletes from Kenya, who traditionally train in the city of Eldoret (elev. 7,000-9,000 feet), dominated in medium and long-distance events.[2] The performance of soccer teams at high altitudes caused FIFA, a governing body in the professional soccer community, to ban international matches played above 8,000 feet.[3] The same research that led to this ban showed high altitude teams perform much better in lower altitude games, to the tune of an average increase of half a goal per 1,000m descended.[3]

The NBA, the premier league for professional basketball, has two teams that hold home games above 4,000 feet, three between 1,000 and 1,200 feet, and the remaining 25 teams play at a home court below 1,000 feet above sea level.[4,5] Professional basketball players are regarded as highly conditioned athletes with programs emphasizing both endurance (aerobic, oxygen-dependent exercise) and quick bursts of speed (anaerobic, oxygen-independent exercise). Of the two types of exercise, it has been found that in a game, basketball is around 80% anaerobic and 20% aerobic.[6] However, different positions require different "attitudes" on the court, some of which will require a consistently fast player while others will require a man to fight for a dominant position.[6] With the staggering evidence pointing to the effect altitude has on athletic performance, high-altitude teams like the Denver Nuggets (Pepsi Center elevation: 5197 ft) and the Utah Jazz (EnergySolutions Arena elevation: 4268 ft) may hold a significant advantage over their sea-level opponents.[4] With the basic understanding that lower air density, and thus less oxygen per cubic centimeter, grants a performance advantage to high-altitude teams, our hypothesis is the point differential for a team in a given game is directly affected by the altitude of the game site with respect to each team's home altitude. In short, we believe high-altitude teams hold an advantage both home and away.

Using regression analysis of data from the 2010-2011 NBA season, we aim to discern, *ceteris parabis*, the significance of the advantage high-altitude teams gain from descending, and conversely, the disadvantage low-altitude teams face when ascending. NBA statistician Dean Oliver has written that the four primary factors that contribute to winning basketball games are:

1) Shooting, measured by effective field goal percentage

(Effective Field Goal % = (Field Goals Made + 0.5*Three-point Field Goals Made)/Field Goals Attempted)

EFG% = (FGM + 0.5*FG3M)/FGA

2) Turnover percentage

(Turnover % = Possessions/Turnovers = (Field Goals Attempted – Offensive Rebounds + Turnovers + 0.4 * Free Throws Attempted)/Turnovers)

TO% = Poss./TO = (FGA - OR + TO + 0.4 * FTA)/TO

3) Offensive rebounds per 100 rebounding opportunities

(Offensive Rebounding % = [Offensive Rebounds / (Offensive Rebounds + Opponents Defensive Rebounds)] * 100)

ORB% = [OR / (OR + Opponents Def Reb)] * 100)

4) Success at the foul line

(Free Throws Made/Field Goals Attempted)
FTM/FGA

(Oliver, 2004).

We will include both home and away values for each of these measures as well, to capture the effects of both defensive production and opponent skill on point differential. We will define the final independent variable and subject of our analysis, altitude difference (*DALT*), as: home team arena altitude (HA) – away team arena altitude (AA). The dependent variable we will use, as a team's measure of success on the basketball court, is margin of victory (*MOV*), defined as: points for (PF) – points allowed (PA).

Research on this topic has several potential uses. Investors considering potential locations for new sports teams or existing teams seeking new homes can use the information our research will provide to determine how location will contribute to their team's ability to succeed in highly competitive professional sports leagues. Furthermore, teams considering trades or free agents should also take into account how a player who is conditioned to play in a high-altitude environment might receive performance benefits with relocation to a low-altitude city, and vice-versa. However, when such transactions take place, players moving from high-altitude cities may lose the competitive advantage they held over the rest of the league during their high-altitude tenure. Relocations like this would correct the potential statistical abnormality that high-altitude training gives to their performance, thus revealing what was previously perceived as superior talent as mere conditioning (if one assumes that conditioning will reflect location and decrease after some time spent at a lower altitude).

**Economic Analysis**

The relevant economic model for this analysis is a production function. A production function is any combination of inputs for which a producer produces the

