

# A Mere Fan Effect on Home-Court Advantage

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## Abstract

The existence of a home-court advantage is one of the most durable empirical patterns in all of sports. Yet, the mechanisms explaining its strength and persistence remain a mystery in large part because of well-known challenges with statistical identification. We use attendance restrictions in place during the 2020–2021 National Basketball Association regular season as an instrument in order to identify the effect of fans and crowd size on home-court advantage. We show that home teams win by 2.13 points, on average, when fans are present at games compared with 0.44 points when no fans are present. This equates to winning approximately 2.2 additional home games over the course of a regular season. In fixed effects instrumental variables regression models, we estimate that the marginal effect of an additional one thousand fans on home-court advantage is 1.7 points. We conclude that the mere presence of home fans, on its own, explains a larger share of home-court advantage than previously thought.

## Keywords

basketball, COVID-19, fans, home-court advantage, NBA

## Introduction

The existence of a home-court advantage is one of the most durable empirical patterns in all of sports. Yet, the mechanisms explaining its strength and persistence remain a mystery in large part because of well-known challenges with statistical identification. Attempts to measure the effect of the presence of home fans on home-court

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advantage, for example, are plagued by concerns about reverse causality. If a positive correlation between crowd size and home team performance is observed in the data, the analyst cannot easily distinguish between the claim that fans cause the home team to play better and the alternative that more successful home teams cause more fans to be in attendance.

Identifying this *mere effect* of fans on home-court advantage requires an instrument, that is, a variable that is correlated with the presence of fans but unrelated to the quality of the home team. In this paper, we use COVID-19-related attendance restrictions in place during the 2020-2021 National Basketball Association (NBA) regular season as such an instrument in order to overcome potential reverse causality and estimate the effect of the presence of fans on home-court advantage. Our empirical setting is especially well-suited to test the hypothesis because the season schedule was determined without knowledge about when and where fans would be permitted to be in attendance, rules for in-game play did not vary with local health conditions, off-court player behavior was centrally regulated by the league, and arena reopening decisions were largely controlled by government officials primarily concerned with protecting public health.

These unique characteristics of our setting also ameliorate many of the empirical concerns that afflict other studies that leverage pandemic-related attendance restrictions to examine similar questions. In particular, our setting has both within-team and cross-sectional variation in the stringency of attendance restrictions, which permits us to both control for unobservable stable characteristics of the home-court (e.g., the maximum noise level in a stadium) and time-varying variables that affect the home-court advantage of all teams (e.g., the nationwide intensity of the pandemic). A constraint of our setting, however, is that all games were played in arenas at considerably less than full capacity. Our ability to estimate the impact of the first few thousand fans in an arena, then, comes at the cost of being able to generalize to settings in which the home team has a near-full stadium and consequently to compare our results with prior studies that compare empty or nearly empty arenas to full or nearly full arenas.

We show that home teams win by 2.13 points, on average, when any fans are present in the arena compared with just 0.44 points when no fans are present. Home teams with nonempty arenas fared approximately as home teams had in prior seasons when no health-related restrictions were in place. In fixed effects instrumental variables regression models that control for the home team and away team, recent home and away team performance, the month of the season, and the intensity of the pandemic in the region, the effect of every additional thousand fans in attendance is 1.74 points. However, the data also imply that the effect of fan attendance on home-court advantage is likely nonlinear. In uninstrumented regression models that transform capacity into a categorical variable, arenas allowing 1 to 3,000 fans in attendance create a home-court advantage of 4.3 points, which is marginally and insignificantly weaker than the 5.1 point coefficient estimate for arenas allowing over 3,000 fans in attendance.

## **Background and Hypotheses**

Home-court advantage is a pervasive phenomenon across all professional sports. However, challenges with statistical identification impede clear inference about the various plausible mechanisms and diverse causal pathways that could explain why home teams tend to outperform away teams (see Jamieson, 2010: For a review). Prior studies explaining home-court advantage emphasize the home team's familiarity with their arena (Loughead et al., 2003) and the physical impact of distant travel on away players (McHill & Chinoy, 2020; Pace & Carron, 1992). Further, in certain sports, crowd noise itself may interfere with on-the-field strategy (Nevill & Holder, 1999) or impact the referee's ability to officiate the game fairly (Dohmen & Sauermann, 2016; Garicano et al., 2005; Guèrette et al., 2021; Unkelbach & Memmert, 2010). While prior studies demonstrate a relationship between fan attendance and home team performance (Moore & Brylinski, 1993; Smith & Groetzinger, 2010), statistical identification of the impact of fan attendance on home-court advantage is complicated by well-known concerns related to reverse causality. If better teams draw more fans, then regressions demonstrating a positive effect of fans on home-court advantage could be an artifact of fans preferring to attend games when their favorite team is likely to win. Consistent estimation of the impact of fans on home team performance requires an instrument that is correlated with the number of fans in attendance but is uncorrelated with the quality of the home team or other omitted variables that are correlated with both crowd size and home team performance.

Restrictions on fan attendance caused by the COVID-19 pandemic during the 2020–2021 NBA regular season provide an unusual opportunity to evaluate the impact of fan attendance on home-court advantage. Prior to the start of the season in 2020 and through the rest of the regular season in 2021, local governments imposed restrictions on the maximum sizes of indoor and outdoor gatherings in order to limit the spread of COVID-19, therefore affecting attendance at NBA games. While some local governments were more cautious and imposed tighter restrictions on maximum allowable attendance, others relaxed restrictions faster and allowed more fans into arenas. Because the phased reopening of arenas for fans was constrained by local government officials and was related to the perceived relative health risks of large gatherings, variability in fan attendance restrictions in this context is independent of characteristics of the home team or the competitiveness of the specific game. Furthermore, on-court competition and off-court player behavior remained centrally regulated by the league. The same health and safety protocols applied to players whether or not fans were present. These features make the maximum number of fans allowed at a game a strong instrument for the actual number of fans at the game in a statistical model predicting the impact of fans on home-court advantage.

Our empirical setting also permits us to emphasize certain fan-driven mechanisms explaining home-court advantage and deemphasize others. All of the games in our

study had very low attendance by usual standards. The defending champions, the Los Angeles Lakers, for example, limited attendance to two thousand fans in a twenty thousand-seat arena. The largest crowd in the sample is 8,359 in the final regular-season game for the Phoenix Suns, which is less than 50% of the maximum capacity of their home arena.

