

From Ghost Games to the Return of the Crowd: Effects of Increased Fan Attendance During and Following COVID-19 on Home Advantage in the German Soccer Bundesliga

Gerd Nufer
Reutlingen University

Aisha Stickel
Reutlingen University

While prior studies have analyzed the effects of COVID-19-induced ghost games on home advantage in Germany's Soccer Bundesliga, none have examined the 2021/22 season—the period immediately following spectator-free matches. This study addresses that gap by analyzing the impact of fan return on home advantage. Using a dataset of all Bundesliga matches from 2017/18 to 2021/22 (N = 1,530), we performed regression analyses incorporating a categorical variable to represent different phases of attendance restrictions. In the 2021/22 season, after a brief phase of stricter capacity limits, we find evidence of a significantly greater home advantage compared to pre-pandemic levels. However, this elevated effect diminishes over time despite rising spectator numbers. The findings highlight the psychological impact of fans on home team players as the primary mechanism driving home advantage. This suggests that fan presence influences mental rather than physical performance. Accordingly, clubs should prioritize players' physical and mental well-being, even outside extraordinary contexts such as the pandemic.

Keywords: soccer, home advantage, fans, crowd support, COVID-19 pandemic, ghost games

INTRODUCTION

The beginning of the 2021/22 Bundesliga season marked the return of fans to the stadiums. After almost the entire 2020/21 season and parts of the 2019/20 season had to take place without spectators due to the COVID-19 pandemic, politicians announced on 07/06/2021 that larger crowds would be allowed back into stadiums on the first matchday of the 2021/22 season (Sportschau, 2021). Under certain conditions, a maximum of 25,000 spectators would be allowed to attend German professional soccer matches. The maximum stadium capacity was limited to 50 percent, with no more than 25,000 spectators allowed. The basic prerequisite for the return of spectators was the approval of the responsible authorities. This took into account the incidence rates, which were not allowed to exceed 35. If the limits were exceeded, a maximum of 5,000 fans were permitted. In addition, the applicable hygiene rules and social distancing rules had to be observed. Fans had to be vaccinated, recovered or tested. 22,925 spectators attended the opening match between Borussia Mönchengladbach and FC Bayern Munich on 08/13/2021 live at Borussia-Park. A 'back

to normal' seemed to be within reach, and the atmosphere in the stadiums was considerably better (SPOX, 2021).

In this paper, we deal with the return of fans to the stadiums. Specifically, we address the question of how the changing number of spectators after the COVID-19-related spectator-free matches affects the home advantage in the German Bundesliga. While numerous studies have already analyzed the so-called 'ghost games' during the pandemic in professional soccer (Leitner et al., 2022), to our knowledge there have been no studies to date that look at the period after the spectator-free matches in the German Bundesliga and thus the influence of partial attendance and increasing spectator numbers on home advantage in the German top-tier soccer league. However, to take a comprehensive look at the influence of spectators on home advantage, both the loss of spectators and the return of fans to the stadiums should be considered.

The studies that have examined ghost games have shown that home advantage in the German Bundesliga in particular was significantly affected by the lack of spectators (e.g. Almeida & Leite, 2021; Benz & Lopez, 2023; Fischer & Haucap, 2021; Hill & van Yperen, 2021; Ramchandani & Millar, 2021; Strawiński & Krawczyk, 2022). In contrast to other leagues where studies have produced mixed results, the results for the German Bundesliga are consistent. Therefore, the German first division is especially suitable for an investigation of the influence of spectator return on home advantage. The reference points of full stadiums to which stakeholders were accustomed were cited as one of the reasons for the strong effects of ghost games on home advantage in the German Bundesliga (Fischer & Haucap, 2021). If the empty stadiums of the ghost game period are assumed to be the new reference points, even partially filled stadiums could significantly impact home advantage. Our paper tries to shed some light on the following questions: How does increased attendance following pandemic-related ghost games affect home advantage in the German Bundesliga? Is the effect of the regained atmosphere on home advantage as pronounced as the effect of the sudden absence of the audience? Is there a positive effect on home advantage even if the crowd's composition and density differ from before the pandemic due to the restrictions?

In order to answer these questions, our paper is structured as follows. First, we explain the factors theoretically underlying home advantage in professional sports, we outline the studies dealing with home advantage in professional soccer during pandemic ghost games and formulate the research hypotheses on the development of home advantage after COVID-19-related ghost games. After the description of the data, variables and method used in this paper, we present the results. Finally, we discuss our results before we draw the conclusion.