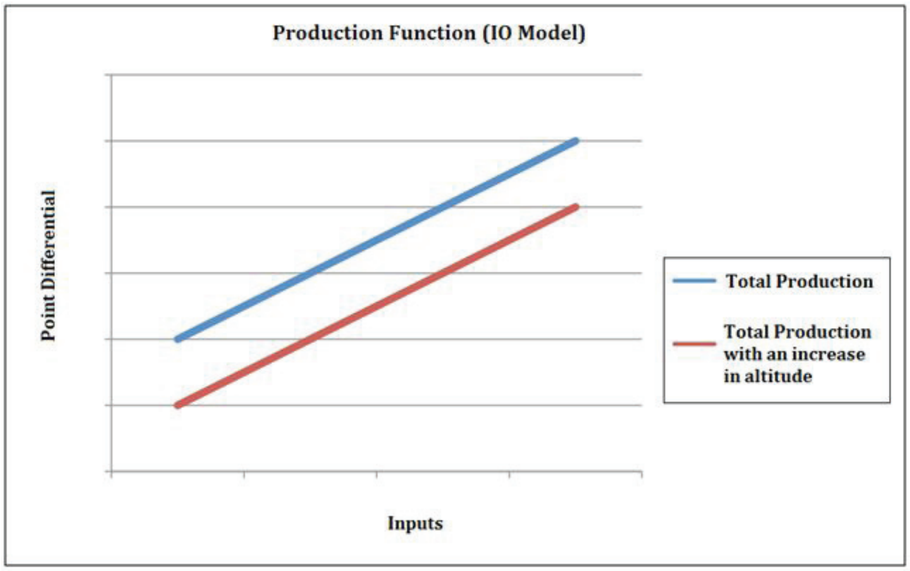


Figure 1: Relationship between game altitude and point differential in NBA basketball games

highest amount of output.[7] In a typical equation, the quantity produced is based on the function of capital and labor.[7] A general production function equation takes the following form:

$$Q = f(X_1 + X_2 \ldots + Xn)$$

where Q, quantity, is a function of in variable and fixed inputs (X).[7] The contribution an addition unit of input makes to the overall product is measured by the marginal productivity as is shown in the equation:

Marginal product of an input = $\Delta q/\Delta x$ [7]

Measuring success in NBA basketball games is quite straightforward; the team that scores more points wins. Teams employ differing strategies for achieving this objective, but all have essentially the same inputs. In the equation proposed in the hypothesis, the output of a given team's production in a game, points, is a function of inputs that most importantly include field goal percentage, turnover percentage, offensive and defensive rebounding, free throw shooting, steals and blocks. These inputs, as in a production function, can be put together in any combination to produce the output, points.[7] That is to say, a team can emphasize outside shooting and have roster dominated by shooters, or a team constructed of more tall players to emphasize rebounding and second chance points.

However, it is the aim of this study to determine whether altitude, measured by the difference between game site elevation and the away team's home elevation, is a significant determinant of outcomes in the production function. Holding all inputs constant, adding altitude as a new technology with an effect on the production of points will constitute a substantial factor in a team's production function if it significantly affects output, points (both scored and allowed). We will not consider altitude change as an input, but rather as a technology change because it affects the efficiency of all inputs in the function. As the hypothesis states and is demonstrated in Figure 1, we believe there is an inverse relationship between altitude change and point differential; as a team ascends their point differential (points for - points against) will decrease, and vice-versa. As Figure 1 shows, we expect a change in altitude to shift the production function down. In other words, holding all else equal, a change in the away team's altitude difference will shift the away team's *MOV* function. The regression analysis of the inputs in this production function will aim to discern the marginal productivity of a change in altitude. For clarity we will interpret altitude change in feet/1000, because the marginal effect of a one-foot change is likely quite small.

**Previous Research**

Using data from the Seoul (1988), Barcelona (1992) and Atlanta (1996) Olympic Games, Tcha and Pershin studied determinants of performance by country and sport.[8] The authors used econometric modeling to determine the impact of various geographic, social, economic and demographic factors on revealed comparative advantage (RCA).[8] Tcha and Pershin divided the whole of the Olympic Games categorically into swimming, athletics, weights, ball games, gymnastics and other, running regressions for each separately.[8] They also compared variables that included relative altitude, coast length, temperature, population, gross domestic product, GDP per capita, and dummy variables for former/current socialist countries and Asian and African countries.[8] From the results, the authors then compared sport specialization with RCA and economic variables such as GDP per capita. The results from the research showed high-income countries did not specialize in sports but rather they diversified their medals showing they were able to be competitive in several sports, a pattern, they claim, to be analogous to a developed economy's behavior in production.

In regards to medals awarded and relative altitude, the regression analysis showed the relative altitude variable was only statistically significant in the athletic (coefficient = 0.8279) and weight events (coefficient = -0.9662). For ball sports, which include basketball, relative altitude showed a statistically insignificant coefficient (-0.2696). According to their research, altitude is not a significant determinant in the outcome of ball sport events. However, lumped together under the ball sports category were disparate sports such as table tennis and volleyball. These sports differ from basketball in type of conditioning demanded, so one would assume that endurance does not play a relatively significant role in determining match outcomes. Were Tcha and Pershin to disaggregate their categories further, running separate regressions for each ball sport, their results would be more conclusive and pertinent to our research. Nonetheless, their analysis showed that relative altitude plays a significant role in determining a country's success in aerobic events (the athletics category), giving credence to our hypothesis.