One possible reason that home teams outperform away teams is spillover effects from the fans themselves. In interviews during the 2020–2021 NBA season, players overwhelmingly emphasize the positive spillovers of the presence of home fans on the home team's players. Portland Trail Blazers point guard Damian Lillard described how even a sparsely attended game impacted him emotionally:

When they told use it was going to be 10 percent [capacity], I was like, I don't know how much difference it's going to make in such a huge building. But man, I guess we didn't realize how bad an empty building was because that felt like a normal game. As soon as we came out to warm up and the fans, you could feel how excited they were to be there. There was chanting before the first layup in the layup line. It was a major, major difference (Holdahl, 2021).

Former Chicago Bulls and current Orlando Magic center Wendell Carter, Jr., similarly, reported that “we just kind of feed off the fans sometimes” and that empty arenas required that home teams “find ways to find energy” (Songco, 2020). Philadelphia 76ers center Dwight Howard echoed the notion that energy from the fans is contagious but also emphasized that fans make the players accountable: “When I get to the court, I gotta’ hold myself to a higher standard because all the fans, they’re looking at me to come out and play with energy and effort every night” (Grasso, 2021). Golden State Warriors Head Coach Steve Kerr also noticed the difference between playing in partially full away arenas and empty home arenas: “What I’ve noticed is that, even if it’s 2,500 fans, the energy is entirely different. We played the Knicks in the first game that fans were allowed in (Madison Square) Garden probably three, four weeks ago, and it was awesome. Those 2,500 fans were so excited to be at a game. They made their presence felt” (Letourneau, 2021).

In contrast, relatively empty arenas with fans kept socially distant from players constrain the potential impact of crowd noise on on-court communication by the away team. Prior research similarly indicates that the impact of fans on referee behavior is mediated by crowd noise and size (Dohmen & Sauermann, 2016; Garicano et al., 2005; Guèrette et al., 2021; Unkelbach & Memmert, 2010). Thus, the potential for referee bias to explain home-court advantage is muted in this context (see also Gong, 2022). In supplemental analyses, we also empirically examine the impact of fan attendance on referee bias in terms of fouls called and find a minuscule, statistically insignificant effect. Our study, which compares empty arenas to games with sparse attendance, is thus an important complement to existing research examining

the effects of additional fans in near-full arenas, where these alternative mechanisms are likely to be more powerful (see, e.g., Belchior, 2020).

These features of our empirical setting also distinguish our study from other recent research that uses COVID-19 restrictions on fan attendance to explore similar research questions. Bryson et al. (2021) and Wunderlich et al. (2021) examine how soccer matches in front of empty and nearly empty stadiums compares with matches played in stadiums with unrestricted attendance and find evidence of reduced referee bias, but an insignificant effect of empty stadiums on goals scored or match outcomes. Sors et al. (2020), in contrast, compare soccer matches played in empty stadiums in 2020 to matches played during the 2016–2019 seasons and finds support for of a weakened home field advantage in games without fans, with similar results identified in Cross & Uhrig (2022) and Scoppa (2021) for European soccer and Arboix-Alió et al. (2022) for European rink hockey. Further muddying the mixed evidence in the professional soccer and rink hockey contexts is the fact that these studies rely almost exclusively on comparisons of matches played prior to and subsequent to the widespread COVID-19 pandemic lockdowns, making it impossible to differentiate the impact of empty stadiums from the impact of the pandemic itself. In European soccer leagues for games played during the pandemic, for example, home team players were required to quarantine in local hotels prior to matches instead of staying at their homes and coaches were permitted five substitutions instead of the usual three (Hill & Van Yperen, 2022).

In our setting, in contrast, all games were played in the shadow of the pandemic. Further, the NBA imposed extensive health and safety protocols on top of local public health regulations that regulated on-the-court and off-the-court behavior. The protocols, for example, forbid all players “from going to bars, lounges or clubs, from attending live entertainment or sports events, from using gyms, spas or pools, or from participating in social gatherings with more than 15 people” (Aschburner, 2020). While we cannot entirely rule out the possibility that unobserved local variability in the intensity of the pandemic is an omitted variable that explains some of the impact of the presence of fans, the risk of such a bias is considerably reduced relative to these other settings. Furthermore, as discussed in the next section, observed coefficients on time-varying measures of pandemic intensity are near-zero and do not approach statistical significance. The time-varying nature of the reopening decisions, their exogeneity with respect to team quality, and the league-wide controls on player behavior thus make our setting as close to an experimental ideal as could be hoped for given the pandemic environment.

## **Data and Models**

Our primary analyses bring together in-game data from the 2020 to 2021 NBA regular season with news reports on limits to fan attendance in each arena. Data for each game are collected from [basketball-reference.com](https://basketball-reference.com) and official NBA game summaries. Supplemental analyses also use data from the 2014–2015

through 2019–2020 and 2021–2022 NBA regular seasons, also collected from [basketball-reference.com](http://basketball-reference.com). Note, in the 2019–2020 season, we only include regular season games through March 10, 2020, one day before the postponement of the season due to the COVID-19 outbreak. Subsequent games were played at a neutral venue.

We make changes to the attendance data in order to correct obvious errors. Specifically, we remove 25 games from our analysis in which [basketball-reference.com](http://basketball-reference.com) and the official NBA game summary report zero attendance, yet there exists photographic, video, or other documentary evidence of fans at the game. These 25 games are listed in the Appendix in Table 5. Either the Toronto Raptors or the Cleveland Cavaliers were the home team in 16 out of the 25 games removed. Second, home games for the Indiana Pacers, Miami Heat, and Sacramento Kings are not included in the regression analyses because these teams continued to report zero attendance once their arenas reopened.<sup>1</sup>

We rely on news sources to determine attendance limits because there is no official NBA source documenting stadium reopening dates or capacity restrictions throughout this period. A list of news sources reporting attendance limits is included in the Appendix in Table 6. We only include sources that report future changes to attendance limits, rather than those that identify changes to limits *ex post* to ameliorate the risk that the source is inferring attendance limits from observed attendance, which would generate a potential violation of the exclusion restriction. In practice, this means that certain games report attendance that exceeds the maximum permitted capacity. While this implies that the attendance limit is measured with some error, the first-stage regression using attendance limits to predict observed attendance remains very strong and there is no reason to believe that measurement error in the attendance limit is correlated with the disturbances in the model predicting home team performance.

We also include a control for the positive COVID-19 case rate in the county in the two weeks prior to the game taking place in our regression models in order to account for the potential for time-varying local pandemic intensity impacting home-court advantage. These data are collected from the *New York Times*<sup>2</sup>. We further control for the recent performance of the home team and the away team to account for the possible correlation between the recent play of the home or away team and the attendance or attendance limit for a focal game.