THEORETICAL FOUNDATIONS

Reasons for Home Advantage in Professional Sports

There are various factors that have been suggested to explain home advantage in professional sports. First, psychological or hormonal differences can be identified between home and away team players. Players have increased self-confidence, higher energy levels and feel less tension when a match takes place in the home stadium (Terry et al., 1998). This in turn can lead to improved performance (Woodman & Hardy, 2003). Furthermore, higher testosterone levels can be measured in home team players due to territorial behavior (Neave & Wolfson, 2003).

Another factor that can contribute to home advantage is the familiarity of the home team with the environment, such as the stadium or the pitch (Courneya & Carron, 1992; Pollard, 2008). Travel factors can also affect the probability of winning. The distance traveled, the length of the trip, the means of transport chosen and the exhaustion associated with travel can all lead to lower performance in away games (Courneya & Carron, 1992).

Particularly relevant for our empirical study is the crowd factor. Spectators can have an impact on the winning probability through their motivational effect on the players of the home team (Courneya & Carron, 1992; Nevill & Holder, 1999; Waters & Lovell, 2002). In addition to their impact on player performance, spectators can also influence referees and their decisions (Dohmen, 2008; Garicano et al., 2005; Nevill et al., 2002). Due to the ghost games played in the 2019/20 and 2020/21 seasons in the Bundesliga as a result of the COVID-19 pandemic, and due to the restrictions on the number of spectators allowed in the 2021/22

season, the effect of supportive crowds on home advantage (holding other factors constant) can be considered comprehensively for the first time.

Literature Review

An increasing research interest followed the COVID-19 pandemic and the associated ghost games in the relationship between spectators and home advantage. Subsequently, numerous empirical studies investigated the effect of crowds on home advantage (match outcome, points, goals) and referee bias (fouls, yellow cards, red cards) in professional soccer. The papers used aggregated data from multiple, mostly European, leagues as well as data from individual leagues. Table 1 provides an overview of the empirical studies and their key findings.

Most studies examining the impact of ghost games in the 2019/20 season on home advantage across multiple soccer leagues find a significant decrease in home advantage (Bilalić et al., 2021; Cross & Uhrig, 2023; Leitner & Richlan, 2021; McCarrick et al., 2021; Scoppa, 2021; Sors et al., 2021). In addition to a decrease in home advantage measured by, e.g., match results, several studies identify a decrease in refereeing decisions favoring home teams in spectator-free matches (Bilalić et al., 2021; Leitner & Richlan, 2021; McCarrick et al., 2021; Scoppa, 2021; Sors et al., 2021). However, some studies do not find a significant effect of missing crowds on home advantage when looking at aggregated data, but do find a reduced referee bias. In these cases, it is argued that the referee bias stems from social pressure exerted by the audience, while the home advantage in terms of match outcomes must have other causes (Bryson et al., 2021; Reade et al., 2022; Wunderlich et al., 2021). In contrast, papers that examined home advantage across multiple leagues, including ghost games in the 2020/21 season, all find a significant reduction in home advantage (Lee et al., 2022; Martins et al., 2022; Sors et al., 2022).

The analysis of individual soccer leagues explains the different results of the studies that examined home advantage using aggregated data. While the home advantage declined in some leagues in the 2019/20 season, it remained constant or even increased in other leagues (Almeida & Leite, 2021; Benz & Lopez, 2023; Correia-Oliveira & Andrade-Souza, 2022; Couto & Sayers, 2022; Hill & van Yperen, 2021; Jiménez Sánchez & Lavín, 2021; Matos et al., 2021; Ramchandani & Millar, 2021; Ribeiro et al., 2022; Strawiński & Krawczyk, 2022). Looking at the German Bundesliga, the results are consistent. All studies analyzing the 2019/20 season find that home advantage significantly decreased or disappeared during the ghost games (Almeida & Leite, 2021; Benz & Lopez, 2023; Correia-Oliveira & Andrade-Souza, 2022; Dilger & Vischer, 2022; Hill & van Yperen, 2021; Jiménez Sánchez & Lavín, 2021; Link & Anzer, 2022; Ramchandani & Millar, 2021; Santana et al., 2021; Strawiński & Krawczyk, 2022; Tilp & Thaller, 2020). In the 2020/21 season ghost games, Destefanis et al. (2022) observe a significant decrease in home advantage in the top leagues of England, Spain, Italy, Germany and France. On the other hand, Vandoni et al. (2022) find a decrease in referee bias in the Italian Serie A, but no significant change in home advantage.