Research of the effects of altitude in forecasting sports performance includes analysis of FIFA World Cup Qualifying matches in South America.[9] Following a 2007 FIFA ruling that no World Cup Qualifying matches be played at elevations above 8,200 feet, Rómulo A. Chumacero analyzed the effects of various factors on outcomes in soccer matches. Included are the quality of the teams playing, socioeconomic characteristics of the countries playing, crowd effects, humidity, temperature, and altitude.[9] Found significant were team rankings prior to the game, humidity and temperature; among the insignificant variables were the socioeconomic factors, the crowd effects, and, most notably, altitude.[9]

Chumacero's results may initially be discouraging for our hypothesis. However, he notes that, because of FIFA's belief that altitude is a significant determinant of match outcomes, there is a mandatory acclimatization period of one week for matches played above 9000 feet, and two weeks for matches played above 9800 feet.[9] Also, Chumacero's two regressions resulted in $R^2$ values of 0.208 and 0.209, respectively, so it is apparent that his estimated equations are not effective in forecasting match outcomes and require further research to conclusively say that altitude is insignificant as an independent variable.[9]

Previous literature includes inquiry in modeling success in basketball games as well. Estimating technical efficiency in basketball games, Rimler *et al*. modeled factors for success in 296 games played in the 2005-2006 season of the men's NCAA Atlantic 10 Conference.[10] Independent variables included in the authors' proposed production function were two-point field goal percentage, three-point field goal percentage, free throw shooting percentage, offensive rebounds, defensive rebounds, personal fouls, assists, turnovers, blocked shots, and steals.[10] Rimler *et al*. found that shooting percentages and offensive rebounding positively impacted point production and turnovers negatively impacted point production, while the effects of defensive variables (e.g. blocks, steals, defensive rebounds) were negligible.[10] Assists appeared to be significant determinants of point production, but Rimler *et al*. deem that assists are merely correlated with shooting percentage and affect point production insofar as they help the offense generate easier shots.[10] The authors conclude that high efficiency contributes to success on the basketball court, but employment of resources (the independent variables suggested by Rimler *et al*., e.g. shooting percentage and offensive rebounding) is far more important.[10]

The variables that Rimler *et al*. found statistically significant in their analysis in NCAA basketball games are, though formulated slightly differently, the same as proposed in our hypothesis. Shooting percentage (both two- and three-point as well as free throw), turnovers and offensive rebounding were concluded to be significant determinants of point production by the authors, reinforcing our proposal to use these variables in our regression analysis.

**Data and Methodology**

For this analysis we will use OLS regression, adjusted for robust standard errors to correct for heteroskedasticity, performed with Gretl 1.9.0. Game data was obtained from Basketball-reference.com, and altitude data is from Google Earth.[5,4] We begin with the following comprehensive estimated equation, to include all potentially influential inputs:

$$MOV = \beta_1 + \beta_2 EFG\% + \beta^3 TOV\% + \beta_4 ORB\% + \beta_5 (FT/FGA) + \beta_6 DRB + \beta_7 STL + \beta_8 BLK + \beta_9 AEFG\% + \beta_{10} ATOV\% + \beta_{11} AORB\% + \beta_{12} A(FT/FGA) + \beta_{13} ADRB + \beta_{14} ASTL + \beta_{15} ABLK + \beta_{16} DALT + \alpha_1 HTL + \alpha_2 LTH + \varepsilon$$

In this equation the dependent variable, margin of victory (*MOV*) is calculated by: (points for – points allowed) for each team in each game of the 2010-11 NBA season. The first independent variable, effective field goal percentage (*EFG%* = (FGM + 0.5*FG3M)/FGA) is a measure of shooting percentage with differential weight on three-point shooting.[11] Next is turnover percentage (*TOV%* = Poss./TO = (FGA - OR + TO + 0.4 * *FTA)/TO*), a measure of possessions per turnover, signifying the likelihood that a team will turn the ball over on a given possession.[11] We also expect offensive rebounding percentage (*ORB%* = [OR / (OR + Opponents Def Reb)] * 100) to be significant as well, because more offensive rebounds lead to more opportunities to score. We include the next independent variable, success at the foul line (*FTM/FGA*) because it takes into account the relative frequency that a team gets to the free throw line as well as the ability to make the free throws attempted. Defensive rebounding (*DRB*) is likely important as well because it prevents the opponent from getting offensive rebounds, thus limiting second chance points. Steals (*STL*) are potentially significant determinants of success in basketball games because they transfer possessions from the offense to defense, leading to opportunities to score. The next variable included in the regression is blocked shots (*BLK*), which have promise for influence on *MOV* because they deny field goal attempts.

