NBA Referee Bias: Do Statistics Suggest a Home Court Advantage? Is there Favoritism toward Teams Facing Elimination?

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Abstract

In the summer of 2007, former National Basketball Association (NBA) referee Tim Donaghy was found to have bet on games that he officiated. Donaghy subsequently alleged that referee bias is rampant throughout the league. The scandal created widespread speculation about the legitimacy of controversial games in recent history, though NBA Commissioner David Stern argued vehemently that Donaghy was an isolated individual in his deviance. In light of this contentious issue, this paper empirically investigates whether there is evidence of referee bias. Specifically, home bias and prolonged playoff series bias are examined through analysis of multiple statistical categories, including discretionary turnovers (DTOs) and non-discretionary turnovers (NTOs). To analyze prolonged series bias, this study observes teams facing elimination (down 2-3, 1-3, or 0-3) as well as those threatening to eliminate (up 3-2, 3-1, or 3-0). In these "one-sided elimination games," or "pre-game 7 elimination games," only a win by the team trailing in the series can extend the series to an additional game, generating added league revenue from ticket and advertisement sales. So, if the data analysis suggests that particular statistics are significantly favored toward teams facing "one-sided elimination," it may suggest prolonged series bias among referees.

1 Introduction and Background

In the summer of 2007, former NBA referee Tim Donaghy pled guilty to two felony charges involving "gambling violations and money laundering" (Munson, 2008). In short, Donaghy was found to have bet on NBA games that he officiated. Given a referee's power to influence games, the indictment implies Donaghy fixed the outcomes of games. Donaghy not only admitted to the charges filed against him but also claimed that the manipulation of NBA games is widespread (Munson, 2008; "Donaghy under Investigation," 2007). He specified that referees favor star players, teams losing during games, and teams losing in playoff series and stunningly, "that the league sometimes knowingly turns a blind eye to these biases, and sometimes even subtly encourages them" (Price, Remer, and Stone, 2012).

As expected, the Donaghy scandal initiated a storm of questioning about the NBA's integrity and created widespread speculation among fans about the legitimacy of controversial games in recent history. Most notably, Donaghy "pointed to Game 6 of the 2002 conference finals between the Los Angeles Lakers and Sacramento Kings. He asserted that the referees intentionally called more fouls on the Kings to try to deliver a win to the Lakers and extend the contest to seven games" (Hassett, 2008). This particular accusation is especially intriguing because the NBA would financially benefit from a highly anticipated playoff series extending to seven games. Hassett sums up this notion: "NBA playoff series are best of seven, so they can run anywhere from four to seven games. If the series runs longer than four, then the league earns more gate revenue, and television broadcasters can sell more advertisements."

NBA Commissioner David Stern has argued strongly that Donaghy is a "rogue, isolated criminal" who should not be trusted with respect to his egregious allegations ("Stern: Bet probe," 2007). Stern also appointed former federal prosecutor Larry Pedowitz to conduct an investigation into the league's officiating, "with a focus on the influence of gamblers and bookies and the biases alleged by Donaghy" (Price, Remer, and Stone, 2012). As elucidated in a 116-page report, which was the culmination of a 14-month probe, Pedowitz found no evidence in line with Donaghy's assertions ("Review of NBA officials," 2008). In contrast, professional gambler Haralabos Voulgaris notes some possible evidence supporting Donaghy's allegations about the 2002 Lakers-Kings Game 6: "In that game, the Lakers shot 27 free throws in the fourth quarter alone. There have only been 19 games since 2003-2004...where one team shot more than 25 free throws in any quarter of a game" ("A Professional Gambler's Take," 2008).

Neither Stern nor Pedowitz nor Voulgaris conducted any formal empirical analysis, however. Therefore, this study will be an econometric attempt to specifically investigate referee bias in the NBA playoffs. In particular, I will analyze home bias as well as prolonged series bias. My motivation for studying home bias is to contribute to economics literature in a topic scarcely studied in basketball. Specifically, Price et al. (2012) claim that their NBA referee bias study "is one of the first papers to study the home bias in a sport other than soccer."

As for the prolonged playoff series bias, I want to step beyond Stern, Pedowitz, and Voulgaris and formally determine whether Donaghy has any merit in his allegations. In particular, do referees tend to make calls that favor teams trailing in a playoff series? The intention is to be able to inform fans as to whether or not they have reason to doubt the legitimacy of playoff games in which only one team is a win away from closing out the series. Such games in which one team leads 3-0, 3-1, or 3-2 are defined as "one-sided elimination games." My aim is to analyze multiple statistical categories, including discretionary turnovers

(DTOs) and non-discretionary turnovers (NTOs), in one-sided elimination games versus other playoff games.

Before proceeding further, however, it is important to address potential reasons why referees would exhibit bias. What costs and benefits for the referees might a home bias or a prolonged series bias entail? One potential reason for the biases could be related to social-psychological factors. In particular, referees might feel pressure to please the tens of thousands of home fans and therefore, make calls that tend to favor the home team. As for the prolonged series bias, referees may feel sympathy for, and thus favor, the “underdog” in the series (Price, Remer, and Stone, 2012). A second reason behind a prolonged series bias could be related to the fact that referees are evaluated in part by coaches and other members of teams (Pedowitz, 2008). In short, referees might have an incentive to build goodwill with teams if they believe the goodwill benefit from favoring losing teams outweighs the cost of disfavoring winning teams. Perhaps a team frustrated with losing the game would be more irritated by close calls favoring the opponent, and perhaps the winning team is not overly bothered by close calls favoring the opponent as long as they hold on for the win.

And lastly, in line with Donaghy’s claims, referees may exhibit bias toward teams facing elimination due to league encouragement. Perhaps the league tells referees to enforce a specific rule more or less strictly, which benefits a specific team in a series. As an example, Donaghy alleges that the NBA sought to extend a 2005 first round Western Conference postseason series between the Dallas Mavericks and Houston Rockets. Houston won the first two games in Dallas. According to Donaghy, after Game 2, the NBA instructed officials to call illegal screens more tightly on the Rockets’ star center, Yao Ming. This is a particularly intriguing assertion because Dallas ultimately overcame their two-game deficit and won the series, becoming only the third team in NBA history to do so after losing the first two games of a series at home (Mitchell, 2011).

As it turns out, I find evidence suggestive of home bias across all statistics I examine, including DTOs, NTOs, fouls, free throws, field goal percentage, steals, and blocks. Meanwhile, my DTO data also hints at a prolonged series bias, though no other statistics seem to significantly favor teams facing elimination. And furthermore, field goal percentage and blocks decrease significantly for teams on the brink of playoff elimination. I analyze these results and speculate as to what facets can be contributed to referee behavior versus player behavior.

2 Literature Review

Considering the depth of questions and debates incited by sports scandals, it comes as no surprise that previous research has been conducted on different forms of referee bias. Price and Wolfers (2010) found that NBA players have up to 4% fewer fouls and score up to 2.5% more points when their race matches that of the refereeing crew. What is more, they elucidated that "the bias in foul-calling is large enough so that the probability of a team winning is noticeably affected by the racial composition of the refereeing crew assigned to the game" (1885). These results are relevant to my study not only because they support the notion that there is NBA referee bias in some form but also because they find that the bias is large enough that it can affect the outcomes of games. Thus, Price and Wolfers give credence to the notion that referees could exhibit significant enough bias to help the team facing elimination pull out a win and extend the series an additional game.