Our main analyses are fixed effects instrumental variables regression models of the following form:

$$\text{pointmargin}_{i,t} = \beta_1 \text{attendance}_{i,t} + \beta_2 \text{pointmargin}_{i,t-1} + \beta_3 \text{recentperformance}_{i,s} + \beta_4 \text{recentperformance}_{j,s} + \beta_5 \text{covid}_{i,t} + u_i + v_j + m_k + \epsilon_{i,t}$$

where point margin is the difference between the home team and away team score, attendance is reported fan attendance, recent performance<sub>*i,s*</sub> and recent performance<sub>*j,s*</sub> are the win percentages over the last 10 games of the home team and away team,

respectively,  $covid$  is the number of COVID-19 cases per 100 thousand people over the previous 2 weeks in the county that hosts the home team arena,  $t \in \{1, \dots, T\}$  indexes games at the home arena,  $s \in \{1, \dots, S\}$  indexes games for the home and away teams,  $u_i$  is a fixed effect for the home team,  $v_j$  is a fixed effect for the away team, and  $m_k$  is a month fixed effect. Note that there is a different fixed effect for each team depending on whether they are home or away.

The attendance variable is endogenous, driven by the potential for better home teams to also draw larger crowds in the arena. In the instrumental variables regression models, we use the maximum allowable capacity as a instrument for observed attendance, which permits consistent estimation of  $\beta_1$  in the presence of an omitted variable, for example, unobserved characteristics of the home team. The two main assumptions for a valid instrument hold for maximum allowable capacity. First, local regulations limiting fan attendance directly affect how many people can attend an NBA game. In each of the five seasons prior to the 2020–2021 regular season, the average attendance for at least half of all teams exceeded 95% capacity and the lowest average attendance across a season of any team since 2014–2015 was 72.4% by the Detroit Pistons in the 2016–2017 season (ESPN.com, 2022). Because no team was permitted to have even 50% capacity in 2020–2021 NBA regular season, the level of attendance was strongly affected by capacity restrictions.

Second, maximum allowable capacity does not have a direct effect on the outcome of the game, only an indirect effect through changes in attendance, our variable of interest. In our setting, changes in maximum capacity had no effect on how the game was played or how both the home and away teams prepared for games. As previously discussed, on-court competition and player health and safety protocols remained centrally regulated by the league. News reports and interviews with team and league officials consistently indicate that the primary constraints to larger crowds during the season were local government officials and state and local public health regulations. For example, the Philadelphia 76ers invited fans to return to the arena at 15% capacity on March 14, 2021, which was their first home game after local officials began permitting 15% capacity attendance at indoor entertainment events state-wide on March 1. On April 4, the local government permitted maximum attendance to increase to 20% of arena capacity, and the 76ers responded by immediately increasing the number of tickets sold. In other cases, arena reopening plans involved special approvals by local public health officials. For example, the Washington Wizards were granted a waiver from the Washington, DC city government to permit 10% of fans into their home arena on April 10 and were granted a second waiver on May 10 to increase maximum attendance to 25% of capacity.

While there are selected examples of teams that restricted attendance to a greater extent than local regulations—for example, the Dallas Mavericks continued to play in an empty arena after a professional hockey team that shares their home arena had begun to permit 5,000 fans—none of the public reports used to determine capacity limits, which are listed in Table 6, indicate that these attendance restrictions were

correlated with the time-varying considerations about the quality of the home team or with considerations relating to a specific game. For example, based on the announcement dates of arena re-openings for the 20 teams in our sample that announced reopening after they had played 10 games of the season, seven had won less than half of their 10 games prior to announcing, six had won exactly half, and six had won more than half of their previous 10 games, which offers additional evidence that the timing of arena reopening is uncorrelated with the quality of the home team.

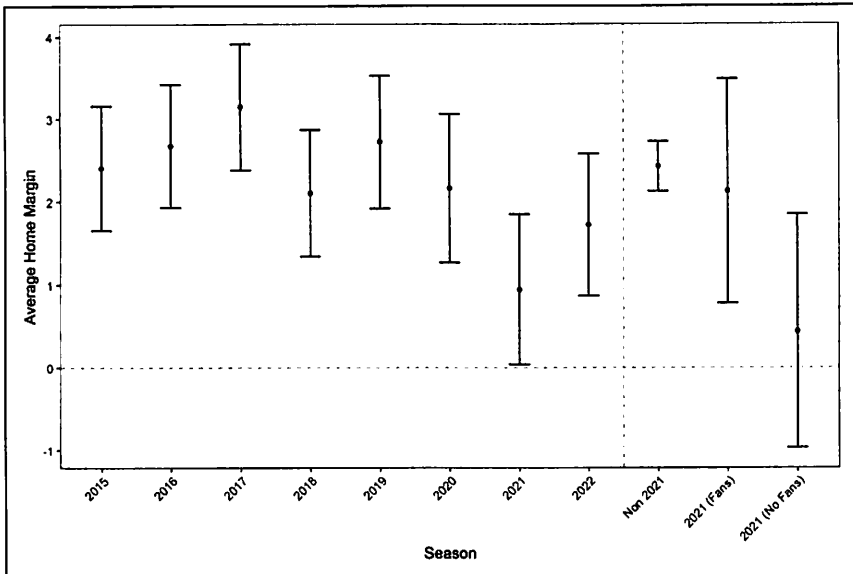
All data and analysis code is available in the “NBA-home-court-advantage” GitHub repository and can be accessed at <https://github.com/kieran-allsop/NBA-home-court-advantage>.

We also present a series of supplemental analyses. First, we examine the possibility that the presence of fans impacts referee bias by re-estimating the models previously described with the difference in the number of fouls called for the home and away teams as the dependent variable. Second, we explore whether the marginal effect of fans on home-court advantage varies with the number of fans in attendance by estimating fixed effects models in which the capacity is treated as a categorical variable. Finally, we estimate fixed effects models on all data collected from 2014–2015 to 2021–2022, which provides additional insight on whether our effect is localized to relatively small crowds or also applies to games with near-full arenas.