The independent variable under scrutiny in this study is altitude, which we have formulated in several ways. The first version of the altitude variable is altitude difference (*DALT* = home team arena altitude – away team arena altitude). Alternately, we will also try two dummy variables, one for low-altitude teams playing at high altitude (*LTH*) and one for high-altitude teams playing at

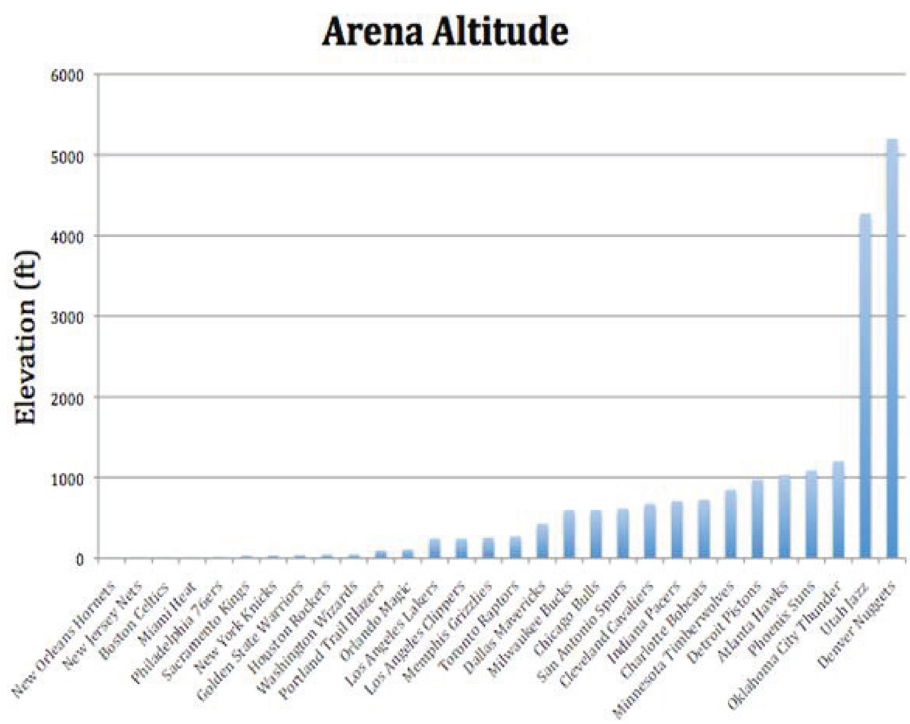


Figure 2: Elevations of all NBA team arenas

Table 1: Summary statistics

| Variable | Mean | Min | Max | N |
|---|---|---|---|---|
| *PTS* | 101.134 | 59 | 144 | 1230 |
| *APTS* | 97.967 | 56 | 137 | 1230 |
| *MOV* | 3.163 | -41 | 55 | 1230 |
| *ALT* | 675.890 | 2 | 5197 | 1230 |
| *DALT* | 3.644 | -5195 | 5195 | 1230 |
| *HTL* | 0.063 | 0 | 1 | 1230 |
| *LTH* | 0.063 | 0 | 1 | 1230 |
| *FG* | 37.778 | 23 | 56 | 1230 |
| *FGA* | 81.192 | 59 | 120 | 1230 |
| *FG%* | 0.466 | 0.291 | 0.658 | 1230 |
| *TP* | 6.561 | 0 | 21 | 1230 |
| *TPA* | 18.128 | 4 | 38 | 1230 |
| *TP%* | 0.356 | 0 | 0.833 | 1230 |
| *FT* | 19.017 | 3 | 45 | 1230 |
| *FTA* | 24.888 | 4 | 59 | 1230 |
| *FT%* | 0.764 | 0.375 | 1 | 1230 |
| *ORB* | 10.962 | 2 | 27 | 1230 |
| *DRB* | 30.820 | 14 | 50 | 1230 |
| *TRB* | 41.781 | 21 | 66 | 1230 |
| *AST* | 22.233 | 8 | 40 | 1230 |
| *STL* | 7.421 | 0 | 22 | 1230 |
| *BLK* | 5.270 | 0 | 15 | 1230 |
| *TOV* | 13.335 | 3 | 28 | 1230 |
| *PF* | 20.282 | 7 | 34 | 1230 |
| *EFG%* | 0.510 | 0.316 | 0.736 | 1230 |
| *TOV%* | 7.636 | 3.415 | 29.067 | 1230 |
| *ORB%* | 26.406 | 4.7 | 51.2 | 1230 |
| *FT/FGA* | 0.238 | 0.033 | 0.672 | 1230 |
| *AFG* | 36.713 | 21 | 53 | 1230 |
| *AFGA* | 81.239 | 59 | 111 | 1230 |
| *AFG%* | 0.453 | 0.296 | 0.629 | 1230 |
| *ATP* | 6.354 | 0 | 22 | 1230 |
| *ATPA* | 17.898 | 3 | 41 | 1230 |
| *ATP%* | 0.351 | 0 | 0.700 | 1230 |
| *AFT* | 18.186 | 4 | 43 | 1230 |
| *AFTA* | 23.841 | 4 | 52 | 1230 |
| *AFT%* | 0.761 | 0.357 | 1 | 1230 |
| *AORB* | 10.863 | 2 | 26 | 1230 |
| *ADRB* | 30.133 | 15 | 47 | 1230 |

