Sub-Perfect Game:

Profitable Biases of NBA Referees*

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Abstract

This paper empirically investigates three hypotheses of biased officiating by National Basketball Association (NBA) referees. Using a sample of 28,388 quarter-level observations from six seasons, we find that NBA referees make calls that favor home teams, teams losing during games, and teams losing in playoff series. All of these biases are likely to be profitable to the league. We identify these effects as caused by referee bias, as opposed to player behavior, by using play-by-play data that allows us to separately analyze turnovers over which referees have relatively high or low discretion to judge. We also find that the biases do not increase in situations where their direct financial benefit to the league would be greater, and conclude that the biases are likely of an implicit nature.

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1 Introduction

Every firm faces a set of rules that constrain the actions they may take to maximize profits. Environmental regulations, tax laws, and ethical codes are all expected to be followed by businesses as they conduct their day-to-day operations. Yet, in many instances, firms may increase revenue by not strictly adhering to these policies. Businesses, therefore, face a tradeoff between regulatory compliance and increased profits. In this paper, we examine the extent to which referees employed by the National Basketball Association (NBA) inconsistently enforce the rules of basketball, and whether this biased behavior may benefit the league's bottom line. As results indicate that the referee biases enhance the NBA's profits, we investigate whether these actions were directly ordered by the league or the result of social pressure and simple human error.

The NBA employs three referees in each basketball contest to objectively enforce the rules. Throughout the game officials make dozens of judgements, many of which lead directly to points being scored, and, thereby, may affect game outcomes. Due to the high speed at which professional basketball is played and split-second time frames in which referees must make decisions, it is unreasonable to expect them to correctly judge every play. However, if refs objectively enforce the rules then their errors should occur at random and not systematically favor any particular team or player. Moreover, if bias was found to exist it would be particularly concerning if the favoritism served to generate monetary gain.

Basketball fans have long suspected NBA referees of favoring teams whose wins would extend playoff series,[1] and Tim Donaghy, a former referee involved in a gambling scandal, has explicitly made this claim (Schwarz (2007)). Hassett (2008) discusses the allegation and finds informal supporting evidence. In this paper, a rigorous empirical investigation uncovers evidence in favor of three referee biases: favoritism of home teams, teams losing within a game, and teams that trail in overall playoff series scores. Each of these biases, if undetected, are likely to increase league revenues. Increasing the probability that the home team wins escalates ticket demand, as the majority of

[1] In the NBA playoffs, a team must defeat its opponent four times to advance to the next round.

people attending games are fans of the home team. Biasing calls in support of the losing team serves to artificially keep scores close and augment the competitiveness of games. Highly contested games are more exciting, and consumers are willing to pay a greater amount for tickets if they can expect a more riveting performance. Finally, favoring teams losing in a playoff series increases the likelihood of additional games being played in the series, which directly leads to higher revenue.[2]

These persistent biases, however, may only be profitable to the league insofar as basketball fans are unaware of the trend. Disregarded the rules compromises the integrity of the product and, consequently, may serve to decrease consumer interest in the sport. Thus, it is unclear whether the NBA, as a profit maximizing entity, would benefit in the long-run from having its refs regularly misjudge games. As such, we empirically investigate if the league directed its officials to enact these biases, and find minimal evidence in support of mandated favoritism. Instead, the referee's inconsistent rule enforcement likely results from psychosocial factors, such as crowd influence and sympathy for losing teams.

In undertaking the empirical analysis, we are faced with the challenge of disentangling referee and player behavior. The statistics most strongly affected by referees, fouls and turnovers, are simultaneously influenced by the style and quality of the players' actions. To separately identify referee and player behavior, we rely upon play-by-play data, which includes a description of each play and the time it occurred. Then, turnovers[3] are classified according to the amount of discretion referees have to judge their occurrence; turnovers that are largely player determined are classified as "non-discretionary", and those where referees must employ more judgement are labeled "discretionary". A turnover caused by a player losing the ball out-of-bounds, for example, is largely an objective call, however, officials exercise more control over determining an offensive foul. To test for the presence of referee bias, we measure how discretionary turnovers are affected, relative to non-discretionary turnovers, by pertinent game sit-

[2]Mark Cuban, the owner of the NBA's Dallas Mavericks, states in an article about poor officiating in the playoffs, "The playoffs are where teams and the NBA itself earn their money. Its where team profits are made, its where TV ratings are made and when TV ratings are good, the league makes more money." (<<http://blogmaverick.com/2006/05/07/how-to-improve-nba-playoff-officiating/>>, last accessed 10-31-2009.)

[3]A turnover occurs when an offensive player loses possession to the defensive team. This may happen, for instance, due to an offensive foul, a traveling violation, or a defensive player stealing the ball.

uations. While this is not a clean treatment and control analysis, as both types of turnovers are influenced by referee and player behavior, identification only relies upon the assumption that referees have a *relatively* greater impact on discretionary than non-discretionary turnovers.

This empirical strategy reveals NBA referees to systematically favor home teams, losing teams, and teams down in playoff series. Home teams enjoy approximately an 11% advantage in discretionary turnovers, but only a 2% edge in non-discretionary turnovers. Teams losing within a game also garner a greater advantage in discretionary turnovers than they do non-discretionary turnovers.[4] Thus, in both cases, the statistic more heavily influenced by referee behavior is relatively more affected, suggesting both the location and score of the game influence refs' ability to objectively make judgements. In addition, the home team's advantage in non-discretionary turnovers increases by 1% for every 1,000 fans in attendance. This finding implies that social pressure exerted by the crowd sways the official's decision-making.

Our statistical tests are constructed primarily to identify the *existence* of bias and their determinants and, therefore, do not estimate their impact on game outcomes. However, Price and Wolfers (2007) find that a 4% advantage in total fouls meaningfully increases the probability that a team wins. While the impact of turnovers on game outcomes may not be as strong as fouls, the aggregated effect of the three types of bias substantially influences teams' total number of turnovers in a game, and has surely swayed some results. Furthermore, the biases directly alter the entertainment value of the game and, thereby, fans' utility.

After determining the presence of referee bias, we examine whether the favoritism exists as an intentional means of increasing profit or is a result of referees acting unconsciously. Bias either directly instructed by league management or tacitly carried out by officials, in an effort to please their employers, would be considered "explicit". On the other hand, "implicit" bias would be a consequence of psychosocial factors and unmotivated by monetary gain. For example, referees may have made calls in an attempt to please the crowd or players, without being cognizant of their effect on league

[4] Testing shows that losing playoff teams are also favored in non-discretionary more than discretionary turnovers, but the evidence is weaker.

profitability.[5]

We conduct several tests to determine whether the biases are implicit or explicit. While no individual result provides conclusive evidence, each shows that the magnitude of referee bias does not increase in situations where it would have increased league revenue. Taken as whole, the evidence leads us to conclude that the biases are likely implicit. Yet, this does not mean the NBA is not partially responsible. It is possible that the league is aware of the systematic favoritism, but fails to correct them in order to realize their benefits. Despite making efforts to improve the consistency of officiating in the last five years, the biases have not decreased following the 2005-2006 season.[6] Given that the biases affect discretionary turnovers, which are unreported in standard box-scores, more than personal fouls, a statistic commonly posted on scoreboards during games and in post-game box-scores, the league has an even lower incentive to eliminate the favoritism.

Our theory of the connection between referee bias and league profits is admittedly speculative, as we do not possess data on league revenues. In addition, we recognize that it is impossible to perfectly manage the officials, and the costs of completely eliminating the biases may be prohibitively high. In spite of this, improvements could be made; the high magnitudes of our estimates suggest that there is some "low-hanging fruit." Mechanisms that may reduce the inconsistent officiating are discussed in the concluding remarks. It may also be the case that the NBA is unaware of the biases, as they might not conduct the same econometric analysis used in this paper. If this is true, we hope documenting these irregularities helps the league address the problem.