Particularly noteworthy is the study by Fischer and Haucap (2021) on the effect of missing crowd support on home advantage in the top three divisions of German soccer. While home advantage decreased in the first division, there were no significant changes in the second and third divisions. Pre-pandemic stadium occupancy is identified as the reason for the observed effects. As players of the lower divisions were used to play in less occupied stadiums before the COVID-19 pandemic, it was easier for them to adapt to empty stadiums. The same authors also examined for the first time not only the short-term effect, but also the longer-term reactions of players by including the ghost games of the 2020/21 Bundesliga season into their analysis. Fischer and Haucap (2022) conclude that the observed recovery of the home advantage is associated with psychological adjustments of the players. Referencing bias changes were not identified as highly relevant for the observed effects in the Bundesliga (Fischer & Haucap, 2021, 2022).

In contrast to the studies mentioned so far, Sors et al. (2023) looked at home advantage and referee bias in national team matches. To this purpose, they analyzed matches of the UEFA Nations League by comparing the 2018/19 season (with spectators) with the 2020/21 season (empty or partially filled stadiums). While home advantage and referee bias emerged in the 2018/19 season, both phenomena were absent in the 2020/21 season. The authors conclude that fans do not only have a decisive influence on home advantage in domestic leagues, but also in national team matches. While there are numerous studies on

ghost games, only few studies address the return of spectators to the stands or the increase in attendance following pandemic-related ghost games.

Although in a different context, Singleton et al. (2023) examined how the reinstatement of spectators affects home advantage. For this purpose, they studied the Egyptian Premier League, which has experienced two periods without fans in the last decade. Fans were first banned in 2012 due to violence in the stadiums and, second, in 2020 because of the COVID-19 pandemic. After six seasons without crowds, up to 5,000 spectators were allowed back into stadiums in the 2018/19 season. The authors do not find a significant change in the point difference once the limited crowds were allowed back in. However, home teams received significantly fewer yellow cards in the 2018/19 season compared to the previous season.

Silva et al. (2022) investigated the 2020 season without spectators and the 2021 season with partly-filled stadiums in the Brazilian Serie A. While they do not find a significant influence of missing spectators on home advantage as compared to the pre-pandemic 2019 season, despite limited attendance, home advantage increased in the 2021 season after the return of spectators. The referee bias, on the other hand, was not significantly affected by increasing spectator numbers.

None of the studies mentioned deals with the post-pandemic spectator return in the German soccer Bundesliga. But since a significant effect of missing spectators on home advantage has been found especially in the first division in Germany, an investigation of spectator return in this league is particularly interesting. We will therefore analyze how increasing spectator numbers after the pandemic-related ghost games affect home advantage in the Bundesliga.

TABLE 1
OVERVIEW OF PEER-REVIEWED STUDIES ON THE EFFECT OF COVID-19-RELATED
GHOST GAMES ON HOME ADVANTAGE AND REFEREE BIAS IN
PROFESSIONAL SOCCER

Author(s) (year)	Soccer leagues ⁽¹⁾	Season(s) ⁽²⁾	Home advantage ⁽³⁾	Referee bias ⁽³⁾
Almeida and Leite (2021)	5	2019/20	+* / -	-
Benz and Lopez (2023)	17	2019/20	+* / -	+* / -
Bilalić et al. (2021)	12 (a)	2019/20	+	+
Bryson et al. (2021)	23 (a)	2019/20	-	+
Correia-Oliveira and Andrade-Souza (2022)	7	2019/20	+* / -	n
Couto and Sayers (2022)	2 (Brazil)	2020	-	+
Cross and Uhrig (2023)	4 (a)	2019/20	+	n
Destefanis et al. (2022)	5	2020/21	+*	n
Dilger and Vischer (2022)	1 (Germany)	2019/20	+*	+*
Endrich and Gesche (2020)	2 (a, Germany)	2019/20	n	+
Fischer and Haucap (2021)	3 (Germany)	2019/20	+* / -	-
Fischer and Haucap (2022)	2 (Germany)	2019/20 and 2020/21	+* / -	-
Hill and van Yperen (2021)	4	2019/20	+* / -	+*
Jiménez Sánchez and Lavín (2021)	8	2019/20	+* / -	n
Lee et al. (2022)	4 (a)	2019/20 and 2020/21	+	n
Leitner and Richlan (2021)	8 (a)	2019/20	+	+
Link and Anzer (2022)	2 (Germany)	2019/20	+*	+*