*(Continued)*

| Variable | Mean | Min | Max | N |
|---|---|---|---|---|
| *ATRB* | 40.996 | 24 | 60 | 1230 |
| *AAST* | 20.764 | 4 | 37 | 1230 |
| *ASTL* | 7.232 | 0 | 18 | 1230 |
| *ABLK* | 4.459 | 0 | 14 | 1230 |
| *ATOV* | 13.845 | 4 | 28 | 1230 |
| *APF* | 21.143 | 8 | 37 | 1230 |
| *AEFG%* | 0.492 | 0.305 | 0.703 | 1230 |
| *ATOV%* | 7.316 | 3.333 | 20.700 | 1230 |
| *AORB%* | 25.838 | 0.222 | 50 | 1230 |
| *AFT/FGA* | 0.227 | 0.045 | 0.566 | 1230 |

*Source:* Data retrieved from Sports Reference LLC (http://www.basketball-reference.com/)

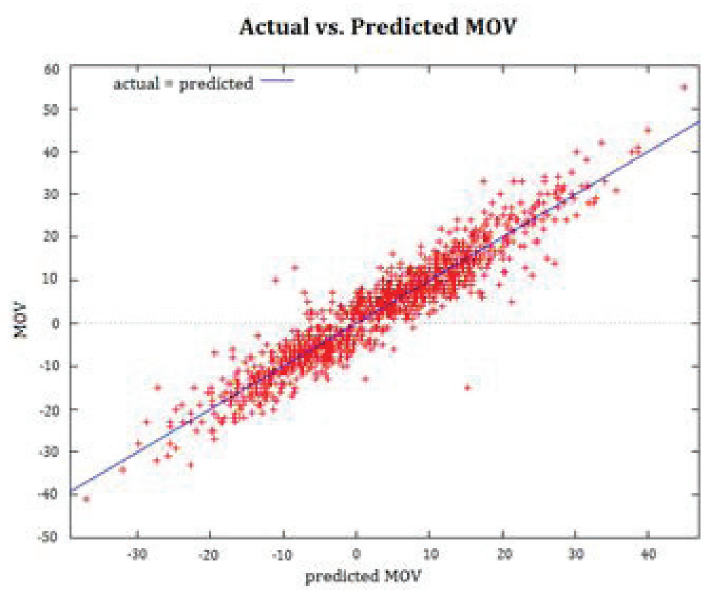


Figure 3: Actual vs. Predicted Margins of Victory (demonstrating goodness of fit) for Model (4)

low altitude (*HTL*). If the altitude difference is greater than or equal to 3069 the dummy *LTH* gets a 1, if not, a 0. This is because all other teams play at least 3069 feet below Utah (EnergySolutions Arena, home of the Utah Jazz, has an elevation of 4268 feet, minus the altitude of the next highest arena, Chesapeake Energy Arena, home of the Oklahoma City Thunder, with an elevation of 1199 feet). This captures the effect of a low-altitude team playing in either Denver or Utah. If the altitude difference is less than or equal to -3069, the dummy *HTL* gets a 1, if not, a 0. This is to capture the effect of a high-altitude team (Denver or Utah) playing in a low-altitude arena. Our sample size is 1230 games, representing all 82 games in the 2010-11 season for each of the 30 NBA teams. Margin of victory minimum (-55) and maximum (55) values represent the January 11 game in which the Los Angeles Lakers beat the Cleveland Cavaliers by 55 points.[5] As shown in Figure 2, there is not much variation in arena elevation in the NBA. Aside from the Utah Jazz and the Denver Nuggets, who both play above 4200 feet, the rest of the league plays below 1200 feet. The minimum altitude (2 ft) is New Orleans Arena, and the maximum altitude (5197 ft) is Denver's Pepsi Arena; the altitude difference minimum and maximum values seen in Table 1 represents matchups between the New Orleans Hornets and the Denver Nuggets. Notably, the mean altitude is 675.89 feet, significantly below the NBA's two high-altitude teams in Denver and Utah. As one might assume, the game statistics show considerable variation, demonstrating a wide variety of team performances throughout the season.