The findings in this paper directly relate to previous economic research on the source of the home advantage in sports, such as Sutter and Kocher (2004), Garicano et al. (2005), and Pettersson-Lidbom and Priks (2007), and research on sports officiating bias,

[5]A third possibility is that referees were directed by gambling related sources. However, this is unlikely to be the source of our findings. Pedowitz (2008), a report commissioned, in part, to investigate the influence of gambling over NBA outcomes, states that sports betting is likely not a corrupting force in the game. Additionally, there is no reason to suspect that the interests of gamblers would systematically correlate with the identified biases.

[6]NBA commissioner David Stern said in response to a game-fixing allegation, "We decided five years ago that we would track literally every call in order to help develop our officials and make them better, and they really effectively are the most measured and metricized group of employees in the world." (<<http://www.nba.com/news/stern_transcript_080612.html>>, last accessed 12-29-2008.) Our data are only available from the 2002-03 season onward, therefore, to test for improvement in officiating consistency, the magnitude of the biases in the first and second half of the sample are compared. There is no significant difference.

e.g., Price and Wolfers (2007), Parsons et al. (2007), and Larsen et al. (2008).[7] This paper also relates to research on the detection of corruption, especially in sports, such as Duggan and Levitt (2002) who uncover evidence that non-linear payoffs in sumo wrestling lead to match fixing and Zitzewitz (2006), who finds that Olympic judges favor athletes from their own country.

Our findings on difficult to detect biases by officials with conflicting incentives applies to sports beyond basketball, as well as a larger class of entertainment contexts. For example, the television quiz shows in the 1950s used biased rule enforcement to make their shows more entertaining, by giving the most charismatic contestants answers in advance.[8] This type of blatant violation of the rules is likely a thing of the past. Today, however, it is possible that game show firms still favor some contestants in a more subtle manner, perhaps by feeding them questions on subjects they are known to be strong on or giving them weaker opponents. It is our hope that this study will enhance understanding of a variety of situations in which firms have incentives to "bend the rules."

2 Hypotheses

The NBA's revenues in the 2006-07 season were $3.6 billion, $1.2 billion of which were from ticket sales and $1 billion from national television sales (Badenhausen et al. (2007)). One obstacle to continued revenue growth for the league is that the integrity of the officiating seems to frequently be under fire. The widespread criticism of refereeing caused the league itself to commission, in 2008, the "Pedowitz Report" – a comprehensive review of the officiating program, with a focus on the influence of gamblers and bookies. The report states, "NBA management sends a clear and consistent message to referees that they are to make accurate and consistent calls and favor no team or player. We have found no evidence that the League has ever deviated from this message."

[7] Rodenberg and Winston (2009) is especially relevant, as it is a recent study on biases of NBA officials. The authors investigated the hypothesis that referees were biased against one particular team, the Dallas Mavericks, and found little supporting evidence.

[8] See, e.g., Van Doren (2008).

Pedowitz (2008) also documents the league's extensive system for monitoring the performance of its officials. The study states that since the 2003-04 season the league has employed 30 "observers," one for each team, who attend every home game of their assigned team. From the report: "After each game, the observer reviews the game on video, rates every call, enters correct and incorrect non-calls, and includes some qualitative assessments of performance."

In this paper, we examine three possible referee biases that potentially enhance league profits.[9] While none of these biases are explicitly illegal, they undermine the credibility of an industry that is based on a well-defined set of rules that ensure fair treatment of all teams.

Hypothesis 1: Referees favor home teams (*home bias*).

Our first hypothesis, that referees favor home teams, follows a line of research on the source of the home team advantage in sports. The conventional wisdom subscribed to by most fans and commentators is that this advantage is due to teams simply playing better at home; they are motivated by the crowd's support, more comfortable playing in a familiar environment, and more rested not being on the road. This theory has been supported by research from other disciplines, for example, Neave and Wolfson (2003) found higher levels of testosterone in athletes while playing at home versus away, and suggest the desire to defend one's "territory" as an explanation.

However, there are several studies showing the home advantage is, at least partly, due to referee bias. Sutter and Kocher (2004) examine German soccer data, which include the number of foul calls made that were determined to be incorrect, and foul calls that should have been made but were not. They find that home teams receive systematically favorable treatment; for example, at the end of games, referees allow play to extend approximately 30 seconds longer when the home team is down by one goal relative to games in which the away team is trailing by the same margin. Pettersson-Lidbom and Priks (2007) and Garicano et al. (2005) uncover similar biases in favor of home teams in soccer, and the latter also finds that a standard deviation increase in attendance leads to a

[9] There are numerous other biases that NBA referees are alleged to have, perhaps the most well known of which is favoritism of "superstar" players. This bias could also be consistent with profit-maximization as the league may benefit from having a small set of players thought by fans to be significantly better than others. We do not examine this hypothesis in this paper, as we limit our scope to team-related biases.

20% increase in the home team bias. Finally, Nevill et al. (2002) provide experimental results showing that soccer referees are directly influenced by crowd reactions.

The goal of these past studies was to estimate the effects of social pressure on decision-making. Our motivation is to both document home bias, as well as other types of favoritism, in a sport other than soccer, and, more importantly, assess whether the NBA permitted referees to favor home teams in order to generate additional revenue. Favoring the home team may increase profits in at least two ways. First, if the home team is more likely to win then attending games becomes more enjoyable for most fans, thereby increasing their willingness to pay for tickets. Second, if fans care about their home teams' game outcomes, and think their attendance positively affects the team's probability of winning, then a bias that reinforces this belief may also increase fans' willingness to pay.

To distinguish between explicit and implicit bias, we analyze whether the magnitude of the home bias is the affected by game attendance, whether the game is nationally televised, or if the game occurs during the playoffs. Higher game attendance increases the social pressure placed upon the referees and, therefore, a positive association between attendance and the level of home bias would evidence implicit bias. Nationally televised games are observed by many people outside the stadium, including many fans of the away team. Consequently, there is a greater cost to disfavoring the away team in this situation; thus, if the bias is explicit its magnitude would decrease during games broadcasted on national television. Finally, in playoff games, fans in the arena are more fervent, increasing the likelihood of implicit bias, and television viewership by both teams' fans is higher, decreasing the financial benefit of an explicit bias. On the other hand, officiating in the playoffs is more closely scrutinized by the press, lowering the likelihood of either type of bias. The net impact of a game occurring in the playoff on the degree of home bias is, therefore, not entirely clear.

Hypothesis 2: Referees favor teams losing during games in order to keep games close (*close bias*).

Hypothesis 2 is motivated by the idea that close games are more exciting to watch, both in person and on television. And, persistently favoring the losing team serves to artificially keep game scores close. This bias could be implicit, as referees might favor trailing teams out of sympathy to the losing players and coach or to make up for previous calls. Conversely, it may also be explicit, as increasing the probability of a close game increases fans' willing to pay for tickets and television viewership. Tim Donaughy, a former referee, has specifically accused a former colleague of favoring losing teams.[10] To identify explicit versus implicit bias, we calculate if the close bias increases in either playoff or nationally televised games. If the bias was implicit it would be independent of television viewership. If it were explicit, however, its magnitude would increase during nationally televised games, as the returns to games being close are higher. Similarly, if the close bias were explicit then it would increase during playoff games.

Hypothesis 3: Referees favor teams down in playoff series in order to extend the series (*playoff bias*).