Parsons et al. (2011) also investigated racial discrimination, though they studied Major League Baseball (MLB) umpires. Interestingly, they found that pitches are more likely to be called strikes when the umpire shares the race/ethnicity of the starting pitcher. During the time period of the study, only a portion of ballparks were outfitted with computers and cameras to monitor umpires' balls and strikes calls. Because umpires are randomly assigned to venues, Parsons et al. could observe differences in umpire behavior between parks with and without monitoring technology, and they found that the discriminatory effect was only observable when umpires' behavior was not well monitored. The impacts shown from monitoring MLB umpires should be taken into account as a potential way to prevent significant home or prolonged series biases among NBA referees.

Moreover, the results reported by Parson et al. are robust to a wide set of controls, including fixed effects for each pitcher, umpire, batter, and catcher. As a result, their main explanatory variable picks up the marginal effect of a racial/ethnic match between the home-plate umpire and pitcher, which purely identifies the umpires' bias. Because any player or race-specific effects are swept out by the fixed effects, differences in umpire or player-specific characteristics are not driving the results. Similarly, in my study, I use round, year, series, and referee fixed effects to ensure that any round, year, series, or referee-specific effects are controlled for, allowing for purer identification of referee bias against away teams as well as teams leading 3-2, 3-1, or 3-0.

Although the two racial discrimination studies provide some precedence for my study in terms of results and controls, Price, Remer, and Stone (2012) has a much stronger relation to my referee bias investigation. Specifically, they divided turnovers into two categories: discretionary turnovers (DTOs) and non-discretionary turnovers (NTOs), providing the basis for my turnover analysis. Price et al. elucidate DTOs in the following manner:

> These are all turnovers that are called by a ref blowing his or her whistle while the ball is in play, and hence would not have occurred without active ref behavior. Both traveling violations and offensive fouls, which comprise the vast majority of the DTOs, are notoriously subjective and inconsistently called in the NBA, which also suggests they are relatively susceptible to bias. Three second and offensive goal-tending violations are also categorized as discretionary, as they are called by a ref whistle with the ball in play, but occur infrequently and bear little weight on the results.

I share this DTO definition, though my data includes multiple types of turnovers Price et al. did not reference in their paper, namely eight-second violations, five-second back to the basket violations, inbounds turnovers, backcourt violations, illegal screens, discontinued dribbles, double dribbles, illegal assists, kicked ball turnovers, palming, punched ball turnovers, jump ball violation turnovers, lane violation turnovers, or basket from below turnovers, all of which are called through active ref behavior.

Price et al. describe their other turnover category, NTOs, as turnovers “determined either directly by player behavior, such as when a defensive player steals the ball from the offense, or when refs make a call [when]…the shot clock has expired.” Of course, referees have minimal discretion over whether they can call a shot clock violation because the shot clock is clearly visible to the crowd and also loudly audible when it expires. I was able to also include double personal turnovers due to the specificity of my turnover examples. (Note that the definitions and descriptive statistics for double personal turnovers as well as all other turnover types are presented in Tables 1 and 2, respectively.) Nevertheless, due to their extreme infrequency, double personal turnovers have a minimal impact on my results.

An important limitation of the Price et al. study is that their data does not adequately specify out of bounds calls. Fortunately, my data provides this information and differentiates bad passes and lost balls into those that were stolen and those that went out of bounds. On top of that, my turnover data indicates stepping out of bounds turnovers, an additional turnover specification that Price et al. were not afforded. The breakdown of these turnover types into DTOs and NTOs is detailed in Section 3.1.

Price, Remer, and Stone specifically test for turnover bias in regards to "favoritism of home teams, teams losing during games, and teams that are behind in a multi-game playoff series." They found that "the home team has a greater than 11% advantage in DTOs on average, but a less than 3% advantage in NTOs." The fact that home teams have such an advantage in DTOs, turnovers primarily driven by referee discretion, compared with NTOs, driven primarily by player behavior, is indicative of referee bias. Regarding close games, Price et al. find that "teams trailing at the start of a minute are systematically favored in the subsequent minute." As for playoff games, "for each game a team is down (up) in the series, it gains (loses) a 3.4% advantage in DTOs, significant at the 5% level."

Price et al. also examine fouls with respect to the "home bias," "close bias," and "playoff bias." They ultimately conclude that the home team has "an over 8% advantage in shooting fouls and a 2.9% advantage in non-shooting fouls, both significantly different from zero at the 1% level." Meanwhile, supporting the "close bias," Price et al. determine that winning teams commit 14-27% more shooting fouls and 12-18% more non-shooting fouls than their opponents. However, they found that fouls do not show evidence for "playoff bias" with statistical significance.

As Kuethe and Zimmer (2009) point out, unjustly refereeing a game in favor of the team trailing in a playoff series results in increased revenue from ticket sales and television broadcasts for both the NBA and the teams involved in the series. They also consider whether calls made by referees on statistics such as turnovers tend to favor large market teams located in densely populated regions of the United States. These teams, such as the Los Angeles Lakers or the New York Knicks, attract a larger population of television viewers and increase merchandising potential. Kuethe and Zimmer ultimately determine that bias exists in playoff games in favor of large market teams. Their results suggest that large market teams are expected to win by a larger margin if they have a higher seed and are expected to lose by a smaller margin if they are the "underdog." They also pinpoint bias in favor of extending a playoff series that includes at least one large market team. Although assessing large market teams is beyond the scope of my study, these results provide evidence for some form of the prolonged playoff series bias, which I hope to detect in my investigation.

Other intriguing previous research exists regarding suspicious trends in the NBA's postseason. Hassett (2008) states:

> Basketball is the one sport that should have the smallest home-field advantage. Every court is the same. Yet in the 2008 playoffs, the home team won 64 of 86 games, or 74 percent of the time. If we exclude the first round, where there are bound to be some blowouts, the home team won 34 out of 42, an 81 percent clip.

Hassett goes on to compare foul and shooting percentage disparities between home and road playoff teams. He compares these statistics to the disparities that occur during the regular season, highlighting some intriguing postseason patterns. Hassett explains:

> During the regular season since 2002-3, the home team generally gets called for 0.8 fewer fouls than the visiting team. During the playoffs since 2003, though, the home-court advantage almost doubles, with the home team being called, on average, for 1.4 fewer fouls than the visiting team. The same holds for field-goal percentage. In the regular season since 2002-3, the home team tends to shoot about 1.3 percentage points better from the field than the away team. In the playoffs since 2003, that difference jumps to 2.3 points. This year, the difference has been 3.5 percentage points. This suggests the home team is allowed to play aggressively.

(Regarding his mention of playing “aggressively,” Hassett earlier notes that a “team can play more aggressive defense once it’s aware that the officials are being kind to them.”) Given such data on home versus road playoff teams, it seems appropriate that an investigation into home and prolonged series biases include analysis of foul calls and free throws.