## Results

Various potential formulations of OLS regressions are shown in Table 2. Margin of victory is measured for the home team, so the coefficients found for each variable signify the effect that a one-unit change has on the home team's *MOV*. For example, in Model (4), the model with the highest $R^2$ value (a measure of a model's goodness of fit), the coefficient on *EFG*% is 135.307. This means that if a team's *EFG*% increased by one unit, their *MOV* would have a resulting increase of about 135 points, holding all else equal. This, however, is entirely unrealistic, so by dividing the coefficient by 100 we get the effect a one-percentage point change in *EFG*% has on the home team's *MOV*: 1.35 points. As shown in Table 1, *TOV*% and *ORB*% are recorded differently than *EFG*%, they are recorded in whole numbers rather than as a decimal. As such, one needn't divide these coefficients by 100 to see their marginal effects on *MOV*. Model (4)'s coefficient for *TOV*%, 0.930, therefore means that a one-percent increase in *TOV*% (Possessions/Turnovers) results in a 0.93-point increase in the home team's *MOV*. Similarly, the coefficient on *ORB*% (Offensive rebounds per 100 opportunities) in Model (4) is 0.471, meaning that a one-percent increase in *ORB*% results in a 0.471-point increase in the home team's *MOV*. The variable for success at the foul line, *FT/FGA*, has an estimated coefficient of 25.393 in Model (4). This means that, all else equal, if a team were to make one free throw per field goal attempted (*FT/FGA* = 1), their *MOV* would increase by over 25 points, as compared to a game in which that team made zero free throws per field goal attempted (*FT/FGA* = 0). The variable for defensive rebounds (*DRB*) has a coefficient of -0.145 in Model (4), which is rather counterintuitive. One would think that, *ceteris parabis*, one additional rebound for the home team would increase their *MOV*, not decrease it. Each defensive rebound prevents one's opponent from getting an offensive rebound, therefore increasing the home team's possessions and limiting the opponent's possessions. However, as seen in Table 2, the coefficient is approximately -0.14 in each of the specified models, meaning that an additional defensive rebound for the home team results in a 0.14-point decrease in that team's *MOV*. One potential explanation for this coefficient is an increased amount of defensive rebounds could signify an increased amount of shots taken by the opposing team, and with more shots taken the opponent has more opportunities to score points. Further study must be devoted to resolve this uncertainty. The coefficient for blocks (*BLK*) has a similarly counterintuitive coefficient (-0.208). This means for each block the home team achieves their *MOV* decreases by 0.208 points. One possible explanation is that blocked shots do not lead to turnovers, but rather are likely to be rebounded by the offense and result in more high-efficiency shots. The coefficient for steals (*STL*) is a positive 0.292, denoting the positive effect that forcing turnovers has on scoring opportunities and *MOV*. The away variables (denoted by the prefix A) have the opposite effect of the variables explained above on determining home team margin of victory. In Model (4), all of the aforementioned variables are statistically significant at the 1 percent level aside from *ABLK*, which is statistically significant at the 10 percent level. Our work confirms previous research on the determinants of basketball game outcomes, which includes shooting percentages, offensive rebounding, and turnovers, but unlike Rimler *et al.* we found defensive rebounds, steals and blocks to be significant.[10,11]

In Models (1) & (3) we included the dummy variables for low altitude team playing at high altitude (*LTH*) and for high altitude team playing at low altitude (*HTL*) in an attempt to capture the effects of playing at an altitude significantly different than their home arena altitude. However, the inclusion of these variables had an adverse effect on the explanatory power of the variable *DALT* because multicollinearity issues arose when the three altitude variables were included. In order capture effects of altitude differences, *DALT* was determined to have more explanatory power and was substituted for *LTH* and *HTL* variables.

In the models where only *DALT* was used to measure the effects of altitude (Models (2) and (4)), the coefficients were nearly identical, both rounding to 0.0002. *DALT* was found to be statistically significant in both Models (2) and (4): at the 1 percent level in Model (2) and at the 5 percent level in Model (4). This consistency across various model specifications is demonstrative of robust results, showing that altitude is indeed a significant determinant of *MOV*. The coefficient of 0.0002 shows the effect a 1-foot increase in altitude has on the margin of victory (+0.0002 points/foot). However, when viewed in terms of 1,000-foot increments the effect on margin of victory is interpreted as (+0.2 points/1,000 ft). This result is unlike the research evaluated above (e.g. Tcha and Pershin, 2003; Chumacero, 2009), insofar as where we find altitude to be a statistically significant determinant of game outcomes, they did not.

Team dummy variables were included in Model (4) to capture any home court advantage effects (aside from altitude). It is noteworthy that *DALT* remained significant in Model (4), even after accounting for any home court effects. This shows that the advantage that high-altitude teams have does not come from any intangible arena effects, but from altitude. Included in Model (4) are dummies for all teams except the Washington Wizards; all coefficients are relative to this omitted team. The only teams that were seen to have any statistically significant coefficients were the Golden State Warriors (10 percent level of significance) and Portland Trail Blazers (5 percent level of significance). Explanations for these coefficients are beyond the scope of this research but may be attributed to arena atmosphere, noise, alcohol sales, etc.