Our third hypothesis, that referees favor teams in order to extend playoff series, has the most direct impact on the NBA's bottom line. Playoff series are best-of-seven; i.e., the first team to win four games wins. Thus, if the team leading in the series has won three games, the series only continues if the trailing team wins the subsequent game. Consequently, the league directly benefits, through ticket sales, television revenues, etc., from longer playoff series.[11] In fact, games "produced" by extending series would be particularly lucrative, since both ticket and television viewer demand is higher for games that occur late in playoff series.[12]

It might appear that favoring teams losing in playoff series, if it were observed to occur, would likely be explicit. Even if the NBA does not directly instruct its officials to undertake this bias, referees are probably aware of the financial benefit from a longer series, and may act to gain favor with their employer. Although referees are not paid per playoff game, they are paid per series, and their assignments to playoff

[10]From Pedowitz (2008) (p.62), "A few ex-referees, including those who have held or hold supervisory positions with the NBA describe Bavetta's [a current NBA referee] calls as reflecting an effort to keep games close or to ingratiate himself with a team."

[11]We were unable to determine whether league television revenues are directly tied to the number of playoff games. However, even if they are not, there is a strong indirect relationship, as the value of televising the playoffs depends on the expected number of games.

[12]It is worth noting that the league changed the format of the first round of the playoffs from best-of-five to best-of-seven starting in the 2003 playoffs. This change was ostensibly made to prevent flukish, or undeserved, upsets, but had the side effect of increasing the total number of playoff games. Yet, the change has affected at most a small percentage of series outcomes; since then, 45 of the 48 teams to first win three games in first round series have proceeded to win a fourth game.

series are based on performance reviews (Pedowitz (2008)). Consequently, if referees maximized earnings, and believed the league wanted them to extend series, referees would consciously favor the team down in the series. This bias, however, could also be implicit, as referees might unconsciously favor the losing team simply to support the “underdog.” It is also plausible that the home crowd is stronger in decisive playoff games, causing the team losing in the series, if playing at home, to be implicitly favored by the refs.

To distinguish between explicit and implicit playoff bias, we test whether the bias is larger in situations where calls are more likely to affect the game outcome. If referees explicitly favored the team losing in the playoff series then the bias would likely increase in situations where it would have a greater impact on determining the game winner. We also investigate if the bias is affected by the television market sizes of the teams. Again, if the bias was implicit, it would be unaffected by the scope of a team’s television market.

We are unable to directly observe the extent to which the league is aware of or permits the three biases. Note, though, if the NBA were strategically allowing the biases then they would persist in the statistical categories least observable to fans and analyst, as this minimizes the probability of detection. We test to see if the three biases have changed over time, as the league claims to have made efforts to improve the consistency of officiating in the last five years (Pedowitz (2008)). If the biases were purely psychosocial and not tolerated by the league then they would to be smaller in the more recent seasons.

3 Data and Empirical Strategy

3.1 Data

To test the hypotheses detailed in the previous section, we utilize play-by-play data obtained from ESPN.com for all NBA regular season and playoff games for the 2002-03 through 2007-08 seasons. These data are superior to typical game-level box scores, as play-by-play data includes a description of each game event and the time at which occurred, and may be aggregated to replicate box-score data if necessary.

Most importantly for our work, a game's box score only includes the total number of turnovers,[13], whereas play-by-play data describe how each turnover within the game occurred, for example, whether it was due to a traveling violation, shot clock violation, etc. Note, however, that play-by-play data are not official league statistics, and may have more measurement error than box score data.[14] Yet, this likely improves the statistical size of our tests and, consequently, the true levels of bias are likely larger than the estimated values.

The primary challenge to our analysis is that nearly all basketball statistics are simultaneously affected by both referee and player behavior. Moreover, it is likely that player behavior changes in the same situations that we hypothesize referee bias occurs. For example, players may play with more intensity at home, or when their team is losing during a game. This problem is addressed by first classifying turnovers based on the amount of discretion the referee has in judging the turnover types. Then, to separate the effect of referee bias from player behavior, we measure how discretionary turnovers change, relative to non-discretionary, in situations where bias is conjectured to exists. If turnover changes were solely a consequence of altered player behavior, such as increased aggressiveness, then non-discretionary turnovers would be affected *at least* as much as discretionary turnovers. In other words, non-discretionary calls serve as a placebo in the analysis of referee behavior.

Traveling violations, offensive fouls, three second violations and goal tending are classified as "discretionary turnovers." The traveling violation is notoriously subjective and inconsistently called in the NBA.[15] In fact, such a large disparity existed between the definition of traveling, as stated in the official NBA rule book, and the way in which referees interpreted the action that the NBA was forced to change the definition prior to the 2009-2010 season. The offensive foul is also highly subjective, and much of the

[13]Pertinent basketball terms are defined in Table 5.

[14]When we aggregate the play-by-play data to game-level box score data they are nearly identical to the official box scores.

[15]After the 2008-2009 season, Joe Borgia, the NBA's vice president of referee operations, "claims the current rule is so confusing that it's impossible to tell if it allows one step or two." (<<http://sports.espn.go.com/nba/news/story?id=3951002>>, last accessed 3-3-2009.)

time could easily be a "no call" or whistled as a foul against the defender. The NBA has recognized the difficulty of calling offensive fouls, and is contemplating instituting fines for players who egregiously "flop" during games.[16] The NBA's consideration supports the classification of offensive fouls as "discretionary", as it has become a highly subjective judgement, and also shows the league is making efforts to address officiating problems. Three seconds and offensive goal-tends are also denoted as discretionary, but occur infrequently and bear little weight on our parameter estimates.

Bad passes, lost balls, and shot clock violations are defined as "non-discretionary turnovers." These types of turnovers are generally more objective, as they are determined directly by player behavior.[17] For example, when a player makes a bad pass that goes directly out of bounds, the referee makes a call to signal a change of possession, but has no discretion over the call.

In addition to the turnover analysis, foul calls, the more common barometer of referee behavior, are examined. Unlike turnovers, it is more difficult to classify fouls by the degree of discretion referees have to call them. For the empirical work fouls are divided into two categories, shooting and non-shooting; however, it is not clear, a priori, which type is affected more by player or referee behavior. Also, fouls tend to receive more attention from fans and commentators than turnovers and, therefore, if the NBA or its officials were attempting to avoid detection of bias then favoritism may be more apparent in turnover statistics.

Table 1 presents summary statistics for the turnover and foul types, aggregated to the team-game-quarter level, used in the subsequent empirical investigation. The table also reports tests of unconditional home-away and winning-losing, at start of quarter, differences in the various statistics. The table provides a preview of the econometric results, as the both the home and losing team have a significant advantage in most discretionary turnover and foul statistics, but not in non-discretionary turnovers.

[16] Defenders flop in order to deceive referees and draw offensive foul calls on the opposing team.

[17] The names of the types of turnovers ("bad passes", "lost balls", etc.) are those used in the ESPN.com play-by-play data. The "lost ball" turnover is one that could plausibly be categorized as discretionary, since lost balls are sometimes due to fouls committed by the opposing team that are not called. Results are similar when lost balls are classified as discretionary turnovers. Double dribble violations are dropped from the analysis, since it is unclear in which group they should be classified; however, they occur infrequently, and results are robust to including them in either turnover group.