Hassett’s article also addresses foul differentials for home teams in one-sided elimination games. Hassett notes that in Game 6 of a series in the 2007 and 2008 playoffs, the home team was called for 4.1 fewer fouls on average if trailing in the series. However, in the seventh game, the same foul differential falls to only 1. This difference suggests that referees tend to extend the series by calling more fouls on the team leading in the series and/or fewer fouls on the team facing elimination. Hassett’s preliminary examination of the home bias in terms of winning percentage, fouls, and free throw percentage provides a strong incentive for my formal study. Furthermore, his results cover only two years of playoff data, though my investigation will use data from five years of playoff games, which will theoretically provide more credible results.

3 Methodology

3.1 Data

I use play-by-play data for all NBA playoff games from 2007-2011. The data for all but one of these 413 postseason games were downloaded from basketballvalue.com. For the lone omitted game, Game 5 of the 2009 Western Conference Finals between the Los Angeles Lakers and the Denver Nuggets, I obtained the play-by-play data from NBA.com and basketball-reference.com.

I analyze play-by-play data rather than box scores in order to have access to more detailed information related to game events and statistics. The detail allows me to divide turnovers into discretionary and non-discretionary categories. The principal challenge in analyzing referee bias is differentiating between referee behavior and player behavior, and this disaggregation attempts to circumvent this obstacle. Theoretically, referees can favor a particular team in their DTO calls, while players have a stronger influence than referees in determining NTOs. Since there is no official NBA differentiation of turnovers into DTOs and NTOs, I investigate three different classifications in my study. My primary classification of turnover types, along with definitions, is elucidated in Table 1.

Traveling violations and offensive fouls make up nearly 78% of DTOs in this first classification (Table 2). These particular turnovers are “notoriously subjective and inconsistently called in the NBA, which also suggests they are relatively susceptible to bias” (Price, Remer, and Stone, 2012). Toward the end of the 2008-09 NBA regular season, Joe Borgia, the NBA’s vice president of referee operations, expressed that the traveling rule was “so confusing that it’s impossible to tell if it allows one step or two” because the rule’s “intent is lost in a tangle of legalistic terminology” (“NBA official,” 2009). Fortunately, prior to the 2009-10 season, the

NBA addressed Borgia's concern by explicitly referencing "two steps" in the writing of a revised traveling rule ("NBA to alter," 2009). Nevertheless, traveling remains inconsistently called to this day. As recently as January, LeBron James was controversially not called for traveling in the final 10 seconds of regulation in a Miami Heat-Los Angeles Clippers game, causing the game to go to overtime (Golliver, 2012). The NBA later acknowledged on @NBAOfficial, its Twitter account "dedicated to clarifying controversial refereeing decisions," that James should have been called for traveling on the crucial play.

With regard to offensive fouls, the block/charge ruling is, according to Denver Nuggets coach George Karl, "an incredibly difficult play to call. I could put 20 on tape that everybody would miss…They're that close" (Thomsen, 2009). In particular, when a ball-handler makes substantial body contact with a defender, the referee must judge if the defender's torso is "set" when the ball-handler begins his "forward" or "upward" motion. If the defender is, indeed, "set," the correct call is a "charging foul" against the ball-handler. Otherwise, it is a "blocking foul" against the defender. Block-charge scenarios are rarely clear-cut, and the referee's decision must be made almost instantaneously after contact occurs, creating a perfect storm for bias.

In addition to traveling calls and offensive fouls, three-second violations, offensive goaltending, eight-second violations, five-second back to the basket violations, inbounds turnovers, backcourt violations, illegal screens, discontinued dribbles, double dribbles, illegal assists, kicked ball turnovers, palming, punched balls, jump ball violation turnovers, lane violation turnovers, basket from below turnovers, and stepping out of bounds are all classified as discretionary in my primary turnover classification (Table 1). However, compared with traveling and offensive fouls, these other DTOs are infrequent and have little weight on the results. Thus, although my DTO classification includes many more turnover types than Price et al. reference in their study, the DTO results are largely driven by traveling calls and charge/block rulings, as was the case for Price et al.

Meanwhile, over 93% of the NTOs in this first classification are bad passes and lost balls. Bad passes and lost balls result primarily from player behavior when the defender steals the ball. Of course, referees could be exhibiting some bias in permitting extra defensive aggressiveness rather than calling a foul when defenders steal bad passes or lost balls. Nevertheless, since referees do not actively make calls to impact these turnover types, stolen bad passes and stolen lost balls are defined as non-discretionary.

Bad passes and lost balls that go out of bounds are in even more of a gray area with respect to player behavior versus referee behavior. For example, referees have minimal discretion in calling turnovers when bad passes sail directly out of bounds with no players in the vicinity. In contrast, if a pass travels through traffic before going out of bounds, such that it may or may not have been tipped by multiple players, the referee must use a great deal of discretion in determining whether the offensive team touched the ball last, in which case it would be a bad pass turnover, or whether the defensive team touched it last, in which case it would not be a turnover. However, these specifics cannot be determined from the play-by-play data. Thus, since bad passes and lost balls that go out of bounds are considered non-discretionary in my primary classification, referees have some discretion over NTOs.

Shot clock violations and double personal turnovers make up the rest of the NTOs. Theoretically, referees could exhibit discretion with shot clock violations when determining whether or not the shot clock should be reset. Specifically, the shot clock is reset whenever a change of possession occurs or whenever the ball touches the rim. If it is difficult to ascertain whether a particular shot nipped the rim, referees could show bias toward the offensive team by ruling that the shot made contact with the rim, resulting in the resetting of the shot clock. Nevertheless, since "the shot clock is publicly viewable and a loud buzzer goes off when it expires," referees have minimal discretion over most shot clock violations. Furthermore, since the 2009-10 season, instant replay was expanded to allow referees to consult replay in order to check whether or not the shot clock expired before a shot was released or a foul was called, further diminishing referees' discretion over shot clock violations ("Instant replay," 2009).

As for double personal turnovers, referees have minimal discretion over these because they are largely impacted by the result of a jump ball (Table 1). Additionally, only one has been committed over the past five years of the NBA playoffs, making it completely inconsequential in terms of this study.

Stepping out of bounds, similar to bad passes and lost balls that go out of bounds, is determined by both player behavior and referee behavior. This type of turnover can range from a player standing with both feet unequivocally out of bounds to a player with a single toe nail touching an out of bounds line. Nevertheless, in my primary classification, I consider stepping out of bounds as a DTO because from my perspective, referees need to more actively call stepping out of bounds turnovers than bad pass or lost ball out of bounds turnovers. Specifically, a player dribbling along the baseline will continue play unless the referee whistles him for stepping out of bounds. On the other hand, game play often tends to stop on its own when the ball rolls out of bounds.

But of course, this primary classification of turnovers into DTOs and NTOs is imperfect since referee discretion over turnovers is not clear-cut. As a result, I analyze a second DTO and NTO classification where stepping out of bounds is considered non-discretionary. This classification serves as a robustness check since stepping out of bounds is less discretionary than traveling calls, offensive fouls, three-second violations, and all other turnovers in the discretionary classification.