Among the models specified, the $R^2$

Table 2: Regressions

| Variable | (1) | (2) | (3) | (4) |
|---|---|---|---|---|
| *const* | 3.205 (0.379) | 3.663 (0.308) | 3.461 (0.335) | 4.005 (0.355) |
| *EFG%* | 135.871*** (8.16e-214) | 135.555*** (1.40e-213) | 134.835*** (5.84e-221) | 135.307*** (4.54e-210) |
| *TOV%* | 0.985*** (2.48e-22) | 0.987*** (1.72 e-22) | 0.993*** (1.67 e-22) | 0.930*** (1.15 e-20) |
| *ORB%* | 0.479*** (1.68 e-81) | 0.479*** (4.56 e-81) | 0.484*** (4.85e-84) | 0.471*** (5.29 e-78) |
| *FT/FGA* | 26.341*** (1.60e-45) | 26.075*** (1.39 e-44) | 26.219*** (7.41e-45) | 25.393*** (7.05 e-39) |
| *DRB* | -0.144*** (0.007) | -0.144*** (0.007) | -0.137** (0.011) | -0.145*** (0.008) |
| *STL* | 0.320*** (2.08 e-08) | 0.323*** (1.89 e-08) | 0.321*** (2.44e-08) | 0.292*** (1.09 e-06) |
| *BLK* | -0.202*** (9.02 e-05) | -0.205*** (8.33 e-05) | -0.198*** (0.001) | -0.208*** (0.001) |
| *AEFG%* | -136.580*** (1.19 e-209) | -136.777*** (1.41 e-210) | -136.118*** (3.35e-209) | -136.367*** (3.95 e-199) |
| *ATOV%* | -1.354*** (1.45e-45) | -1.354*** (1.81 e-45) | -1.360*** (5.02e-46) | -1.335*** (1.86 e-43) |
| *AORB%* | -0.435*** (1.28 e-56) | -0.435*** (2.75 e-56) | -0.433*** (1.09e-55) | -0.438*** (5.59 e-53) |
| *AFT/FGA* | -25.590*** (1.39 e-52) | -25.578*** (8.70 e-54) | -25.447*** (3.65e-52) | -25.154*** (2.04 e-49) |
| *ADRB* | 0.145*** (0.007) | 0.142*** (0.009) | 0.145*** (0.007) | 0.146*** (0.007) |
| *ASTL* | -0.386*** (2.67 e-09) | -0.390*** (1.76 e-09) | -0.382*** (4.46e-09) | -0.394*** (2.05 e-09) |
| *ABLK* | 0.093 (0.104) | 0.085 (0.127) | — | 0.107* (0.090) |
| *DALT* | -9.082e-5 (0.683) | 0.0002*** (0.010) | — | 0.0002** (0.015) |
| *HTL* | -1.578 (0.146) | — | -1.182*** (0.009) | — |
| *LTH* | 1.122 (0.277) | — | 0.805* (0.098) | — |
| *HOME_ATL* | — | — | — | 0.224 (0.829) |
| *HOME_BOS* | — | — | — | -0.093 (0.925) |
| *HOME_CHA* | — | — | — | -0.203 (0.828) |
| *HOME_CHI* | — | — | — | 0.793 (0.409) |
| *HOME_CLE* | — | — | — | -0.901 (0.336) |
| *HOME_DAL* | — | — | — | -0.476 (0.691) |
| *HOME_DEN* | — | — | — | 0.399 (0.724) |
| *HOME_DET* | — | — | — | 0.082 (0.932) |
| *HOME_GSW* | — | — | — | 1.765* (0.057) |
| *HOME_HOU* | — | — | — | 1.238 (0.171) |
| *HOME_IND* | — | — | — | 0.822 (0.364) |
| *HOME_LAC* | — | — | — | -0.569 (0.546) |
| *HOME_LAL* | — | — | — | 1.327 (0.177) |
| *HOME_MEM* | — | — | — | 0.426 (0.667) |
| *HOME_MIA* | — | — | — | 0.500 (0.604) |
| *HOME_MIL* | — | — | — | 0.424 (0.657) |
| *HOME_MIN* | — | — | — | -0.756 (0.399) |
| *HOME_NJN* | — | — | — | -0.565 (0.582) |
| *HOME_NOH* | — | — | — | 0.326 (0.747) |
| *HOME_NYK* | — | — | — | 1.552 (0.140) |
| *HOME_OKC* | — | — | — | 1.102 (0.230) |
| *HOME_ORL* | — | — | — | -0.055 (0.958) |
| *HOME_PHI* | — | — | — | 0.127 (0.893) |
| *HOME_PHX* | — | — | — | -0.732 (0.446) |
| *HOME_POR* | — | — | — | 2.231** (0.014) |
| *HOME_SAC* | — | — | — | -0.448 (0.620) |
| *HOME_SAS* | — | — | — | 0.102 (0.914) |
| *HOME_TOR* | — | — | — | -0.179 (0.863) |
| *HOME_UTA* | — | — | — | -0.175 (0.863) |
| *Adjusted R2* | 0.891 | 0.891 | 0.891 | 0.892 |
| *Model S.E.* | 4.161 | 4.161 | 4.163 | 4.140 |
| *Observations* | 1230 | 1230 | 1230 | 1230 |