3.2 Formal Model

The following is a formal presentation of the identification strategy employed in subsequent empirical investigation. It's purpose is to precisely state how referee bias can be cleanly detected using the discretionary/non-discretionary turnover distinction in conjunction with a few simple assumptions. Let T_D be discretionary turnovers, T_N be non-discretionary turnovers, X_R be a measure of referee favoritism (referee favoritism is increasing in X_R), and X_P be a measure of player behavior (an increase in X_P corresponds to a change in player behavior that causes turnovers to decrease). Let Z be a variable that takes higher values in situations in which favorable bias is hypothesized to occur; for example, Z could be a dummy equal to one when the team is at home, losing during the game, or trailing in the playoff series. As both X_R and X_P may be affected by Z, assume the following:

$$X_R = \gamma_0^1 + \gamma_1 Z + \epsilon_1 \tag{1}$$

$$X_P = \gamma_0^2 + \gamma_2 Z + \epsilon_2. \tag{2}$$

Here, Z is assumed to be independent of ϵ_1 and ϵ_2. The hypothesis of interest is that $\gamma_1 > 0$; which, in words, simply means that referee bias increases in situations in which Z also increases.

The econometric difficulty is that neither X_R nor X_P are observable and, consequently, equation (1) cannot be directly estimated. Therefore, to test the hypothesis, additional assumptions are required. Suppose T_D and T_N are affected by both referee and player behavior as follows:

$$lnT_D = \beta_0^1 + \beta_1^1 X_R + \beta_2^1 X_P + u_1 \tag{3}$$

$$lnT_N = \beta_0^2 + \beta_1^2 X_R + \beta_2^2 X_P + u_2. \tag{4}$$

In both equations, the X's are restricted to be independent of the u's. Equations (3) and (4) are specified as log-linear so that the coefficients can be interpreted as percentage effects, however, results are not dependent upon this functional form. To identify referee bias, two additional assumptions are made.

Assumption 3.1. $\beta_1^1 < \beta_1^2 \leq 0$.

Assumption 3.2. $\beta_2^2 \leq \beta_2^1 \leq 0$.

Assumption 3.1 implies that, on average, referee behavior has a greater percentage effect on discretionary turnovers than non-discretionary. Assumption 3.2 states that player behavior has a weakly greater percentage effect on non-discretionary turnovers than discretionary. These assumptions do not place any restrictions on the magnitude of any of the effects or the existence of referee bias.

Then, by substituting equations (1) and (2) into equations (3) and (4) we obtain the following:

$$lnT_D = \tilde{\beta}_0^1 + (\beta_1^1\gamma_1 + \beta_2^1\gamma_2)Z + \tilde{u}_1 \tag{5}$$

$$lnT_N = \tilde{\beta}_0^2 + (\beta_1^2\gamma_1 + \beta_2^2\gamma_2)Z + \tilde{u}_2. \tag{6}$$

Here, $\tilde{\beta}_0^1 = \beta_0^1 + \beta_1^1\gamma_0^1 + \beta_2^1\gamma_0^2$ and $\tilde{u}_1 = \beta_1^1\epsilon_1 + \beta_2^1\epsilon_2 + u_1$ and $\tilde{\beta}_0^2$, and $\tilde{u}_2$ are defined analogously. Equations (5) and (6) can be estimated directly, as Z, T_D and T_N are observable and the single RHS variable in each equation is exogenous.

To test for the presence of referee bias, we first estimate whether Z is negatively associated with an advantage in discretionary turnovers:

$$\begin{aligned} \beta_1^1\gamma_1 + \beta_2^1\gamma_2 &< 0 \leftrightarrow \\ \gamma_1 &> -\frac{\beta_2^1}{\beta_1^1}\gamma_2. \end{aligned} \tag{7}$$

Since $\frac{\beta_2^1}{\beta_1^1} \geq 0$ by Assumptions 3.1 and 3.2, if $\gamma_2 \leq 0$ then $\gamma_1 > -\frac{\beta_2^1}{\beta_1^1}\gamma_2$ implies $\gamma_1 > 0$, which is equivalent to the existence of referee bias.

This test will not be sufficient, however, if $\gamma_2 > 0$. To account for this case, the estimates from equations (5) and (6) can be employed in the following test:

$$\begin{aligned} \beta_1^1\gamma_1 + \beta_2^1\gamma_2 &< \beta_1^2\gamma_1 + \beta_2^2\gamma_2 \leftrightarrow \\ \frac{\beta_2^1 - \beta_2^2}{\beta_1^2 - \beta_1^1}\gamma_2 &< \gamma_1. \end{aligned} \tag{8}$$

By Assumptions 3.1 and 3.2 $\frac{\beta_2^1-\beta_2^2}{\beta_1^2-\beta_1^1} \geq 0$, therefore, if $\gamma_2 > 0$ then $\frac{\beta_2^1-\beta_2^2}{\beta_1^2-\beta_1^1}\gamma_2 < \gamma_1$ implies $\gamma_1 > 0$. Thus, for all γ_2, testing (7) and (8) is sufficient for testing $\gamma_1 > 0$ and, thereby, identifying the existence of referee favoritism.

Practically speaking, to perform the hypothesis test, equations (5) and (6) must first be separately estimated. Then, to identify the existence of referee bias, the discretionary turnover situational bias coefficient, $\beta_1^1\gamma_1 + \beta_2^1\gamma_2$, must be significantly greater than zero *and* the non-discretionary turnover situational bias variable, $\beta_1^2\gamma_1 + \beta_2^2\gamma_2$. It important to note that this test does not require that player behavior affects both types of turnovers in the same way (i.e. it is not assumed that $\beta_2^1 = \beta_2^2$). However, in order to isolate the magnitude of the bias, $\beta_1^1\gamma_1$, additional assumptions are required. By assuming $\beta_2^1 = \beta_2^2$ and $\beta_1^2 = 0$, we can difference the estimates of $\beta_1^1\gamma_1 + \beta_2^1\gamma_2$ and $\beta_1^2\gamma_1 + \beta_2^2\gamma_2$ to obtain $\beta_1^1\gamma_1$. Yet, these assumptions are fairly strong and, therefore, we only refer to conservative approximations of the estimates that rely upon them.

4 Analysis

The following analysis is based, almost exclusively, on quarter-level data, which allow us to control for within-game dynamics in a simple, transparent way. Using quarter rather than game-level data is necessary to avoid the hypothesized biases possibly interacting with each other, which would confound the estimation results. For example, if referees indeed favored both home teams and teams losing during games, failing to control for within-game scores could cause the varying biases to nullify each other. In this case, home teams would be favored at the beginning of games when neither team is losing, then home teams would be disfavored after taking the lead; therefore, in game-level data home bias would be under-estimated. The downside of using quarter-level data is that within-quarter dynamics are not as tightly controlled for. Consequently, as score margins can change substantially within within quarters, the magnitude of the close bias may be underestimated.

The analysis of each hypothesis is performed using four unique dependent variables: shooting fouls, non-shooting fouls, discretionary, and non-discretionary turnovers. As each is a count variable–they only take non-negative integer values–Poisson regression is the most appropriate estimation technique. The Poisson model is estimated via maximum likelihood, under the assumption that the dependent variable takes a Poisson distribution with log-mean equal to a linear function of the regressors.[18] The log-linearity also provides the advantage that the estimates can be interpreted as percentage changes. The disadvantage is that it is not possible to obtain estimates of covariances of coefficients across equations. For this reason, results of across-equation tests are not reported. However, for all feasible covariances, those with absolute value less than the product of the standard errors, we often show coefficients are significantly different. In the following subsections, unless otherwise specified, any discussion of across-equation differences refers to significance levels for all feasible covariances.