Author(s) (year)	Soccer leagues ⁽¹⁾	Season(s) ⁽²⁾	Home advantage ⁽³⁾	Referee bias ⁽³⁾
Martins et al. (2022)	8 (a)	2019/20 and 2020/21	+	n
Matos et al. (2021)	1 (Portugal)	2019/20	-	n
McCarrick et al. (2021)	15 (a)	2019/20	+	+
Ramchandani and Millar (2021)	5	2019/20	+* / -	n
Reade et al. (2022)	7 (a)	2002/03 until April 2020	-	+
Ribeiro et al. (2022)	2 (Brazil)	2020	-	n
Santana et al. (2021)	1 (Germany)	2019/20	+*	n
Scoppa (2021)	9 (a)	2019/20	+	+
Sors et al. (2021)	8 (a)	2019/20	+	+
Sors et al. (2022)	10 (a)	2020/21	+	+
Sors et al. (2023)	1 (UEFA Nations League)	2020/21	+	+
Strawiński and Krawczyk (2022)	4	2019/20	+* / -	n
Tilp and Thaller (2020)	1 (Germany)	2019/20	+*	+*
Vandoni et al. (2022)	2 (Italy)	2020/21	+ / -	+ / -
Wunderlich et al. (2021)	10 (a)	2019/20	-	+

(1) Number of leagues (country, if only a single country was analyzed); (a) if aggregated data.

(2) Season(s) with ghost games after the COVID-19-induced break.

(3) + if significant effect; +* if significant effect (also) in the German Bundesliga; - if no significant effect; n if not analyzed. Home advantage variables: match outcome, points, goals. Referee bias variables: fouls, yellow cards, red cards.

Research Hypotheses

In our empirical analysis multiple periods are considered, we describe the different phases. The focus of our paper will be on the evolution of the home advantage with increasing spectator numbers in the 2021/22 season after the pandemic ghost games. Since players become accustomed to empty stadiums over time in the 2020/21 season (Fischer & Haucap, 2022), the positive effect of even small crowds should be significantly larger immediately after the ghost games compared to before the COVID-19 pandemic. Relevant to these considerations are the respective reference points: Attendance before the pandemic was consistently high, meaning that players were used to crowd support. However, immediately after the ghost games, the increase in spectator numbers should have a higher psychological effect on players due to the comparison with spectator-free matches. Similar to the motivational effect of spectators on home team players, the social pressure on referees and thus the influence of fans on refereeing decisions should be significantly higher immediately after the ghost games, even in matches with only partially filled stadiums.

Hypothesis 1: *In the immediate aftermath of pandemic-related ghost games, a larger home advantage exists even with only partially filled stadiums compared to before the COVID-19 pandemic.*

However, it can be assumed that both the above-average effect of crowds on players of the home teams and the above-average influencing effect of fans on referees are of temporary nature. Therefore, it is hypothesized that agents adapt to the return of spectators and that the home advantage decreases to pre-pandemic levels (e.g. Odermatt & Stutzer, 2019).