From the opposite perspective, I include a third classification in which all out of bounds turnovers, whether stepping, passing, or losing the ball out of bounds, are considered discretionary. The reasoning stems from the argument that out of bounds turnovers are more discretionary since they are called by the referees during game play. In contrast, bad passes and lost balls that are stolen are not called by the referees but rather determined by players on the court.

In addition to such extensive turnover analysis, I also examine fouls, free throws, field goal percentage, blocks, and steals. Unlike turnovers, these statistics cannot be divided up based on the degree of perceived referee discretion. Fouls are the only candidate among these five statistics that could be disaggregated into types. However, all fouls by their very nature are discretionary, making a discretionary versus non-discretionary classification impossible.

Beyond the statistics, the play-by-play data also provides the exact time when each event occurred. Time remaining is especially important to take into account when analyzing fouls. In particular, at the end of games, the losing team sometimes chooses to foul in order to stop the clock and send their opponent to the free throw line. This tactic forces the leading team to shoot pressure free throws and maximizes the number of possessions for the trailing team. So as to prevent this late game fouling from distorting the analysis of referee bias, all fouls committed as well as free throws attempted in the final 2 minutes of either a regulation or overtime period have been dropped from the data.

Summary statistics for all types are presented in Table 3. Means for all statistics are shown at the team-game-level. Team-game-level averages are also shown for home games, away games, games in which the team faces elimination (i.e., down 2-3, 1-3, or 0-3), and games in which the team is threatening to eliminate its opponent prior to game 7 (i.e., up 3-2, 3-1, 3-0). The table, a preview of econometric results, suggests a home court advantage across all statistics, as home teams average fewer turnovers and fouls yet more free throws, steals, and blocks and have a higher field goal percentage. Meanwhile, the advantages for teams facing elimination seem contained to DTOs, while field goal percentage seems to be a disadvantage.

In addition to the play-by-play data, I obtained referee data. In particular, I used game box scores on ESPN.com to find the three referees for every playoff game in my dataset. This fixed effects approach, used by neither Price et al. nor Kuethe and Zimmer, takes into account individual heterogeneity among referees.

The data's unit of analysis is every NBA playoff game since 2007. The data can be characterized as a panel since it contains multiple statistics for 413 individual playoff games over a five-year period. For each playoff game, the statistics are tracked for both teams, accounting for two variables for each of the statistics to be analyzed.

3.2 Model

The following equation is used to investigate whether statistics, including DTOs, NTOs, fouls, free throws, field goal percentage, steals, and blocks, suggest favoritism toward home teams or teams facing elimination:

$$Statistic_{\mathrm{TG}} = \beta_0 + \beta_1(face\_elim)_{\mathrm{TG}} + \beta_2(threat\_elim)_{\mathrm{TG}} + \beta_3(home)_{\mathrm{TG}} +$$

$$\sum_{i=4}^{6}\beta_i(\text{round dummies})_{\mathrm{G}} + \sum_{i=7}^{10}\beta_i(\text{year dummies})_{\mathrm{G}} + \sum_{i=11}^{84}\beta_i(\text{series dummies})_{\mathrm{G}}$$

$$+ \sum_{i=85}^{133}\beta_i(\text{referee dummies})_{\mathrm{G}} + \varepsilon_{\mathrm{TG}} \qquad (1)$$

The dependent variable, *Statistic*, whether it is DTOs, NTOs, fouls, free throws, field goal percentage, steals, or blocks, represents a particular statistic for team T in game G.

The independent variable *face_elim* is a dummy equal to 1 if the team is facing elimination. "Facing elimination" is defined to mean that the team is one loss away from playoff elimination prior to game 7. Thus, the team is down 2-3, 1-3, or 0-3 in the best of seven series. On the other hand, the *threat_elim* variable is a dummy equal to 1 if the team is threatening to eliminate its opponent from the postseason. I define "threatening to eliminate" as signifying that the team is one win away from eliminating its opponent prior to game 7. Thus, the team is leading the best of seven series by a mark of 3-2, 3-1, or 3-0. In game 7s, teams are technically both facing elimination and threatening to eliminate. However, in order to investigate prolonged series bias, I did not set either dummy variable equal to 1 for a game 7. Because series cannot extend beyond a seventh game, referees no longer have an incentive to exhibit prolonged series bias.

The independent variable *home* is a dummy equal to 1 if the team is playing on their home court. This dummy is included for the purposes of investigating home bias. Dummy variables have also been constructed to account for rounds, series, and referees. The round, year, series, and referee fixed effects account for individual heterogeneity among rounds, years, series, and referees, respectively, in the model.

The estimated coefficients for β_1 and β_3 are expected to be statistically different from zero and negative for DTOs and fouls, yet statistically different from zero and positive for free throws, field goal percentage, steals, and blocks. In other words, I expect teams facing elimination and home teams to have fewer discretionary turnovers and fouls called against them yet more free throws, steals, and blocks and a higher field goal percentage compared with their opponent. Failure to reject this provides evidence suggestive of prolonged series bias and home bias, respectively.

In contrast, estimated coefficients for β_2 are expected to be statistically different from zero and positive for DTOs and fouls, yet statistically different from zero and negative for free throws, field goal percentage, steals, and blocks. In other words, I expect teams threatening to eliminate their opponent to have more discretionary turnovers and fouls called against them yet fewer free throws, steals, and blocks and a lower field goal percentage compared with their opponent. Failure to reject this provides evidence suggestive of prolonged series bias and home bias, respectively.

Regarding NTOs, I do not expect the estimated coefficients for β_1, β_2, or β_3 to be statistically different from zero. I disaggregated turnovers into NTOs with the assumption that this statistic is more reflective of player behavior than referee behavior, and I do not expect player behavior to significantly change (improve or worsen) in elimination games or home games. Considering all games in this dataset are playoff games, teams ought to play with a sense of urgency in all games I am investigating. Therefore, I hypothesize that teams will show relative consistency in their performance. So, if estimated coefficients for β_1, β_2, or β_3 are statistically different from zero regarding DTOs (in the ways described above) yet not statistically different from zero regarding NTOs, my arguments for prolonged series bias and home bias, driven by referee behavior, are strengthened.

Also of note, I have implemented a regression estimation that is robust to the correlation of errors within each game, rather than to identically distributed errors across all 413 playoff games from 2007-2011. All regressions analyzed in this study are cluster-robust.

4 Analysis

The regression results, highlighted in Table 4, provide a number of insights. First of all, holding elimination games, rounds, years, series, and referees constant, home teams are favored across all statistics I analyzed, including DTOs, NTOs, fouls, free throws, field goal percentage, steals, and blocks.

In particular, teams commit fewer DTOs while playing at home, significant at the 1% level regardless of the DTO-NTO classification. More specifically, home teams commit approximately 0.45, 0.40, and 0.56 fewer DTOs compared to when they play on the road, in the 1^{st}, 2^{nd}, and 3^{rd} classifications, respectively, which is meaningful given that teams playing in the postseason from 2007-2011 averaged only about 3.6, 3.4, and 5.8 DTOs per game (in the 1^{st}, 2^{nd}, and 3^{rd} classifications, respectively, as shown in Table 3). Thus, home teams commit approximately 9.7% to 12.6% fewer DTOs, depending on the classification, compared to when they play on the road.