For each dependent variable two specifications are examined; one with controls for the team's performance in the quarter, and the other without any performance controls. The controls are dummy variables representing score margin categories for the quarter ("Score Margin Dummies").[19] The benefit of including these variables is they directly control for changes in player behavior. The cost is that they are determined simultaneously with the dependent variables and, in fact, are caused in part by the dependent variables. This misspecification is not likely not problematic, as the coefficients on the score margin dummies are not of interest; if anything, since score margins are also affected by referee behavior, including these variables weakens the estimates of referee bias. Finally, quarter fixed effects and "matchup" (team-opponent-season) fixed effects are included in all models. Thus, our estimated effects are solely a result of the variation in a team's performance from their mean performance against the same

[18]The Poisson distribution assumption for a variable requires that its mean and variance are equal; Table 1 shows that this is not problematic for our data. Results are very similar when we use other model specifications.

[19]The categories are: lose quarter by more than five points, lose by one to five points, win by zero to five points. Winning by more than five points is the omitted category.

opponent, in the same season. Including these fixed effects allows us to tightly control for variation in team quality and the composition of game pairings.[20]

All analysis is conducted at the team-game-quarter level, using a sample with two observations for each quarter of each game (one for each team). The final three minutes of the fourth quarters are dropped, as game play often changes dramatically in those situations. For example, losing teams sometimes intentionally commit more fouls in those minutes for strategic reasons. Standard errors are clustered by game to account for the repetition of game-quarters in the sample.

4.1 Home Bias

Table 2 provides the results from the Poisson regressions, and the estimates are consistent with the existence of referee favoritism. The home team experiences approximately 8% to 11% fewer discretionary turnovers, but only a 2% to -2% advantage in non-discretionary turnovers. The discretionary turnover coefficients are significantly greater than both zero and the non-discretionary turnover coefficients at the 1% level, which implies the existence of bias. The home team also has a 5%-6% advantage in shooting fouls and a 1% advantage in non-shooting fouls, significantly different from zero at the 1% and 5% levels, respectively.

Not only do the results suggest that referees systematically favor home teams, but they also imply that the bias is implicit and not directly ordered by league management. The home advantage in discretionary turnovers increases by more than 1.0% for every 1,000 fans in attendance, which is significantly different from the non-discretionary estimate by at least 5%. Therefore, the home bias is, at least partially, a consequence of social pressure, as it increases with number of people present in the arena. The estimated attendance effects are much smaller for all of the other dependent variables, but also significantly different from zero at 5% for non-shooting fouls. The matchup fixed effects specification controls for the possibility that player behavior and public attendance are both correlated with the quality and type of game opponent. That is, the result is not simply caused by teams playing differently against, say, better

[20] Results are very similar when we simply use team-season or opponent-season fixed effects.

opponents, which also attract larger crowds.

Further evidencing that the home bias is not explicitly mandated by the NBA, is the finding that the bias does not decrease in nationally televised or playoff games. If the league was seeking to avoid detection they would instruct officials to call the game more judiciously, as public scrutiny is higher in these settings. In fact, the bias is estimated to increase by around 4% for discretionary turnovers in the playoffs, further suggesting the bias is implicit, as the league would benefit from home bias being smaller in games with larger television viewership.[21]

The home bias has not changed in games taking place in the 2005-06 season or later, except for non-shooting fouls, whose bias increases in those seasons. Thus, the favoritism has not been reduced by the league's improved referee monitoring.[22]

These findings strongly support the home bias hypothesis. This result is in step with previous literature on the topic; however, we also provide evidence that, although the bias likely serves to drive up ticket demand, it is a consequence of social pressure and not explicit league direction. Furthermore, it is noteworthy that the bias persists in the NBA in spite of the league's claim of close monitoring of its officials, and it is important to confirm this phenomenon in a sport other than soccer. Finally, note that the bias is strongest for discretionary turnovers, the statistical category in which bias is most difficult to detect without play-by-play data.

4.2 Close Bias

Estimation results reported in Table 2 support the close bias hypothesis, as teams trailing at the start of a quarter are systematically favored throughout the subsequent period. Using a set of dummy variables that account for separate categories of start of quarter score differences,[23] we find that as the score margin grows the losing team

[21] These results are not reported, but are available upon request.

[22] We also tested for whether the home bias is stronger in the fourth quarter, and found that it was not. Since the crowd is generally strongest in at this time, the result is somewhat surprising. It can be explained, however, by the referee convention of making fewer calls at the end of games in order to " let the players decide the games." This convention may exist partly because those calls are more highly scrutinized.

[23] The categories are "home team down more than 10 points", "home team down by 10 to 4 points", "home team winning by 4 to 10 points", and "home team winning by more than 10 points." The excluded category accounts for the game score differential being 3 points or less. Dummy variables are used in place of actual score differences to allow for the "close bias" to have a non-linear impact on the dependent variables.

receives increasingly favorable treatment, in terms of discretionary turnovers, from the referees. When a team trails by more than 10 points at the start of a quarter they have 10% fewer discretionary turnovers called on them in the subsequent quarter, relative to teams who start a quarter trailing or winning by no more than three points. Surprisingly, teams trailing by more than 10 points perform *better* in discretionary turnovers than teams engaged in a close game.[24] Conversely, teams losing by a wide margin actually commit more non-discretionary than teams winning or losing by a slim margin. Thus, discretionary turnovers are affected more by the score margin and, in accordance with the model presented in section 3.2, stands as strong evidence in support of referees favoring losing teams. The results further implicate referees of favoritism, as teams down 4-10 points have over 5% fewer discretionary turnovers than baseline teams, which is significantly different from zero at 1%, and significantly different from the non-discretionary turnover estimate at at least the 5% level. The differences between estimates of discretionary and non-discretionary turnover effects for teams up by 4-10 points and greater than 10 points are marginal.[25]

Having identified the close bias, we now explore if the behavior is mandated by the NBA. To do so, the extent to which the magnitude of the bias changes in nationally televised and playoff games is measured.[26] An explicit bias generated by the league instructing referees to keep games close would increase in these situations, as the benefit to having a close, exciting game is higher. Similar to the case of home bias, the econometrics imply that the bias is implicit and due to psychosocial factors; television and playoff status have no effect on the magnitude of the bias and, if anything, the bias is smaller in televised games.[27] Yet, these results do not completely rule out explicit bias; in televised and playoff games the probability of detection is greater, and may serve to decrease the bias. Still, it is highly plausible that the favoritism of home teams is implicit. Pedowitz (2008) specifically refers to bias of this type motivated by a desire of

[24]Turnovers adversely affect a teams changes of winning. Thus, a decrease in turnovers corresponds to a better quality of play.

[25]Also, losing teams have a 2-4% advantage in shooting fouls. This, again, suggests referee bias, but the theoretical distinction is not as clear as in the case of discretionary versus non-discretionary.

[26]These tests are conducted by interacting a linear start of quarter score difference variable with dummies for whether the game is televised or in the playoffs.

[27]Again, these results are not reported, but are available upon request.

a referee to be ingratiated with all teams. Referees may also favor the losing team out of a simple preference for equality, or to make up for previous calls that have caused one team to take the lead. Moreover, as the home team's score margin increases, scrutiny of the officiating from the home crowd likely decreases. Since referees do respond to the home crowd, the close bias may be partly caused by the magnitude of home bias changing throughout the game.[28] Yet, even if the close bias is implicit, the league is not actively correcting the problem. In results unreported, the degree to which losing teams are favored has not decreased over time.

Note that, as with the home team bias, the close bias is possibly welfare improving. All teams go through periods in which they are below average, and fans may appreciate generous treatment in their down periods, even at the cost of being penalized during up periods. Still, this is clearly another example of inconsistent rule enforcement and a violation of the league's officiating policy.