*(Continued)*

*Source:* Data retrieved from Sports Reference LLC (http://www.basketball-reference.com/)

Notes: Alternative model formulations using OLS; *** = significant at the 1 percent level; ** = significant at the 5 percent level; * = significant at the 10 percent level; p-values shown in parenthesis underneath each coefficient

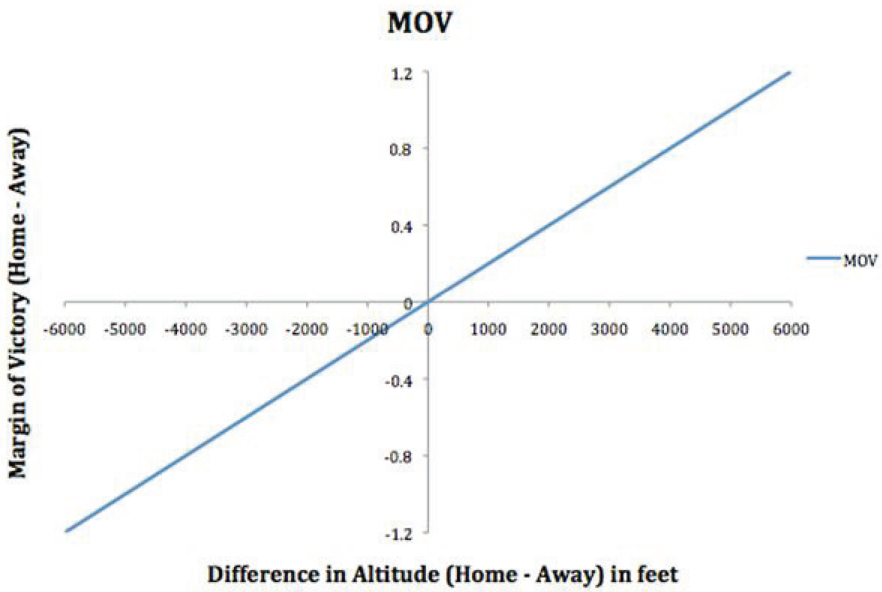


Figure 4: Difference in altitude's effect on margin of victory

values are all very similar (0.891) with Model (4) only slightly higher at 0.892. This signifies a marginal improvement in the goodness of fit, and all four versions of the model have good explanatory value in determining the margin of victory for a home team. We believe that Model (4) is the specification that best forecasts home team *MOV*. This model includes no insignificant variables, incorporates home team dummy variables to account for any intangible home arena effects and has the highest $R^2$ value of the variations specified. Model (4)'s $R^2$ of 0.892 means that over 89% of the variation in *MOV* is explained by the regression's variables. As Figure 3 demonstrates, Model (4) fits the data quite well and as such has substantial predictive power.

**Conclusion**

Based on results gathered from the regression analysis, we can prove a correlation between home and away altitude and NBA game performance. This means that high-altitude teams do hold an advantage over their low-altitude counterparts. To interpret the *DALT* coefficient, the difference in altitude (home minus away) must be considered. At 0.0002, the coefficient is significant in that a 1,000-foot increase in the altitude difference between home and away teams leads to a 0.2-point advantage to the home team. However small this may seem, the New Orleans Hornets (elevation 2 ft.) face a disadvantage of almost 1.04-points when playing the Denver Nuggets at 5,197 feet above sea level. The same holds true for the Nuggets traveling to New Orleans. The difference in altitude becomes -5,195, leading to about a 1.04-point disadvantage for the Hornets. These results show an obvious advantage for high-altitude teams in the NBA.

Our original hypothesis held to be true; there exists a positive correlation between the size of the altitude difference of home and away teams and margin of victory in the NBA. We can conclude that altitude, as seen as a new technology in the production function, affects point production for any team in the NBA. The results do not agree with previous research conducted by Chumacero and Tcha & Pershin, whose literature showed altitude as an insignificant input in the outcomes of soccer and ball sports, respectively. The results did show certain defensive inputs, blocks, steals and defensive rebounding, to be significant, contrary to the findings of Rimler *et al*.

Nonetheless, certain changes could be made in order to better predict margin of victory, and therefore determine with more certainty to what extent altitude is an important technology in the production function of NBA game performance. For example, including more seasons to have even more observations would prove helpful to reinforce the robust nature of our findings. Also, we would like to compare vertical distance traveled to horizontal distance traveled in order to discern travel affects on NBA performance. Inclusion of a dummy variable for back-to-back games could prove to be significant as well, especially if the second were played at a high altitude. All of these research variables would help to strengthen the predictive power of the regression and better predict margin of victory for a given NBA team.

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