In addition to this primarily referee-driven benefit for home teams, a player-driven advantage also seemingly exists for teams playing on their home court in the playoffs. Specifically, teams commit fewer NTOs while on their home court, significant at the 5% level regardless of the DTO-NTO classification. In particular, home teams commit approximately

0.52, 0.58, and 0.42 fewer NTOs, in the 1^{st}, 2^{nd}, and 3^{rd} classifications, respectively. Meanwhile, teams playing in the postseason from 2007-2011 averaged about 9.8, 10.0, and 7.6 NTOs per game (in the 1^{st}, 2^{nd}, and 3^{rd} classifications, respectively, as shown in Table 3). Thus, home teams commit approximately 5.3% to 5.8% fewer NTOs, depending on the classification, compared to when they play on the road.

Despite the fact that teams playing at home tend to commit only one fewer DTO and one fewer NTO (compared to when they play on the road) over approximately two games, I contend that these results are economically significant. Whether a DTO or an NTO, every turnover costs the team a possession and opportunity to score and potentially sparks momentum for the other team, giving them an opportunity to start a run (i.e., to score several field goals in quick succession while holding the opponent to few or none). Furthermore, approximately 57.6% of playoff games from 2007-2011 have had a single digit scoring differential (winning team's score minus the trailing team's score) entering the fourth quarter, and 54.0% of games have had a single digit scoring differential as of six minutes to go in the fourth. Thus, in the majority of postseason games, every possession is extremely important, including deep into the fourth quarter.

Given that home teams seem to be benefitted by both referee and player behavior, it is not surprising that teams playing at home had advantages in terms of fouls, free throws, field goal percentage, blocks, and steals, all of which are jointly influenced by referee and player behavior. For instance, if a referee is being kind to the home team, the referee may allow the home team to play particularly aggressive defense. Thus, while on defense, the home team may be able to more closely guard ball-handlers and contest shooters without being called for fouls, resulting in fewer fouls and more blocks and steals for the home team as well as fewer free throws and a lower shooting percentage for the away team. In this vein, home teams in the 2007-2011 postseason had about 1.4 fewer fouls called against them, attempted about 1.7 more free throws, shot about 1.7% better from the field, and blocked about 0.7 more shots compared to when they played away from home (of course, holding elimination games, rounds, years, series, and referees constant), all of which were significant at the 1% level. Teams playing at home even had about 0.3 more steals per game, significant at the 10% level.

But while home teams seem to benefit from both referee and player behavior, teams facing elimination are benefitted primarily through referee behavior. In particular, using the 1st DTO classification, and holding home teams, rounds, years, series, and referees constant, teams facing elimination prior to game 7 (i.e., teams down 2-3, 1-3, or 0-3) commit approximately 0.36 fewer DTOs compared to all other playoff games. This is statistically significant at the 10% level.

It is important to note that, with two observations for every playoff game from 2007-2011, the dataset contains 826 observations. Thus, the dataset is limited, and is it important to note that too many control variables make it increasingly difficult to find statistically significant results. Therefore, for each statistic, I ran two regressions, omitting referee fixed effects from the second in order to see how much the coefficient on *face_elim* increased in statistical significance with more degrees of freedom. Of course, the results from the regressions without referee fixed effects are far from infallible, since they do not account for individual heterogeneity among referees.

So, although teams facing elimination committed fewer DTOs (as far as the 1st classification) at the 10% significance level compared to all other playoff games, the decrease in DTOs is shown to be at the 5% significance level when the referee dummy variables are dropped. Meanwhile, both with and without referee fixed effects, the regression results elucidate that teams facing elimination do not have statistically significant NTO differences in elimination games prior to game 7 (games that they enter down 2-3, 1-3, or 0-3) compared with all other playoff games. This discrepancy between DTOs and NTOs implies that referee behavior, rather than player behavior, is the driving force favoring a prolonged playoff series.

Additionally, although with the 2^{nd} and 3^{rd} DTO classifications we do not see statistically significant DTO differences in elimination games (prior to game 7) compared with all other playoff games, the removal of referee fixed effects causes the coefficient on *face_elim* to be more negative (i.e., teams facing pre-game 7 elimination are more benefitted through fewer DTOs) and thus different from other playoff games at a greater statistical significance level. In short, teams facing pre-game 7 elimination commit approximately 0.34 and 0.39 fewer DTOs (in 2^{nd} and 3^{rd} classifications, respectively) in elimination games compared to all other playoff games, holding home teams, rounds, years, and series constant. These coefficients are statistically significant at the 10% and 10.6% levels, respectively.

In addition to analyzing whether DTOs and NTOs are significantly different for teams facing pre-game 7 elimination (as compared to their other playoff games), we observe how DTOs and NTOs for teams facing elimination (down 2-3, 1-3, or 0-3) compare with DTOs and NTOs for teams threatening to eliminate their opponent (up 3-2, 3-1, or 3-0). We do this with a joint hypothesis test, *face_elim* = *threat_elim*, with results shown in Table 5.

We are specifically interested in the one-sided alternative hypothesis that *face_elim* < *threat_elim*, i.e., that the change in DTOs and NTOs when teams face (pre-game 7) elimination is less than (more negative than) the change in DTOs and NTOs when teams are threatening to eliminate their opponent (before game 7). Unfortunately, the F-statistic treats positive and negative misses symmetrically, so this is not an ideal test against a one-sided alternative. Despite the imperfect test, we can reject the null hypothesis for the 1st DTO classification that *face_elim* = *threat_elim* at the 10% significance level. On the other hand, we cannot reject this null for the 1st NTO classification. These joint hypothesis results seem to provide further evidence to the argument that the benefits, in terms of turnovers, for teams facing elimination are primarily referee driven, rather than player driven, since they are evident in DTOs but not NTOs.

Further substantiating this claim is that, holding home court, rounds, years, series, and referees constant, teams facing (pre-game 7) elimination have a lower field goal percentage and fewer blocks compared with other playoff games, significant at the 1% and 5% levels, respectively. Thus, if anything, the statistics seem to suggest a decline in player production for teams facing elimination.

5 Conclusions

Motivated by the Tim Donaghy scandal in the summer of 2007, which brought into question the integrity of the NBA, this study attempts to investigate referee bias in the NBA playoffs. In particular, this study examines whether home teams or teams facing postseason elimination are benefitted in terms of DTOs, NTOs, fouls, free throws, field goal percentage, steals, or blocks.

Analyzing the playoff data from 2007-2011, we find that home teams have a benefit across all statistics investigated in this study. Namely, home teams commit approximately 0.46 fewer DTOs and 0.52 fewer NTOs (in the 1st classification) compared with their performance on the road, holding (pre-game 7) elimination games, rounds, years, series, and referees constant. For perspective, 0.46 is 12.6% of the mean DTOs committed by teams in NBA playoff games from 2007-2011, and 0.52 is 5.3% of the mean NTOs committed by teams over that span. These results are not only statistically significant at the 1% and 5% levels, respectively, but also economically significant.