4.3 Playoff Bias

Hypothesis 3, that the league attempts to extend playoff series by favoring particular teams, is explored in this subsection.[29] Although the theory is especially well known and easy to link to direct revenue increases, investigating it is relatively difficult due to the limited number of playoff series in the data sample. Despite this challenge, we start by looking at mean game-level turnover differences, categorized by playoff series score, which are graphed in Figure 1. The games are grouped by the win-loss record of the home team for the series coming into the game, and ordered by the approximate degree to which the home team winning would extend the series.[30] Games to the left, in Figure 1, are those in which home team wins are more likely to extend the series, and games to the right are those in which away team wins are more likely to extend

[28] If this was the complete explanation for the close bias, it would not be a separate phenomenon from home bias; however, this likely not the case. As noted, there are other reasons for the close bias, at least one of which has been formally documented in Pedowitz (2008). More importantly, the estimates imply the home team's advantage is greatest when it is losing by a wide margin rather than when the game is close. Since the crowd is likely strongest when the game is close, the results indicate the close bias is not merely due to officials responding to the crowd.

[29] We have also tested for another alleged playoff bias: that the league favors large market teams in the playoffs in all games, not just those that would extend the series, to increase television ratings of the later playoff rounds. Only weak evidence in support this conjecture is uncovered and, therefore, do not report results.

[30] There are 16 playoff teams and four playoff rounds. Each round consists of paired matchups between the teams, each of which consists of a best-of-seven series. Thus, there are 16 possible series scores (home wins-away wins) at the start of each playoff game.

the series. The sample sizes are especially small for games in which the home team is up 2-0 and 3-0 (four and two, respectively), as the visiting team rarely wins the first two games of a series.[31]

The figure indicates two patterns. First, most of the plots for discretionary fouls lie below zero (the horizontal axis), which is consistent with the home bias discussed earlier. Second, the bias towards the home team is larger in games in which the home team winning would be more likely to extend the series. Both of these patterns are weaker for non-discretionary turnovers. As a rough statistical check, a linear prediction is fitted through the points for each type of turnover. The discretionary turnover line is positively sloped and steeper than that of non-discretionary turnovers, which indicates that more subjective referee calls are more influenced by the playoff situation.

To formally test the playoff bias hypothesis, we use Poisson regression models similar to those described above, with two main differences. First, the sample is restricted to only include playoff games, and second, two new binary variables, "Bias For" and "Bias Against" are added to the regression. Bias For is equal to one when the team is down in the series 0-2, 0-3, 1-3 or 2-3 at the start of the game, as these are situations in which teams are most likely to be favored. Bias Against is defined analogously. The series score 0-2 is included in the Bias For situations because a loss by a trailing team would render the series effectively over, as no team has ever won a series after falling behind 0-3. Moreover, favoritism of teams down 0-2 may be more subtle, and difficult to detect, than favoritism of teams on the brink of elimination.

When a Poisson regression of discretionary turnovers on the Bias For and Bias Against variables is estimated, we obtain coefficients of -0.065 and 0.097, respectively, indicating teams facing elimination in the series, or down 0-2, receive a 16.2% discretionary turnover advantage.[32] When the same regression is estimated using non-discretionary turnovers as the dependent variable, the coefficients are equal to -0.007 and -0.018 and are not significantly different. These results confirm the patterns displayed in Figure 1; discretionary fouls are called less frequently for teams whose win

[31] The team with the better regular season record is the home team for the first two games of each playoff series. Thus, in cases when the home team is leading 2-0 or 3-0, the underdog has won every game in the series.

[32] The difference is significant at the 1% level.

lengthens the series, while non-discretionary fouls are called regardless of series status. The estimates do not, however, account for confounding variables, such as home status, attendance, team quality, etc. Simply controlling for home game reduces the discretionary turnover advantage of teams possibly favored to extend the series to 11.0%.

Table 3 presents estimation results from models that incorporate the full set of control variables, including matchup fixed effects.[33] While the bias variable coefficient estimates are generally not significant, teams down 0-2, 0-3, 1-3 or 2-3 do have an 11.7% advantage over their opponents[34] in discretionary turnovers when player behavior is controlled for, which is significant at the 5% level. The advantage is not significant, however, for any other statistical category – including non-discretionary turnovers. It is equal to up to 2.9% for shooting fouls, but is negative 1.6% for non-shooting fouls. Due to the relatively large standard errors, the discretionary turnover estimates are not significantly different from those for non-discretionary turnovers for all feasible covariances. Still, the results stand as evidence that teams are favored in ways consistent with the league's profit motives, and the favoritism is strongest in the category least scrutinized by fans and for which referees have the most discretion.

To examine whether this bias is implicit or explicit, we measure the degree to which the favoritism increases in more important game situations. If the bias were explicit, it should be stronger when its expected returns are higher – when the bias is more likely to affect which team wins the game. While referees are watched especially closely in these situations, making the predicted effects somewhat unclear, if the bias were found to systematically increase in more pivotal game situations it would be suspicious and indicative of explicit bias.

To conduct these tests, the data set is refined to the minute-level, and a new dummy variable is constructed that is equal to one in minutes that occur in the fourth quarter and the score margin at the start of the minute is five or fewer points. The characterization of the dummy variable is admittedly *ad hoc*, but the results are robust to changes in the definition. The dummy variable is interacted with the Bias For and Bias Against

[33]The fixed effects are quarter-level means from the regular season games between the two teams. For simplicity and due to Table 2 indicating only slight non-linear effects, a linear term is used to control for start of quarter score difference.

[34]The 11% advantage is calculated by subtracting the Bias Against estimate, .068, from the Bias For estimate, -.049.

variables, and the subsequent estimation results are reported in Table 4. The interaction terms are largely insignificant, and the signs for the discretionary turnover results appose the existence of explicit bias. The results imply the discretionary turnover playoff bias disappears in these critical game minutes; perhaps the referees improve their performance when it matters most. Also of note, the estimates on the non-interacted newly constructed dummy variables are substantial and significant only for non-discretionary turnovers. These estimates indicate that only non-discretionary turnovers are highly affected by changes in style of play in more consequential game situations. Finally, we test whether the bias is larger in series between large television market teams, and if the bias has changed over time. In general, these results are neither statistically nor economically significant. Moreover, they do not point towards explicit bias or the playoff bias decreasing over time.[35]

The estimation results, taken as a whole, suggest that teams down in playoff series are favored implicitly, though the evidence is not overwhelming. Officials may have subconsciously favored the underdog or made calls to do the league's bidding. On the other hand, it is also possible that the home crowd is stronger in games where the home team faces elimination and, thereby, the playoff bias is caused in part by an increased home bias. The greater strength of the home crowd would not likely be fully captured by the attendance variable; most playoff games have full attendance and, consequently, there is little variation in attendance within a playoff series. Providing further support of the playoff bias as a precipitant of the home bias, the playoff bias is substantially stronger when the team down in the series is the home team. Yet, if this were true then the home bias would increase when the series score is 3-3; the home crowd is likely to be strongest in these games. But, when we recode Bias For (Bias Against) as equal to one in these games for home (away) teams, both the magnitude and significance of the playoff bias decreases. Therefore, the increased home bias is not the entire source of the playoff bias.

[35]We do not report these results in the interest of brevity, but they are available upon request. To examine the connection between television market size and playoff bias, we calculate whether the advantage of favored teams increases as the total Nielsen television market size of the two teams increases.

5 Concluding Remarks

In this paper three variants of NBA referee bias are identified: home bias, close-game bias, and playoff bias. In addition, all three are found to likely be a consequence of psychosocial pressure and not league mandate. Yet, each of these biases are consistent with increased league revenue, and the favoritism has not decreased in response to the NBA's increased monitoring of its officials. If the biases remain undetected by the public then the league has minimal incentive to instruct its officials to judge games objectively. Thus, we present clear evidence that firms may circumvent a set of rules in order to increase profits.