## Results

We begin by displaying the means and 95% confidence intervals of the point margin for the home team, our primary dependent variable, in each regular season from 2014–2015 to 2021–2022, depicted in the first eight bars in Figure 1. During the 2020–2021 regular season, home teams had an average point advantage of 0.94 points, which was noticeably lower than the 2.43-point home-court advantage over the prior six seasons and 2021–2022 season (presented in the ninth bar of the figure). The final two columns on the graph divide the 2020–2021 season into games with and without fans in attendance. In the 438 games without fans in attendance, the home-court advantage was 0.44 points and insignificantly different from zero ( $t$ -statistic: 0.609,  $p$ -value: 0.543). It is also significantly lower than in prior seasons ( $t$ -statistic: 2.705,  $p$ -value: 0.007). With fans in attendance, in contrast, the home-court advantage increased to 2.13, which was significantly greater than zero points ( $t$ -statistic: 3.085,  $p$ -value: 0.002) and very much in line with the home-court advantage observed in prior seasons ( $t$ -statistic: 0.420;  $p$ -value: 0.675). However, the difference between average home-court advantage conditional on the presence of fans during the 2020–2021 season is only marginally significant ( $t$ -statistic: 1.70;  $p$ -value: 0.090). These raw conditional means are suggestive evidence that the presence of fans following stadium reopening contributes to home-court advantage. However, the described potential for endogeneity or omitted variables raise concerns that these estimates of the mere effect of fans could be biased or have inflated standard errors.

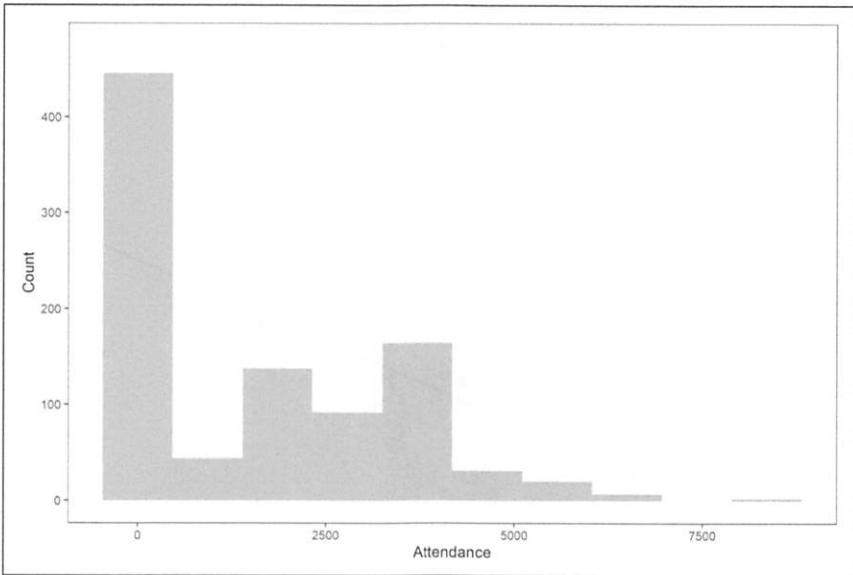




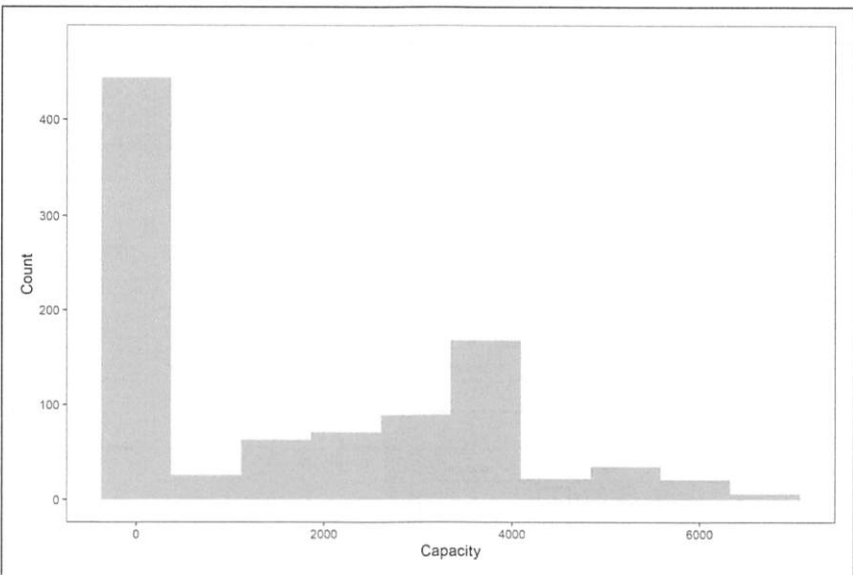
**Figure 1.** Average home point margin—2014–2015 to 2021–2022 National Basketball Association (NBA) regular seasons.

We next display the distributions of our key independent variables prior to reporting regression results. Figure 2 displays a histogram of fan attendance by game for the 2020–2021 regular season. Figure 3 displays a similar histogram of maximum allowable capacity. Figure 4 plots the bivariate relationship between fan attendance and maximum allowable capacity for games where the capacity was greater than zero. They are correlated at the 0.88 level. The similarity between Figures 2 and 3 and the correlation displayed in Figure 4 demonstrate that maximum allowable capacity is a strong instrument for attendance across the 2020–2021 regular season. It is also worth highlighting that Figures 2 and 3 provide information into the scope and distribution of our data. We are able to assess the strength of additional fan attendance on home-court advantage only for the first 8,000 fans; a value that is significantly under full capacity for a typical NBA arena.

To assess the extent of within-team and cross-sectional variation in our data, Figure 5 shows the maximum allowable capacity for each team in the data across the 2020–2021 regular season. For some teams, we obtain five different levels of maximum capacity across the season while for others there is only one maximum capacity value. Increases in maximum capacity appear to occur at different times in the season for different teams and increases differ in magnitude across the league. We further observe decreases in capacity with the Memphis Grizzlies, Toronto Raptors, and Minnesota Timberwolves.<sup>3</sup>