I believe even one fewer DTO or NTO committed over a two game span is economically significant because there must be reasoning behind why players sacrifice their bodies to dive for loose balls and to step in front of sprinting or leaping 250+ pound men in an effort to take a charge. In short, players believe that every possession matters. Kevin Pelton, ESPN Insider and writer for the WNBA's Seattle Storm, agrees: "Arguably the most important discovery made by statistical analysts in basketball is the critical importance of possessions." Since fewer turnovers limits wasted possessions and provides additional opportunities for field goal attempts, they can have meaningful impacts on a postseason game, especially since over 57% of playoff games from 2007-2011 were within 10 points or less with six minutes remaining in the fourth quarter.

Since referee behavior, shown through DTOs, and player behavior, evidenced through NTOs, contribute to a home court advantage, it is not surprising that teams playing at home in the playoffs from 2007-2011 had about 1.4 fewer fouls, about 1.7 more free throws, about a 1.7% better field goal percentage, about 0.3 more steals, and about 0.7 more blocks compared to when they played away from home (of course, holding elimination games, rounds, years, series, and referees constant). All of these results were significant at the 1% level, except the steals discrepancy, which was significant at the 10% level. Due to the importance of each playoff possession, I assert that all of these results are economically meaningful, too.

In my prolonged series bias investigation, I found that teams facing elimination (before game 7) commit approximately 0.36 fewer DTOs, significant at the 10% level, while holding home court, rounds, years, series, and referees constant. For perspective, 0.36 is 9.9% of the mean DTOs committed by teams in NBA playoff games from 2007-2011. In contrast, though, teams facing elimination did not have a statistically significant decrease in NTOs compared to other playoff games. What is more, the coefficient on *face_elim* was positive, the opposite of what would be expected if teams facing eliminated were benefitted with fewer turnovers. These results jointly suggest that referees exhibit bias toward teams facing elimination by calling fewer turnovers against them. At the same time, player performance does not significantly increase when a team is on the brink of elimination. This assertion regarding player behavior is reinforced by the fact that both field goal percentage and blocks decrease significantly for teams facing elimination, at the 1% and 5% levels, respectively. So, a prolonged series bias, suggested by the DTO results, seems to be primarily influenced by referee behavior.

Despite this evidence suggestive of bias through referee behavior, I cannot go so far as to imply orchestration on the part of the league. In short, direct league manipulation is not shown and is beyond the scope of this study. The results suggest a home bias and provide some potential evidence for Donaghy's claims that referees are biased towards teams losing in playoff series. However, the results do not pinpoint the factors behind the biases and continued analysis into referee behavior ought to be conducted.

Furthermore, these findings on difficult-to-detect biases extend to a larger class of rule-based goods and services beyond sports. Price et al. (2012) assert that "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." Such blatant disregard for fair play is hopefully a thing of the past. Nevertheless, this study suggests that even in the present day it is possible to favor game participants, whether on a game show or in a playoff atmosphere, in a more subtle manner.

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Tables

Table 1: Turnover Types and Definitions

Turnover Type	Definition
Discretionary Turnovers	
Traveling*	Progressing in any direction while in possession of the ball (without dribbling), which is in excess of prescribed limits as noted in Rule 10-Section XIV.
Offensive foul*	Illegal contact committed by the offensive player.
Three seconds*	An offensive player remains in the painted lane in front of the basket for more than three consecutive seconds.
Offensive goaltending*	A player interferes with the ball when it is on a downward trajectory or is in an extended cylinder-shaped region above the rim.
Eight-second violation***	A team shall not be in continuous possession of a ball which is in its backcourt for more than 8 consecutive seconds.
Five-second back to the basket violation***	A player in the frontcourt, below the free throw line extended, is not permitted to dribble the ball with his back or side to the basket for more than five seconds.
Inbounds turnover***	A thrower-in shall not (1) carry the ball onto the court; (2) fail to release the ball within 5 seconds; (3) touch it on the court before it has touched another player; (4) leave the designated throw-in spot; (5) throw the ball so that it enters the basket before touching anyone on the court; (6) step over the boundary line while inbounding the ball; (7) cause the ball to go out-of-bounds without being touched inbounds; (8) leave the playing surface to gain an advantage on a throw-in; (9) hand the ball to a player on the court.
Backcourt violation***	A player shall not be the first to touch a ball which he or a teammate caused to go from frontcourt to backcourt while his team was in control of the ball.
Illegal screen##	When picking a stationary opponent from the backside, you must give that player a step. When picking a stationary player from the front or side, a player can go right next to him as long as he does not make illegal contact. If the opponent is moving, you must get to your position and give him an opportunity to stop and/or change direction.
Discontinued dribble###	A break in the dribbling rhythm occurs due to the dribbler's hand moving under the ball (though the hand does not have to be "completely under" the ball).
Double dribble**	A violation in which a player dribbles the ball, stops, then begins to dribble again.

Illegal assist***	A player may not assist himself to score by using the basket ring or back-board to lift, hold or raise himself. Also, a player may not assist a teammate to gain height while attempting to score.
Kicked ball turnover***	A player shall not kick the ball intentionally.
Palming**	A violation in which a player moves his hand under the ball and scoops it while dribbling. Also: carrying the ball.
Punched ball turnover***	A player shall not strike the ball with his fist intentionally.
Jump ball violation#	Neither jumper may tap the tossed ball before it reaches its highest point, neither jumper may leave his half of the jumping circle until the ball has been tapped, neither jumper may catch the tossed or tapped ball until it touches one of the eight non-jumpers, the floor, the basket, or the backboard, neither jumper is permitted to tap the ball more than twice on any jump ball, etc.
Lane violation turnover***	A player who occupies a free throw lane space shall not touch the floor on or across the free throw lane line, nor shall any player 'back out' more than 3' from the free throw lane line. A player who does not occupy a free throw lane space must remain behind the three-point line. This restriction applies until the ball leaves the free thrower's hands. The free throw shooter may not cross the plane of the free throw line until the ball touches the basket ring, backboard, or the free throw ends.
Basket from below***	A player shall not cause the ball to enter the basket from below.
Step out of bounds	A player shall not step out of bounds while in possession of the ball.
Non-discretionary Turnovers	
Bad Pass*	A pass that either is stolen by the defensive team or goes out of bounds.
Lost Ball*	Having the ball either directly stolen by the defensive team or stepping out of bounds with possession of the ball.
Shot Clock*	The offensive team fails to take a shot that hits the rim within 24 seconds of possession.
Double Personal	A player, whose team is in possession of the ball, is part of a double technical foul assessment, which results in a jump ball. If the other team gains possession after the jump ball, that player has committed a "double personal" turnover.