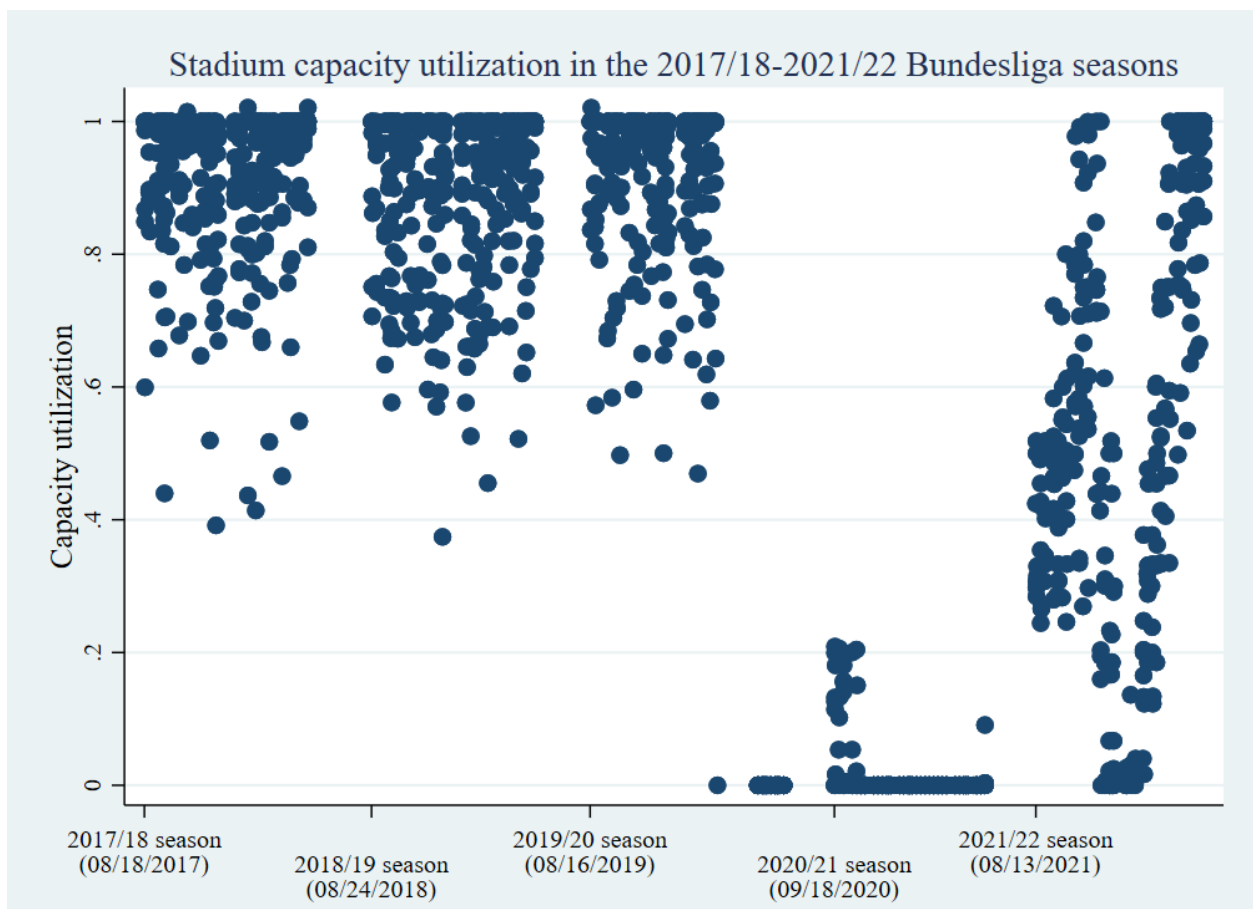
Hypothesis 2: *Despite increasing spectator numbers, the above-average effect disappears over time and the home advantage decreases to pre-pandemic levels.*

METHODOLOGY

Data and Variables

For the empirical analysis, we built a dataset comprising all matches of German soccer's first division in the five seasons 2017/18 to 2021/22 ($N = 1,530$). The generated dataset contains information from several sources as well as own calculations. Results data and match statistics are available at football-data.co.uk, average market values, stadium-specific information and changes in coach at transfermarkt.de. Matchdays and spectator numbers can be found at kicker.de. Kick-off times and table positions are available at fussball.de. The matches were divided into seven different phases according to the stadium capacity utilization displayed in Figure 1.

FIGURE 1
STADIUM CAPACITY UTILIZATION IN THE 2017/18-2021/22 BUNDESLIGA SEASONS



The first phase ('before') includes the matches with relatively stable attendance in the pre-pandemic period. In the 2019/20 season, the first ghost game due to the COVID-19 pandemic took place on March 11, 2020. In total, there were 83 ghost games taking place in this first ghost game period ('ghost games 1'). At the beginning of the 2020/21 season, there was a short period with small crowds being allowed into stadiums ('crowd 1'). From matchday 6 onwards, the remainder of the season was again played without fans in the stadiums ('ghost games 2'). This second ghost game period comprises 261 matches. The 2021/22 season can be divided into three further phases: In the first period, spectator numbers increased constantly ('crowd 2'), followed by another short phase with more severe capacity restrictions and a few ghost games ('restrictions'), until spectator numbers increased again from matchday 21 onwards ('crowd 3'). The

stadium capacity utilization during the last matchdays of the 2021/22 season is comparable to the capacity utilization rates in the pre-pandemic seasons. An overview of the phases can be found in Table 2.