**Figure 2.** Histogram of attendance—2020–2021 National Basketball Association (NBA) regular season.



**Figure 3.** Histogram of maximum allowable capacity—2020–2021 National Basketball Association (NBA) regular season

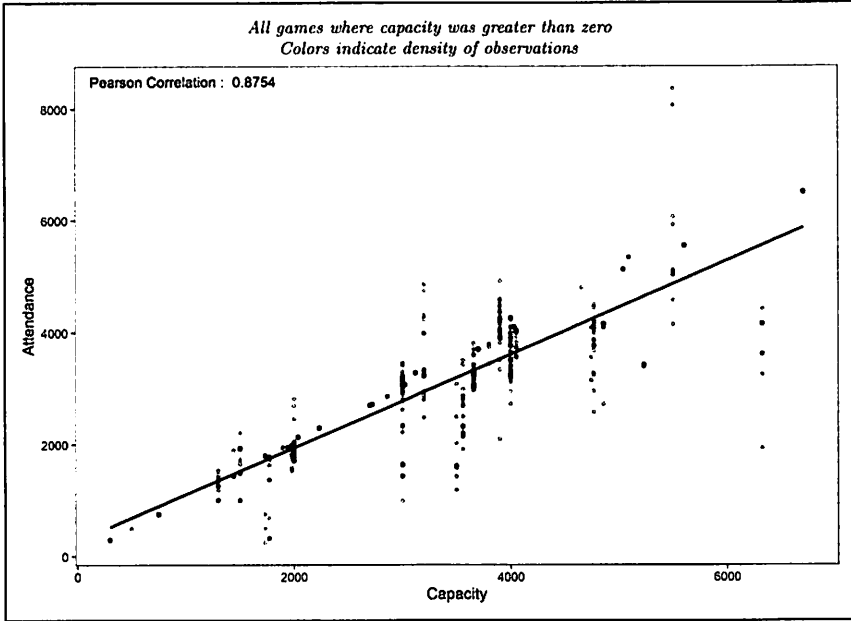


Figure 4. Correlation of attendance and maximum allowable capacity—2020–2021 National Basketball Association (NBA) regular season.

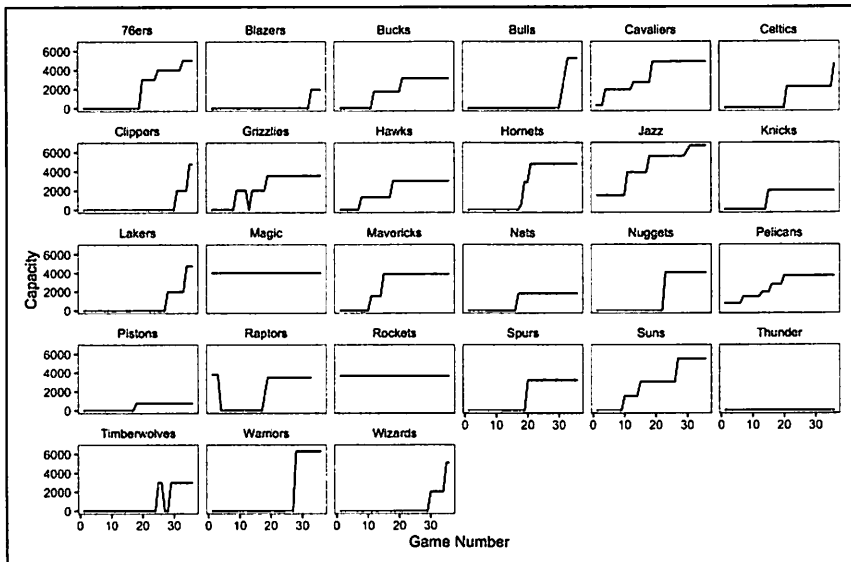


Figure 5. Maximum allowable capacity by team—2020–2021 National Basketball Association (NBA) regular season

**Table 1.** Regression Results—2020–2021 National Basketball Association (NBA) Regular Season.

Variables	(1) Home margin	(2) Home margin	(3) Foul margin	(4) Foul margin
Attendance (1,000 fans)	1.355** (0.640)	1.742** (0.694)	−0.217 (0.200)	−0.181 (0.216)
Home performance	−0.170 (0.426)	−0.226 (0.358)	0.0993 (0.123)	0.0940 (0.122)
Away performance	0.0674 (0.344)	0.0740 (0.362)	0.101 (0.119)	0.102 (0.105)
Cases per thousand people	−0.000156 (0.00209)	0.000135 (0.00235)	−0.00125 (0.000846)	−0.00123 (0.000803)
Home team dummy	Yes	Yes	Yes	Yes
Away team dummy	Yes	Yes	Yes	Yes
Month dummy	Yes	Yes	Yes	Yes
Instrumented	No	Yes	No	Yes
Observations	808	808	808	808
R-squared	0.084	0.083	0.106	0.106
Number of home teams	27	27	27	27

Robust standard errors in parentheses.  
 \*\*\* $p < .01$ , \*\* $p < .05$ , \* $p < .1$ .

**Table 2.** First-stage Regression Results—2020–2021 National Basketball Association (NBA) Regular Season.

Variables	(1) Attendance	(2) Attendance
Capacity	0.747*** (0.0147)	0.747*** (0.0147)
Home performance	0.0290*** (0.0106)	0.0290*** (0.0106)
Away performance	0.00297 (0.0103)	0.00297 (0.0103)
Cases per thousand people	−0.0307*** (0.00724)	−0.0307*** (0.00724)
Home team dummy	Yes	Yes
Away team dummy	Yes	Yes
Month dummy	Yes	Yes
Observations	808	808
R-squared	0.911	0.911
F-statistic	1,111.41	1,111.41
Number of home	27	27

Standard errors in parentheses  
 \*\*\* $p < .01$ , \*\* $p < .05$ , \* $p < .1$ .

**Table 3.** Regression Results—2020–2021 NBA Regular Season.

Variables	(1) Home margin	(2) Home margin
Capacity (Greater than 0)	4.527** (2.074)	
Capacity (1-3,000 fans)		4.336* (2.114)
Capacity (Over 3,000 fans)		5.064* (2.582)
Home performance	-0.175 (0.400)	-0.175 (0.400)
Away performance	0.0797 (0.353)	0.0816 (0.353)
Cases per thousand people	-0.00119 (0.00248)	-0.00112 (0.00241)
Home team dummy	Yes	Yes
Away team dummy	Yes	Yes
Month dummy	Yes	Yes
Instrumented	No	No
Observations	808	808
R-squared	0.086	0.086
Number of home teams	27	27

Robust standard errors in parentheses.

\*\*\* $p < .01$ , \*\* $p < .05$ , \* $p < .1$ .

Categorical capacity variables compare to attendance value of 0.

Next, we report our main regression analyses, which focus on variability in fan attendance during the 2020–2021 season and are presented in Table 1. Model 1 reports results from an (uninstrumented) fixed effects model. The marginal effect of an additional one thousand fans on home-court advantage is approximately 1.36 points and the effect is significant at the 0.05-level. Model 2 reports results from the instrumental variables fixed effects model. The results are largely similar, with an estimated marginal effect of 1.74 points per one thousand fans. The effect remains significant at the 0.05-level. These results provide strong evidence that the presence of fans promotes home-court advantage.