Notes: Definitions for terms with * obtained from Price, Remer, and Stone (2012).
Definitions for terms with ** obtained from http://www.nba.com/analysis/00422966.html.
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Table 2: Turnover Descriptive Statistics

Turnover Type	**1st Classification**	**2nd**	**3rd**
Total Turnovers (TOs)	11,073	11,073	11,073
Discretionary Turnovers (DTOs)	3,006 (27.1%)	2,784 (25.1%)	4,827 (43.6%)
Non-discretionary Turnovers (NTOs)	8,067 (72.9%)	8,289 (74.9%)	6,246 (56.4%)
Discretionary Turnovers	3,006	2,784	4,827
Traveling	724 (24.1%)	724 (26.0%)	724 (15.0%)
Offensive foul	1,616 (53.8%)	1,616 (58.0%)	1,616 (33.5%)
Three seconds	228 (7.6%)	228 (8.2%)	228 (5.7%)
Offensive goaltending	39 (1.3%)	39 (1.4%)	39 (0.8%)
Eight-second violation	8 (0.3%)	8 (0.3%)	8 (0.2%)
Five-second back to the basket violation	2 (0.1%)	2 (0.1%)	2 (0.04%)
Inbounds turnover	15 (0.5%)	15 (0.5%)	15 (0.3%)
Backcourt violation	52 (1.7%)	52 (1.9%)	52 (1.1%)
Illegal screen	9 (0.3%)	9 (0.3%)	9 (0.2%)
Discontinued dribble	19 (0.7%)	19 (0.7%)	19 (0.4%)
Double dribble	20 (0.7%)	20 (0.7%)	20 (0.4%)
Illegal assist	3 (0.1%)	3 (0.1%)	3 (0.06%)
Kicked ball turnover	8 (0.3%)	8 (0.3%)	8 (0.2%)
Palming	24 (0.8%)	24 (0.9%)	24 (0.5%)
Punched ball turnover	1 (0.03%)	1 (0.04%)	1 (0.02%)
Jump ball violation	5 (0.2%)	5 (0.2%)	5 (0.1%)
Lane violation turnover	10 (0.3%)	10 (0.4%)	10 (0.2%)
Basket from below	1 (0.03%)	1 (0.04%)	1 (0.02%)
Step Out of Bounds	222 (7.4%)	----------	222 (4.6%)
Bad Pass – Out of Bounds	----------	----------	1,125 (23.3%)
Lost Ball – Out of Bounds	----------	----------	696 (14.4%)
Non-discretionary Turnovers	8,067	8,289	6,246
Bad Pass – Out of Bounds	1,125 (13.9%)	1,125 (13.6%)	----------
Bad Pass – Stolen	3,313 (41.1%)	3,313 (40.0%)	3,313 (53.0%)
Lost Ball – Out of Bounds	696 (8.6%)	696 (8.4%)	----------
Lost Ball – Stolen	2,371 (29.4%)	2,371 (28.6%)	2,371 (38.0%)
Lost Ball – Non-specified	3 (0.04%)	3 (0.04%)	3 (0.05%)
Step Out of Bounds	----------	222 (2.7%)	----------
Shot Clock	558 (6.9%)	558 (6.7%)	558 (8.9%)
Double Personal	1 (0.01%)	1 (0.01%)	1 (0.02%)

Table 3: Team-Game-Level Summary Statistics

Statistic	General Mean (SD)	Home Mean (SD)	Away Mean (SD)	Diff (Home-Away)
DTOs (1st Classification)	3.6392 (1.947)	3.3995 (1.905)	3.8789 (1.962)	–0.4794***
DTOs (2nd Classification)	3.3705 (1.871)	3.1598 (1.839)	3.5811 (1.882)	–0.4213***
DTOs (3rd Classification)	5.8438 (2.389)	5.5521 (2.287)	6.1356 (2.455)	–0.5835***
NTOs (1st Classification)	9.7663 (3.226)	9.5206 (3.199)	10.0121 (3.238)	–0.4915**
NTOs (2nd Classification)	10.0351 (3.273)	9.7603 (3.242)	10.3099 (3.284)	–0.5496**
NTOs (3rd Classification)	7.5617 (2.796)	7.3680 (2.733)	7.7554 (2.848)	–0.3874**
Fouls	21.1344 (4.244)	20.4334 (4.121)	21.8354 (4.254)	–1.4020***
Free Throws	23.6235 (7.5290)	24.5061 (7.6338)	22.7409 (7.326)	1.7652***
Field Goal Percentage	0.4427 (0.055)	0.4507 (0 .056)	0.4347 (0.053)	0.0160***
Steals	6.8814 (2.662)	7.0387 (2.700)	6.7240 (2.616)	0.3147*
Blocks	5.0218 (2.574)	5.3511 (2.615)	4.6925 (2.493)	0.6586***

Statistic	Facing Elimination# Mean (SD)	Threatening to Eliminate## Mean (SD)	Diff (Face-Threat)
DTOs (1st Classification)	3.2887 (2.071)	3.9072 (2.011)	–0.6185**
DTOs (2nd Classification)	3.0928 (1.947)	3.5979 (2.009)	–0.5051*
DTOs (3rd Classification)	5.5052 (2.403)	6.0722 (2.534)	–0.5670
NTOs (1st Classification)	10.0103 (3.343)	9.4227 (3.191)	0.5876
NTOs (2nd Classification)	10.2062 (3.310)	9.7320 (3.284)	0.4742
NTOs (3rd Classification)	7.7938 (2.795)	7.2577 (2.877)	0.5361
Fouls	21 (4.306)	21.4433 (3.987)	–0.4433
Free Throws	24.2680 (7.039)	23.4433 (7.742)	0.8247
Field Goal Percentage	0.4290 (0.050)	0.4442 (0.056)	–0.0152**
Steals	6.5773 (2.757)	7.1649 (2.625)	–0.5876
Blocks	4.5052 (2.246)	4.7320 (2.383)	–0.2268

Notes: *, **, and *** denote 10%, 5%, and 1% significance, respectively (for differences; two-tailed tests, unequal variances).
"Facing Elimination" signifies that the team is trailing in the series 2-3, 1-3, or 0-3.
"Threatening to Eliminate" signifies that the team is leading the series 3-2, 3-1, or 3-0.

Table 4: Regression Results

	DTOs (1st Classification)	
Variable	**Coefficient with Ref FEs (RSE)**	**Coefficient w/o Ref FEs (RSE)**
Face_Elim	–0.3567 (0.201)*	–0.4140 (0.200)**
Threat_Elim	0.1727 (0.228)	0.1154 (0.223)
Home	–0.4551 (0.133)***	–0.4551 (0.129)***
Round 2	–0.6603 (0.945)	–1.625 (0.995)
Round 3	–1.006 (1.105)	–1.1772 (0.656)*
Round 4	–0.1324 (0.727)	–1.7075 (1.202)
Year 2	0.1108 (0.755)	–1.1878 (1.268)
Year 3	–0.5350 (0.693)	–0.4575 (0.619)
Year 4	–0.3900 (0.827)	–0.7075 (0.997)
Year 5	–1.0158 (0.827)	–0.5825 (0.981)

	DTOs (2nd Classification)	
Variable	**Coefficient with Ref FEs (RSE)**	**Coefficient w/o Ref FEs (RSE)**
Face_Elim	–0.2717 (0.189)	–0.3357 (0.190)*
Threat_Elim	0.1548 (0.223)	0.0907 (0.221)
Home	–0.4017 (0.124)***	–0.4017 (0.120)***
Round 2	–0.4821 (0.917)	–1.25 (0.978)
Round 3	–0.8237 (1.034)	–1.093 (0.543)**
Round 4	–0.2510 (0.787)	–1.6311 (1.170)
Year 2	0.1094 (0.743)	–1.0193 (1.228)
Year 3	–0.4799 (0.645)	–0.3811 (0 .607)
Year 4	–0.4816 (0.771)	–0.7561 (1.004)
Year 5	–1.2113 (0.747)	–0.7561 (0.884)