We recommend that the league monitor referee behavior in the biased situations more carefully. And, they should keep an especially close eye on discretionary turnovers, the variable most strongly affected by the biases. It is certainly difficult to perfectly judge discretionary turnovers, as the speed at which professional basketball is played prevents the actions from being perfectly observed. Yet, whether justified or not, the suspicious nature of these biases may cause fans' enjoyment of the NBA to decrease. It is also possible to excessively monitor the referees, and the league should be careful not to become overzealous in its supervision officials. This could create a host of new problems, as, for example, referees might feel compelled to make calls in one game to make up for perceived disparities in previous games. Hopefully simply calling attention to and raising awareness of the biases will help to alleviate them. Finally, it might be helpful to report traveling and offensive foul violations in box scores. Making these numbers observable to the general public would improve transparency, and likely be beneficial due to the "sunshine principle."

References

Badenhausen, K., Ozanian, M.K. and Settimi, C. (2007). "The Business Of Basketball", *Forbes*, December 6.

Duggan, M., and S. Levitt. (2002). "Winning Isn't Everything: Corruption in Sumo

Wrestling", *American Economic Review*, vol. 92(5), 1594-1605.

Garicano, L, I. Palacio-Huerta, and C. Prendergast. (2005). "Favoritism Under Social Pressure", *The Review of Economics and Statistics*, vol. 87(2), 208-216.

Hassett, K. (2008). "NBA Home Bias Suggests Referees Committing Fouls", *AEI Short Publications*, June 23.

Larsen, T. and Price, J. and Wolfers, J. (2008). "Racial Bias in the NBA: Implications in Betting Markets", *Journal of Quantitative Analysis in Sports*, vol. 4(2), article 7.

Neave, N., and S. Wolfson. (2003). "Testosterone, Territoriality, and the Home Advantage", *Physiology and Behavior*, vol. 78, 269-275.

Nevill, A.M., N.J. Balmer, and A.M. Williams. (2002). "The Influence of Crowd Noise and Experience Upon Refereeing Decisions in Football", *Psychology of Sport and Exercise*, vol. 3, 261-272.

PARSONS, C.A. and SULAEMAN, J. and YATES, M. and HAMERMESH, D.S.. (2007). "Strike Three: Umpires' Demand for Discrimination", NBER Working Paper.

Pettersson-Lidbom, P. and Priks, M. (2007). "Behavior under Social Pressure: Empty Italian Stadiums and Referee Bias", Working Paper.

Price, J., and J. Wolfers. (2007). "Racial Discrimination Among NBA Referees", NBER Working Paper No. W13206.

Pedowitz, L. (2008). "REPORT TO THE BOARD OF GOVERNORS OF THE NATIONAL BASKETBALL ASSOCIATION", Wachtell, Lipton, Rosen & Katz.

Rodenberg, R.M., and W.L. Winston. (2009). "Payback Calls: A Starting Point for Measuring Basketball Referee Bias and Impact on Team Performance", Working Paper.

Schwarz, A. (2007). "N.B.A. Referee Is the Focus of a Federal Inquiry", *The New York Times*, July 21.

Sutter, M., and M. Kocher. (2004). "Favoritism of Agents – The Case of Referees' Home Bias", *Journal of Economic Psychology*, vol. 25, 461-469.

Van Doren, Charles. (2008). "All the Answers: The quiz-show scandals–and the aftermath", *The New Yorker*, July 28, 2008.

Zitzewitz, E. (2006). "Nationalism in Winter Sports Judging and Its Lessons for Organizational Decision Making", *Journal of Economics and Management Strategy*, vol. 15(1), 67-99.

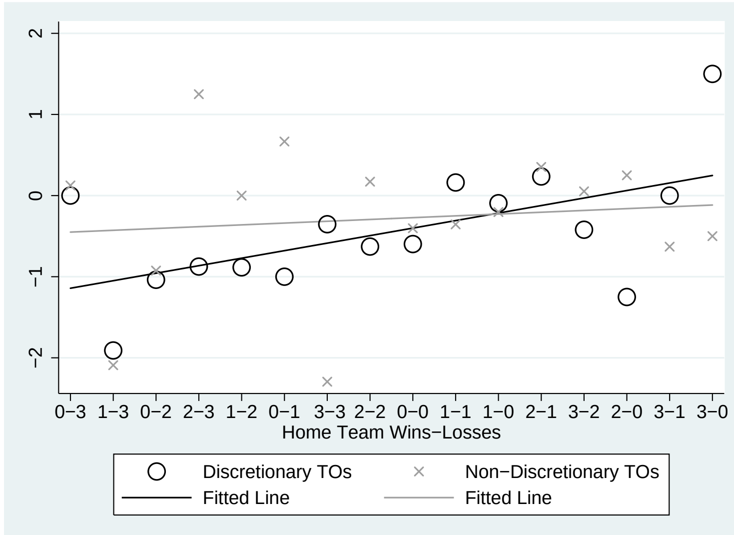

Figure 1: Mean Game-Level Turnover Differences (Home Minus Away) by Playoff Series Score (Home Wins-Losses)

Table 1: Basketball Terminology

Turnover	An offensive team loses possession to the defensive team without making a shot attempt.
Travel	An offensive player takes more than two consecutive steps without dribbling the basketball.
Three seconds	An offensive player remains in the lane for more than three consecutive seconds.
Goal tending	A player prevents a shot from going in the basket when the ball is on a downward trajectory.
Offensive foul	Illegal contact committed by the offensive player.
Shot clock	The offensive team fails to shoot, and hit the rim, within 24 seconds of possession time.

Table 2: Quarter-Level Summary Statistics

	Home	Away		Winning	Losing/Tied	
	Mean (SD)	Mean (SD)	Difference	Mean (SD)	Mean (SD)	Difference
Discretionary Turnovers						
Travel	0.227 (0.486)	0.272 (0.530)	-0.0444 ***	0.254 (0.514)	0.247 (0.506)	0.0070
Three seconds	0.082 (0.288)	0.074 (0.274)	-0.0080 ***	0.091 (0.301)	0.071 (0.269)	0.0196 ***
Offensive foul	0.469 (0.693)	0.508 (0.727)	-0.0382 ***	0.525 (0.734)	0.468 (0.696)	0.0574 ***
Offensive goal-tend	0.012 (0.111)	0.013 (0.115)	-0.0009	0.012 (0.111)	0.013 (0.114)	-0.0010
Non-Discretionary Turnovers						
Bad pass	1.445 (1.225)	1.419 (1.230)	-0.0264 **	1.425 (1.232)	1.436 (1.225)	-0.0108
Lost ball	0.679 (0.847)	0.715 (0.873)	-0.0358 ***	0.698 (0.856)	0.697 (0.862)	0.0019
Shot clock	0.058 (0.246)	0.064 (0.260)	-0.0060 ***	0.069 (0.270)	0.056 (0.243)	0.0123 ***
Non-Shooting Fouls						
Personal	1.751 (1.309)	1.750 (1.312)	-0.0006	1.850 (1.352)	1.695 (1.283)	0.1552 ***
Loose ball	0.309 (0.558)	0.318 (0.567)	-0.0097 **	0.340 (0.582)	0.299 (0.551)	0.0418 ***
Inbounds	0.002 (0.050)	0.003 (0.054)	-0.0004	0.003 (0.056)	0.002 (0.050)	0.0005
Clearing	0.006 (0.077)	0.007 (0.086)	-0.0013 *	0.008 (0.089)	0.006 (0.077)	0.0019 **
Away from ball	0.005 (0.068)	0.004 (0.065)	-0.0002	0.005 (0.070)	0.004 (0.064)	0.0008
Shooting Fouls						
Non-flagrant	2.310 (1.427)	2.430 (1.476)	-0.1203 ***	2.521 (1.496)	2.285 (1.422)	0.2359 ***
Flagrant	0.010 (0.099)	0.012 (0.109)	-0.0020 **	0.010 (0.102)	0.011 (0.105)	-0.0003

Notes: Sample includes all regular season and playoff quarters from 2002-2003 - 2007-2008 seasons with play-by-play data available on ESPN.com; overtime periods, last three minutes from fourth quarters and quarters in which one team scored five or fewer or greater than 40 points dropped. "Winning" = winning by one or more points at start of quarter; "Losing/Tied" = losing or tied at quarter start. In total there are 28,338 quarters in the sample. *, **, *** denote 10%, 5% and 1% significance, respectively (for differences; two-tailed tests, unequal variances).