In the third and fourth columns of the table, we also report the results from models in which the dependent variable is the foul margin. The coefficient on fan attendance is insignificantly different from zero in both models. These results, thus, do not support the claim that the impact of fans on home-court advantage is mediated by an impact on the referees.

We also present results estimated on data that include the 25 games removed from our main analysis. In the appendix in Table 7, we produce the results for the same

**Table 4.** Regression Results—2014–2015 to 2021–2022 National Basketball Association (NBA) Regular Seasons.

Variables	(1) Home margin	(2) Home margin
Attendance (1,000 fans)	0.0140 (0.109)	0.920 (0.620)
Home performance	−0.00372 (0.0987)	−0.0503 (0.102)
Away performance	0.125 (0.0991)	0.121 (0.0967)
Home team-season dummy	Yes	Yes
Away team-season dummy	Yes	Yes
Month dummy	Yes	Yes
Instrumented	No	Yes
Observations	8,171	8,171
R-squared	0.256	0.250

Robust standard errors in parentheses

\*\*\* $p < .01$ , \*\* $p < .05$ , \* $p < .1$

models using the uncorrected data. In the fixed effects model, the effect of fan attendance is attenuated somewhat, which is to be expected given the inclusion of additional data where zero attendance is incorrectly reported. In the instrumented model, however, the results are very similar to those found in Table 1 using the corrected data. In both the corrected and uncorrected datasets, the impact of attendance on the foul margin is insignificant in both the uninstrumented and instrumented models.

We also report the first-stage results of the two-stage least squares regressions in Table 2 in order to demonstrate the strength of maximum permitted attendance as an instrument for observed attendance. The high value of the  $F$ -statistic for excluded instruments in the first stage regressions exceed all standard thresholds for tests of weak instruments, for example, the Stock-Yogo threshold for 10% bias in the instrument is 16.38. This, along with the high correlation coefficient indicates that maximum allowable capacity is a strong instrument for fan attendance.

In Table 3, we present the results of the same regressions as in the first column of Table 1, but include capacity as a binary variable indicating whether or not fans were allowed to be present (in the first column) and then as a categorical variable with categories for zero capacity, 1 to 3, 000 fans and greater than 3, 000 fans (in the second column). These models permit us to explore whether home-court advantage increases linearly with arena capacity or if the marginal effect varies in the support of the data. In the regressions with capacity included as an indicator variable, the presence of fans is associated with a 4.53 point increase in home-court advantage. Of note, the coefficient values in the categorical variable for 1 to 3, 000 and more than 3, 000 fans, which are 4.3 and 5.1 points, respectively, are very close to this coefficient estimate as well. These analyses imply that the effect of fans on home-court advantage is

likely nonlinear, with the marginal effect evaluated near zero fans being much larger than the marginal effect evaluated at a few thousand fans.

Lastly, we present the results of models estimated on all of the data from the 2014–2015 to the 2021–2022 NBA Regular Season, when there were no pandemic-driven restrictions on fan attendance. These data therefore primarily include games with near-capacity crowds. The first column reports coefficients from an uninstrumented fixed effects model and finds a small and insignificant positive effect of attendance on home-court advantage. The second column includes the maximum allowed attendance as an instrument for observed attendance. Again, the effect is insignificantly different from zero and very imprecisely estimated, in part due to the much weaker conditional correlation between maximum capacity and observed attendance. Together, these results offer suggestive evidence that the impact of fans on home-court advantage is stronger for small crowds than for those at near capacity.

## **Discussion and Conclusion**

Our paper uses instrumental variables regression to examine whether fan attendance causes home-court advantage. By utilizing exogenous variation in capacity limits during the 2020–2021 NBA regular season, we avoid the problems of reverse causality that plague other empirical studies. We find a strong effect of fan attendance on home team performance. Games with fans are associated with a 1.69 point increase in home-court advantage relative to games with no fans. Further, in fixed effects instrumental variables regression models, the marginal effect of an additional one thousand fans predicts a 1.74 point increase in the home point margin.

It is helpful to place in context the size of this effect in terms of team performance. FiveThirtyEight's Pythagorean expectation estimates teams' winning percentages as a function of expected points scored and points allowed. Multiplying the formula by the number of home games in a season allows us to predict the effect of fans in attendance on the number of home wins expected in a season. According to [basketball-reference.com](http://basketball-reference.com), teams scored, on average, 112.1 points per game in the 2020–2021 NBA season. When we consider that, on average, home-court advantage improves by 1.69 points when fans are in attendance, this equates to approximately 2.2 additional home wins over the course of a full NBA regular season. Further, if we use our predicted estimate in column 1 of Table 1 that an additional 1,000 fans in attendance improves home-court advantage by 1.74 points and the fact that average attendance in the 2020–2021 season when capacity was greater than zero was 2,960, then this equates to approximately 6.4 additional home wins over a full season. Alternatively, using our predicted estimate in column 1 of Table 3, having fans in attendance versus having no fans in attendance adds approximately 5.7 home wins over the season.

However, there are important scope conditions to this result. First, the effect of fans on home-court advantage is only identified over the support of the data.

The maximum attendance for any game during the 2020–2021 regular season was 8,359, which remains far below maximum capacity of any arena. We strongly caution against using these coefficient estimates to inform, for example, the impact of adding an additional one thousand fans when arenas are near full capacity. The fact that our study evaluates empty and near-empty arenas also makes it difficult to compare our results to prior work that evaluates the mechanisms causing home-court advantage in arenas near or at capacity. For example, common explanations for referee bias, which include the psychological effects of crowd size and noise, are unlikely to be as powerful in settings with such restricted attendance.

Second, our ability to estimate the effect is a result of this study being conducted during a pandemic, which impacts the external validity of the study. If fans make it easier for players to ignore off-the-court distractions, for example, the effect size could be overstated in our context. Further, the psychological effect of having fans present after a year of empty arenas could differ from the impact, for example, of having fans absent for random games scattered throughout a normal regular season. In contrast, if external stress makes players less sensitive to their external environment, the effect size could be understated. Of note, the absence of fans at a professional sports arena is always going to be associated with unusual circumstances of some sort. Any empirical estimate of the impact of fans on home-court advantage will face similar concerns about external validity.