	DTOs (3rd Classification)	
Variable	**Coefficient with Ref FEs (RSE)**	**Coefficient w/o Ref FEs (RSE)**
Face_Elim	–0.3522 (0.252)	–0.3910 (0.242)#
Threat_Elim	0.1046 (0.278)	0.0659 (0.269)
Home	–0.5625 (0.164)***	–0.5625 (0.158)***

NTOs (1st Classification)		
Variable	**Coefficient with Ref FEs (RSE)**	**Coefficient w/o Ref FEs (RSE)**
Face_Elim	0.3246 (0.386)	0.2780 (0.363)
Threat_Elim	–0.3656 (0.371)	–0.4121 (0.348)
Home	–0.5233 (0.236)**	–0.5233 (0.228)**
Round 2	3.6777 (2.237)	0.75 (1.647)
Round 3	5.5483 (2.720)	0.2753 (0.715)
Round 4	2.9328 (1.502)*	0.5216 (1.949)
Year 2	2.9561 (1.545)*	0.8180 (2.128)
Year 3	0.5432 (1.226)	0.7716 (0.840)
Year 4	–1.3251 (1.889)	1.2716 (1.510)
Year 5	0.1516 (2.151)	0.8966 (1.687)

NTOs (2nd Classification)		
Variable	**Coefficient with Ref FEs (RSE)**	**Coefficient w/o Ref FEs (RSE)**
Face_Elim	0.2396 (0.389)	0.1997 (0.366)
Threat_Elim	–0.3476 (0.380)	–0.3874 (0.357)
Home	–0.5766 (0.239)**	–0.5766 (0.231)**
Round 2	3.4995 (2.215)	0.375 (1.729)
Round 3	5.3655 (2.735)**	0.1911 (0.787)
Round 4	3.0515 (1.447)**	0.4453 (2.042)
Year 2	2.9574 (1.545)*	0.6495 (2.173)
Year 3	0.4881 (1.194)	0.6953 (0.787)
Year 4	–1.2335 (1.861)	1.3203 (1.486)
Year 5	0.3470 (2.137)	1.0703 (1.713)

NTOs (3rd Classification)		
Variable	**Coefficient with Ref FEs (RSE)**	**Coefficient w/o Ref FEs (RSE)**
Face_Elim	0.3201 (0.334)	0.2550 (0.311)
Threat_Elim	–0.2975 (0.332)	–0.3626 (0.318)
Home	–0.4158 (0.208)**	–0.4158 (0.202)**

FOULS

Variable	Coefficient with Ref FEs (RSE)	Coefficient w/o Ref FEs (RSE)
Face_Elim	–0.2899 (0.465)	–0.1836 (0.433)
Threat_Elim	–0.1197 (0.409)	–0.0133 (0.403)
Home	–1.3941 (0.254)***	–1.3941 (0.246)***
Round 2	–3.6783 (3.009)	–1.75 (1.683)
Round 3	–0.8608 (3.843)	–3.1087 (1.456)**
Round 4	–2.4886 (2.570)	0.0951 (1.902)
Year 2	0.8900 (2.559)	4.5488 (2.707)*
Year 3	2.5802 (1.266)**	3.8451 (1.556)**
Year 4	5.2760 (1.937)***	5.9701 (2.324)**
Year 5	0.3818 (2.335)	2.4701 (2.615)

FREE THROWS

Variable	Coefficient with Ref FEs (RSE)	Coefficient w/o Ref FEs (RSE)
Face_Elim	0.0038 (0.782)	0.0960 (0.723)
Threat_Elim	–0.4796 (0.851)	–0.3873 (0.757)
Home	1.7429 (0.484)***	1.7429 (0.468)***
Round 2	–7.8575 (6.482)	0.5 (2.969)
Round 3	1.1216 (7.360)	–8.7488 (2.545)***
Round 4	–7.4369 (5.810)	1.0427 (3.599)
Year 2	–2.3416 (5.611)	7.5093 (5.219)
Year 3	3.1228 (2.655)	4.4177 (3.324)
Year 4	6.2235 (4.520)	7.6677 (4.027)*
Year 5	–2.7950 (3.914)	–0.4573 (4.049)

FIELD GOAL PERCENTAGE

Variable	Coefficient with Ref FEs (RSE)	Coefficient w/o Ref FEs (RSE)
Face_Elim	–0.0156 (0.006)***	–0.0168 (0.006)***
Threat_Elim	0.0029 (0.006)	0.0016 (0.006)
Home	0.0168 (0.004)***	0.0168 (0.004)***
Round 2	0.0078 (0.040)	0.0394 (0.006)***
Round 3	–0.0057 (0.045)	0.0109 (0.016)
Round 4	0.0334 (0.021)	0.0520 (0.037)
Year 2	0.0299 (0.023)	0.0656 (0.041)
Year 3	0.0216 (0.029)	0.0249 (0.033)
Year 4	0.0622 (0.038)	0.0700 (0.039)*
Year 5	0.0545 (0.039)	0.0504 (0.041)

Variable	*STEALS* Coefficient with Ref FEs (RSE)	Coefficient w/o Ref FEs (RSE)
Face_Elim	–0.3275 (0.314)	–0.3472 (0.298)
Threat_Elim	0.3277 (0.312)	0.3080 (0.294)
Home	0.3449 (0.199)*	0.3449 (0.192)*

Variable	*BLOCKS* Coefficient with Ref FEs (RSE)	Coefficient w/o Ref FEs (RSE)
Face_Elim	–0.6074 (0.258)**	–0.6607 (0.246)***
Threat_Elim	–0.2484 (0.242)	–0.3016 (0.231)
Home	0.6751 (0.195)***	0.6751 (0.188)***
Round 2	–0.4002 (1.454)	–0.625 (1.060)
Round 3	1.1240 (1.779)	–1.7868 (0.863)**
Round 4	0.9109 (0.838)	0.9509 (1.670)
Year 2	3.5907 (0.780)***	3.3637 (1.813)*
Year 3	2.4318 (0.759)***	2.3259 (0.749)***
Year 4	4.1017 (1.461)***	3.201 (1.447)**
Year 5	3.0225 (1.549)*	2.9509 (1.676)*

Notes: "RSE" denotes "Robust Standard Errors"
*, **, and *** denote 10%, 5%, and 1% significance, respectively
# denotes significance at the 10.6% level

Table 5: Testing Joint Hypothesis *Face_Elim* = *Threat_Elim*

Basketball Statistic	**F-statistic**	**Prob > F**
DTOs (1st Classification)	3.41	0.0656
DTOs (2nd Classification)	2.39	0.1230
DTOs (3rd Classification)	1.59	0.2076
NTOs (1st Classification)	1.58	0.2094
NTOs (2nd Classification)	1.13	0.2882
NTOs (3rd Classification)	1.66	0.1985
Fouls	0.10	0.7505
Free Throws	0.28	0.5985
Field Goal Percentage	4.60	0.0326
Steals	2.16	0.1422
Blocks	1.10	0.2944