Table 3: Home and Close Bias Estimation Results

	Discretionary Turnovers		Shooting Fouls		Non-Shooting Fouls		Non-Discretionary Turnovers	
Home Game	-0.1119***	-0.0857***	-0.0666***	-0.0471***	-0.0099**	-0.0117**	-0.0187***	0.0159***
	(0.0082)	(0.0082)	(0.0045)	(0.0044)	(0.0050)	(0.0051)	(0.0053)	(0.0051)
Attendance × Home	-0.0130***	-0.0104***	-0.0006	0.0013	-0.0039**	-0.0040**	-0.0029	0.0005
	(0.0029)	(0.0029)	(0.0016)	(0.0016)	(0.0018)	(0.0018)	(0.0019)	(0.0018)
Quarter Start Score Diff < - 10	-0.1487***	-0.1296***	-0.0425***	-0.0281***	-0.0043	-0.0056	0.0117	0.0363***
	(0.0186)	(0.0186)	(0.0097)	(0.0097)	(0.0110)	(0.0110)	(0.0111)	(0.0109)
-10 $\leq$ Score Diff ≤ -4	-0.0633***	-0.0526***	-0.0258***	-0.0184**	0.0038	0.0030	-0.0103	0.0025
	(0.0156)	(0.0155)	(0.0084)	(0.0083)	(0.0091)	(0.0091)	(0.0095)	(0.0094)
4 $\leq$ Score Diff $\leq$ 10	0.0655***	0.0556***	0.0508***	0.0435***	0.0306***	0.0313** *	0.0442***	0.0314***
	(0.0152)	(0.0151)	(0.0082)	(0.0082)	(0.0090)	(0.0089)	(0.0095)	(0.0093)
10 < Score Diff	0.0928***	0.0749***	0.1100***	0.0958***	0.0359***	0.0371** *	0.1311***	0.1068***
	(0.0175)	(0.0174)	(0.0093)	(0.0092)	(0.0107)	(0.0107)	(0.0109)	(0.0108)
Score Margin Dummies		✓		✓		✓		✓

Notes: N = 56,776. Poisson models with matchup (team-opponent-season) fixed effects, quarter fixed effects, and de-meaned attendance (in thousands) included in all specifications. “Score Diff” = start of quarter own score minus opponent score (dummy variables for difference being less than -10, greater than -11 and less than -3, etc.). “Score Margin Dummies” are dummy variables equal to one if lose quarter by more than five points, lose by one to five points, win by zero to five points (winning by more than five points is omitted category). Robust standard errors clustered by game. *, **, *** denote 10%, 5% and 1% significance.

Table 4: Playoff Bias Estimation Results

	Discretionary Turnovers		Shooting Fouls		Non-Shooting Fouls		Non-Discretionary Turnovers	
Bias For	-0.039	-0.049	-0.034	-0.041	0.050*	0.051*	-0.012	-0.027
	(0.053)	(0.054)	(0.027)	(0.027)	(0.029)	(0.029)	(0.034)	(0.033)
Bias Against	0.057	0.068	-0.020	-0.012	0.036	0.035	-0.032	-0.016
	(0.045)	(0.045)	(0.028)	(0.028)	(0.031)	(0.031)	(0.034)	(0.032)
Home Game	-0.028	0.011	-0.107***	-0.085***	0.004	0.002	-0.037	0.013
	(0.057)	(0.058)	(0.028)	(0.029)	(0.029)	(0.029)	(0.038)	(0.035)
Attendance × Home	-0.072***	-0.066***	0.005	0.010	-0.021**	-0.022**	-0.009	0.001
	(0.022)	(0.022)	(0.011)	(0.011)	(0.011)	(0.011)	(0.015)	(0.014)
Quarter Start Score Diff	0.007***	0.005**	0.006***	0.005***	0.001	0.001	0.005***	0.002
(Own - Opponent Score)	(0.002)	(0.002)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Score Margin Dummies		✓		✓		✓		✓
p-value for H_0:								
Bias For = Bias Away	0.1057	0.0474	0.6562	0.3688	0.6444	0.6124	0.6627	0.8028

Notes: N = 3,792 (playoff game team-quarters only). Bias For = 1 if team down in series 0-2, 0-3, 1-3, 2-3; 0 otherwise. Bias Against = 1 if team up in series 2-0, 3-0, 3-1, 3-2; 0 otherwise. Match-up (team-opponent-season) fixed effects (regular season means) and de-meaned attendance (in thousands) used in all models. "Score Margin Dummies" are dummy variables equal to one if lose quarter by more than five points, lose by one to five points, win by zero to five points (winning by more than five points is omitted category). Robust standard errors clustered by game. *, **, *** denote 10%, 5% and 1% significance.

Table 5: Playoffs Only, Minute-Level Sample

	Disc. TOs	Shoot. Fouls	Non-Shoot. Fouls	Non-Disc. TOs
Bias For	-0.051	-0.054*	0.048	-0.021
	(0.056)	(0.028)	(0.030)	(0.034)
Bias Against	0.074*	-0.019	0.033	-0.042
	(0.045)	(0.029)	(0.031)	(0.034)
Home Game	-0.126***	-0.056***	-0.031	-0.034
	(0.036)	(0.019)	(0.019)	(0.024)
Attendance × Home	-0.067***	0.008	-0.019*	-0.005
	(0.022)	(0.011)	(0.011)	(0.015)
Bias For × Critical	0.133	0.134	-0.026	0.131
	(0.179)	(0.101)	(0.102)	(0.119)
Bias Against × Critical	-0.286	0.002	-0.013	0.254*
	(0.185)	(0.107)	(0.100)	(0.134)
Home × Critical	-0.201	-0.101	-0.005	0.053
	(0.129)	(0.071)	(0.074)	(0.096)
Critical	0.055	0.082	0.115*	-0.271***
	(0.094)	(0.059)	(0.063)	(0.083)
p-value for H_0:				
Bias For = Bias Away	0.0403	0.2772	0.6533	0.6419
BF × Critical = BA × Critical	0.0617	0.2208	0.9059	0.4449
BF + (BF×Crit) = BA + (BA×Crit)	0.1784	0.3566	0.9848	0.5254

Notes: N = 44,532. Poisson models with matchup (team-opponent-season) fixed effects (regular season means), and de-meaned attendance included in all specifications. Bias For = 1 if team down in series 0-2, 0-3, 1-3, 2-3; 0 otherwise. Bias Against = 1 if team up in series 2-0, 3-0, 3-1, 3-2; 0 otherwise. Critical = 1 if minute occurs in 4th quarter and minute-start score margin less than 6. Robust standard errors clustered by game. *, **, *** denote 10%, 5% and 1% significance.