With those caveats in mind, we cannot help but reemphasize just how strong of an effect we observe in this setting. With no fans in the stands, there is no evidence of a home-court advantage. With fans in the stands, the home-court advantage rebounds to its usual magnitude. The outsized effect of fan attendance on home-court advantage implies that this mechanism has likely been under-emphasized in the literature to date, especially relative to alternative mechanisms with smaller effects on game outcomes that have been easier to identify empirically. The mere effect of the first few hundred or thousand fans in the stands in an otherwise nearly empty arena is thus a good deal larger than the literature—and, for that matter, many of the players—previously thought.


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## Supplemental material

Supplemental material for this article is available online.

## Notes

1. The authors have not been able to determine why it is that these errors exist in the data, but also have no reason to believe these errors are systematically correlated with any of the variables of interest.
2. COVID-19 case rate data for the New York Knicks and the Brooklyn Nets is aggregated over all five boroughs in New York City.
3. The raw data for Figure 5 is presented in Table 6 in the Appendix.

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## A Appendix

**Table 5.** Games Reporting Zero Attendance with Photographic or Video Evidence of Fans.

Date	Home team	Away team
1/25/2021	Cleveland Cavaliers	Los Angeles Lakers
1/27/2021	Utah Jazz	Dallas Mavericks
2/1/2021	Cleveland Cavaliers	Minnesota Timberwolves
3/19/2021	Cleveland Cavaliers	San Antonio Spurs
3/19/2021	Toronto Raptors	Utah Jazz
3/20/2021	Memphis Grizzlies	Golden State Warriors
3/21/2021	Cleveland Cavaliers	Toronto Raptors
3/26/2021	Toronto Raptors	Phoenix Suns
4/2/2021	Boston Celtics	Houston Rockets
4/4/2021	Boston Celtics	Charlotte Hornets
4/6/2021	Toronto Raptors	Los Angeles Lakers
4/8/2021	Toronto Raptors	Chicago Bulls
4/15/2021	Atlanta Hawks	Milwaukee Bucks
4/16/2021	Toronto Raptors	Orlando Magic
4/18/2021	Atlanta Hawks	Indiana Pacers
4/18/2021	Toronto Raptors	Oklahoma City Thunder
4/19/2021	Boston Celtics	Chicago Bulls
4/21/2021	Toronto Raptors	Brooklyn Nets
4/21/2021	Cleveland Cavaliers	Chicago Bulls
4/24/2021	Utah Jazz	Minnesota Timberwolves
4/27/2021	Toronto Raptors	Brooklyn Nets
5/2/2021	Boston Celtics	Portland Trail Blazers
5/8/2021	Toronto Raptors	Memphis Grizzlies
5/11/2021	Toronto Raptors	Los Angeles Clippers
5/16/2021	Toronto Raptors	Indiana Pacers

**Table 6. Stadium Capacity Limits—2020–2021 National Basketball Association (NBA) Regular Season.**

Team	Date	Capacity limit	Source
Atlanta Hawks	1/26/2021	1, 300	NBA.com. "Hawks to Increase Capacity." May 3, 2021.
	3/13/2021	3, 000	NBA.com. "Hawks to Increase Capacity." May 3, 2021.
	5/22/2021	45% (7, 625)	NBA.com. "Hawks to Increase Capacity." May 3, 2021.
Boston Celtics	3/22/2021	12% (2, 235)	TD Garden. "TD Garden Welcomes Return of Fans." February 25, 2021.
	5/10/2021	25% (4, 656)	TD Garden. "TD Garden Re-Opening Updates." April 27, 2021
Brooklyn Nets	2/23/2021	10% (1, 773)	Income, Net. "New York to Permit Some Fans." NetsDaily. February 10, 2021.
Charlotte Hornets	3/11/2021	500	NBA.com. "Hornets to Welcome Fans Back." March 2, 2021.
	3/13/2021	15% (2, 862)	NBA.com. "Hornets to Welcome Fans Back." March 2, 2021.
	3/26/2021	25% (4, 769)	NBA.com. "Hornets to Increase Spectrum Center Capacity." March 23, 2021.
Chicago Bulls	5/8/2021	25% (5, 229)	Seligman, Andrew. "Boston Celtics vs Chicago Bulls." NBA.com. May 8, 2021.
Cleveland Cavaliers	12/22/2020	300	Rabinowitz, Amanda and Fitzgerald, Sean. "After Nine Months Off." WKSU. December 23, 2020.
	1/11/2021	10% (1, 944)	Axelrod, Ben. "Cleveland Cavaliers Tickets on Sale." WKYC. January 6, 2021.
	2/4/2021	14% (2, 720)	Fedor, Chris. "Cleveland Cavaliers Approved for Attendance." cleveland.com. February 4, 2021.
	2/25/2021	25% (4, 858)	Fedor, Chris. "Cleveland Cavaliers Approved for Attendance." cleveland.com. February 4, 2021.
Dallas Mavericks	2/8/2021	1, 500	Trigg, Dalton. "Mavs Welcome Back." Sports Illustrated. February 5, 2021.
	2/22/2021	3, 900	Caplan, Callie. "Mavs to Admit 3,900." The Dallas Morning News, February 15, 2021.
Denver Nuggets	4/2/2021	4, 050	NBA.com. "Ball Arena to Host 4,050 Fans." March 18, 2021.
Detroit Pistons	3/17/2021	750	Ainsworth, Amber. "Detroit Pistons to Welcome Fans." FOX 2 Detroit. March 3, 2021.
	4/23/2021		

*(continued)*

Table 6. (continued)

Team	Date	Capacity limit	Source
Golden State Warriors		35% (6, 322)	NBA.com. "Warriors to Welcome Fans." April 8, 2021.
Houston Rockets	12/22/2020	3, 660	Tulp, Chris. "Rockets to have 16%-20%." TalkBasket.net. December 17, 2020.
Indiana Pacers	1/24/2021	1, 000	Roberts, Mary. "Pacers to Allow Fans." Inside Indiana Business. January 8, 2021.
	3/4/2021	25% (4, 481)	NBA.com. "Pacers Announce Public Ticket Sales." January 8, 2021.
Los Angeles Clippers	4/18/2021	2, 000	Woike, Dan. "Here's when Lakers, Clippers, Kings Fans." Los Angeles Times. April 2, 2021.
	5/6/2021	25% (4, 767)	NBC Los Angeles. "LA County Officially Eases COVID-19 Business Restrictions." May 6, 2021.
Los Angeles Lakers	4/15/2021	2, 000	NBC Los Angeles. "Lakers to Play in Front of Staples Center." April 15, 2021.
	5/6/2021	25% (4, 767)	NBC Los Angeles. "LA County Officially Eases COVID-19 Business Restrictions." May 6, 2021.
Memphis Grizzlies	2/4/2021	2, 000	Barnes, Evan. "Memphis Grizzlies to Allow." Memphis Commercial Appeal. January 28, 2021.
	3/5/2021	20% (3, 559)	Davis, Corey. "Grizzlies to Sell Limited Single-Game Tickets." Memphis Business Journal. March 2, 2021.
Miami Heat	1/28/2021	1, 500	Fernandez, Gabriel. "Heat to Use Coronavirus-Detecting Dogs." CBS Sports. January 24, 2021.
	2/24/2021	3, 000	Winderman, Ira. "Heat to Expand Capacity." South Florida Sun Sentinel. February 11, 2021.
Milwaukee Bucks	2/16/2021	10% (1, 734)	NBA.com. "Milwaukee Bucks to Increase Fan Capacity." March 11, 2021.
	3/20/2021	18% (3, 121)	NBA.com. "Milwaukee Bucks to Increase Fan Capacity." March 11, 2021.
Minnesota Timberwolves	4/5/2021	3, 000	Theige, Kyle. "Timberwolves to Welcome Back." Canis Hoopus. March 13, 2021.
New Orleans Pelicans	12/22/2020	750	NBA.com. "New Orleans Pelicans Announce Plans." December 17, 2020.
	1/29/2021	1, 440	Elchenhofer, Jim. "Pelicans Shootaround Update." NBA.com. January 29, 2021.
	2/17/2021	1, 900	Clark, Christian. "Pelicans will allow 1,900 fans." nola.com. February 10, 2021.

(continued)

**Table 6.** (continued)

Team	Date	Capacity limit	Source
	2/24/2021	2,700	NBA.com. "New Orleans Pelicans Announce Increased Capacity." February 22, 2021.
	3/11/2021	3,700	NBA.com. "Pelicans Announce Second Half." March 10, 2021.
New York Knicks	2/23/2021	10% (1,981)	Relix.com. "Madison Square Garden to Open." February 26, 2021.
Orlando Magic	12/22/2020	4,000	NBA.com. "Magic to Allow 4,000 Fans." December 15, 2021.
Philadelphia 76ers	3/14/2021	15% (3,023)	Carchidi, Sam. "About 3,100 Fans are Allowed Back." <i>The Philadelphia Inquirer</i> . March 2, 2021.
	4/4/2021	20% (4,031)	Ralph, Pat. "More fans permitted to attend games at Citizens Bank Park." <i>Philly Voice</i> . April 5, 2021.
	5/7/2021	25% (5,039)	Connell, Jack. "Wells Fargo Center to Allow 25%." <i>The Liberty Line</i> . April 27, 2021.
Phoenix Suns	2/7/2021	1,500	Olson, Kellan. "Suns to Begin Allowing Fans." <i>Arizona Sports</i> . February 2, 2021.
	2/16/2021	3,000	Baker, David. "Phoenix Suns Will Double the Number of Fans." <i>AZFamily.com</i> . February 10, 2021.
	4/7/2021	5,500	Olson, Kellan. "Suns to Increase Capacity." <i>Arizona Sports</i> . March 31, 2021.
Portland Trail Blazers	5/7/2021	10% (1,944)	NBA.com. "Trail Blazers to Welcome Limited Fans." May 5, 2021.
Sacramento Kings	4/20/2021	1,600	NBA.com. "Sacramento Kings Welcome Fans." April 12, 2021.
San Antonio Spurs	3/12/2021	3,200	Young, Royce. "After San Antonio Spurs." <i>ESPN.com</i> . March 1, 2021.
Toronto Raptors	12/22/2020	3,800	Burkett, Brenton. "Welcome to Tampa, NBA!" <i>WTSP.com</i> . December 23, 2020.
	1/9/2021	0	Rafferty, Scott. "Fans no Longer Allowed at Toronto Raptors." <i>NBA.com Canada</i> . January 9, 2021.
	3/19/2021	3,500	Encina, Eduardo. "Raptors to Open Home Games." <i>Tampa Bay Times</i> . March 8, 2021.
Utah Jazz	12/22/2020	1,500	Walden, Eric. "Utah Jazz Will Initially Allow 1,500 Fans." <i>The Salt Lake Tribune</i> . November 24, 2020.
	2/2/2021	3,902	Walden, Eric. "Utah Jazz Will Increase Vivint Arena Capacity." <i>The Salt Lake Tribune</i> . February 1, 2021.

(continued)

**Table 6.** (continued)

Team	Date	Capacity limit	Source
	3/12/2021	5,600	Anderson, Ben. "Jazz Increasing Fan Capacity." KSLsports.com. March 11, 2021.
	5/1/2021	6,700	Steinbrecher, Lauren. "Jazz Expand Home Game Capacity." FOX 13 Salt Lake City. April 30, 2021.
Washington Wizards	4/21/2021	10% (2,036)	NBA.com. "Capital One Arena Opens to Wizards Fans." April 12, 2021.
	5/14/2021	25% (5,091)	NHL.com. "MSE Increases Capital One Arena to 25%." May 10, 2021.

Teams started the season (12/22/2020) with zero capacity unless stated otherwise  
 Oklahoma City Thunder had zero fan capacity throughout the 2020-21 NBA regular season

**Table 7.** Regression Results—2020–2021 National Basketball Association (NBA) Regular Season—Uncorrected Data.

Variables	(1) Home margin	(2) Home margin	(3) Foul margin	(4) Foul margin
Attendance (1,000 fans)	0.981 (0.619)	1.651** (0.719)	-0.232 (0.168)	-0.150 (0.230)
Home performance	-0.0273 (0.336)	-0.0959 (0.312)	0.0318 (0.109)	0.0233 (0.109)
Away performance	0.190 (0.330)	0.201 (0.336)	0.0704 (0.111)	0.0717 (0.0979)
Cases per thousand people	-0.000860 (0.00215)	-0.000347 (0.00236)	-0.00118 (0.000820)	-0.00112 (0.000788)
Home team dummy	Yes	Yes	Yes	Yes
Away team dummy	Yes	Yes	Yes	Yes
Month dummy	Yes	Yes	Yes	Yes
Instrumented	No	Yes	No	Yes
Observations	923	923	923	923
R-squared	0.095	0.093	0.105	0.104
Number of home teams	30	30	30	30

Robust standard errors in parentheses.

\*\*\* $p < .01$ , \*\* $p < .05$ , \* $p < .1$ .