TABLE 2
OVERVIEW OF THE SEVEN PHASES OF STADIUM CAPACITY UTILIZATION IN THE
2017/18-2021/22 BUNDESLIGA SEASONS

Phase name	Time period	Season (matchdays)	Description
Before	08/18/2017-03/08/2020	2017/18, 2018/19, 2019/20 (1-25)	Matches with relatively stable attendance in the pre-pandemic period
Ghost games 1	03/11/2020-06/27/2020	2019/20 (26-34)	The first ghost game due to the COVID-19 pandemic took place on March 11, 2020. After a break of approximately two months, the remaining matches of the season were played behind closed doors
Crowd 1	09/18/2020-10/26/2020	2020/21 (1-5)	Short period with small crowds being allowed into stadiums
Ghost games 2	10/30/2020-05/22/2021	2020/21 (6-34)	The remainder of the season (with exception of the last matchday) was again played without fans in the stadiums
Crowd 2	08/13/2021-11/21/2021	2021/22 (1-12)	Spectator numbers increased constantly
Restrictions	11/26/2021-01/23/2022	2021/22 (13-20)	More severe capacity restrictions and a few ghost games
Crowd 3	02/04/2022-05/14/2022	2021/22 (21-34)	Spectator numbers increased again

Three alternative variables were generated to measure home advantage (Fischer & Haucap, 2021). Two dummy variables serve as indicators for a home or away win ('home win' and 'away win'), the third variable reflects the point difference (points of the home team – points of the away team, 'point difference') and also considers draws. This variable can take three values – the value -3 for an away win, the value 0 for a drawn match and the value 3 for a home win. A categorical variable divides the matches into the seven spectator phases ('phases') described above, dummy variables derived from it serve as indicators for matches in the respective phases and are required for the empirical analysis.

The control variables follow Fischer and Haucap (2021) and can be assigned to four categories: team quality, geographical, match-specific and stadium-specific factors. Team quality is approximated by the difference between the average market values (in € million, 'average market value difference') and the difference between the table positions (table positions prior to the current match, 'table position difference'). Geographical factors include the distance between the stadiums of the home and away team (straight line distance in km, 'distance stadiums') and the absolute altitude difference between the stadiums (altitude of the stadiums in m above sea level, 'altitude difference'). The distance between the stadiums is used as an indicator for the distance traveled or the length of the trip. The match-specific factors contain dummy variables for new coaches ('new coach home' and 'new coach away'). For these variables, the first three Bundesliga matches under a new coach and only changes in coach during the season were considered. All matches where the distance between the stadiums is less than 50 km are defined as derbies ('derby') and matches are considered to be played during the week ('during the week') when they take place between Tuesday and Thursday.

Furthermore, matches are classified as late kick-off matches ('late match') if the kick-off time is later than 6 pm. Finally, the category of stadium-specific information includes a dummy variable that indicates the existence of a running track ('running track'), the proportion of standing places ('proportion of standing places') and the stadium capacity ('ln(capacity)'). All differences were calculated by subtracting away team data from home team data. Moreover, variables reflecting match statistics were generated for robustness checks.

Statistical Method

In order to empirically investigate the development of the home advantage after the pandemic-related ghost games, we conducted various regression analyses according to the following equation:

$$Y_{it} = \beta_0 + phases_t' \beta_1 + X_{it}' \beta_2 + \varepsilon_{it} \quad (1)$$

where the categorical variable containing the different phases of capacity restrictions ($phases_t$) was included using dummy coding. The pre-pandemic period ('before') serves as the reference phase in each case. X_{it} is a matrix that considers all control variables described above to avoid an omitted variable bias. OLS regressions were estimated in models with the point difference of team i at time t as the dependent variable Y_{it} (e.g. Bryson et al., 2021; Fischer & Haucap, 2021; Scoppa, 2021; Strawiński & Krawczyk, 2022), and probit regressions were estimated in models with the dummy variables for home and away wins as the dependent variable Y_{it} in order to determine the effects on winning probabilities (e.g. Dilger & Vischer, 2022; Fischer & Haucap, 2021; Strawiński & Krawczyk, 2022). Since OLS results might be biased, we will also test an alternative model using ordered probit regressions (e.g. Cross & Uhrig, 2023; Fischer & Haucap, 2022; McCarrick et al., 2021).

RESULTS

Descriptive Statistics

An overview of the data and variables described in the previous section is provided in the summary statistics in Table 3, which also shows that across the five seasons there was an overall home advantage of 43.9% home wins and only 31.4% away wins. The development of home advantage over time is first analyzed descriptively.

TABLE 3
SUMMARY STATISTICS

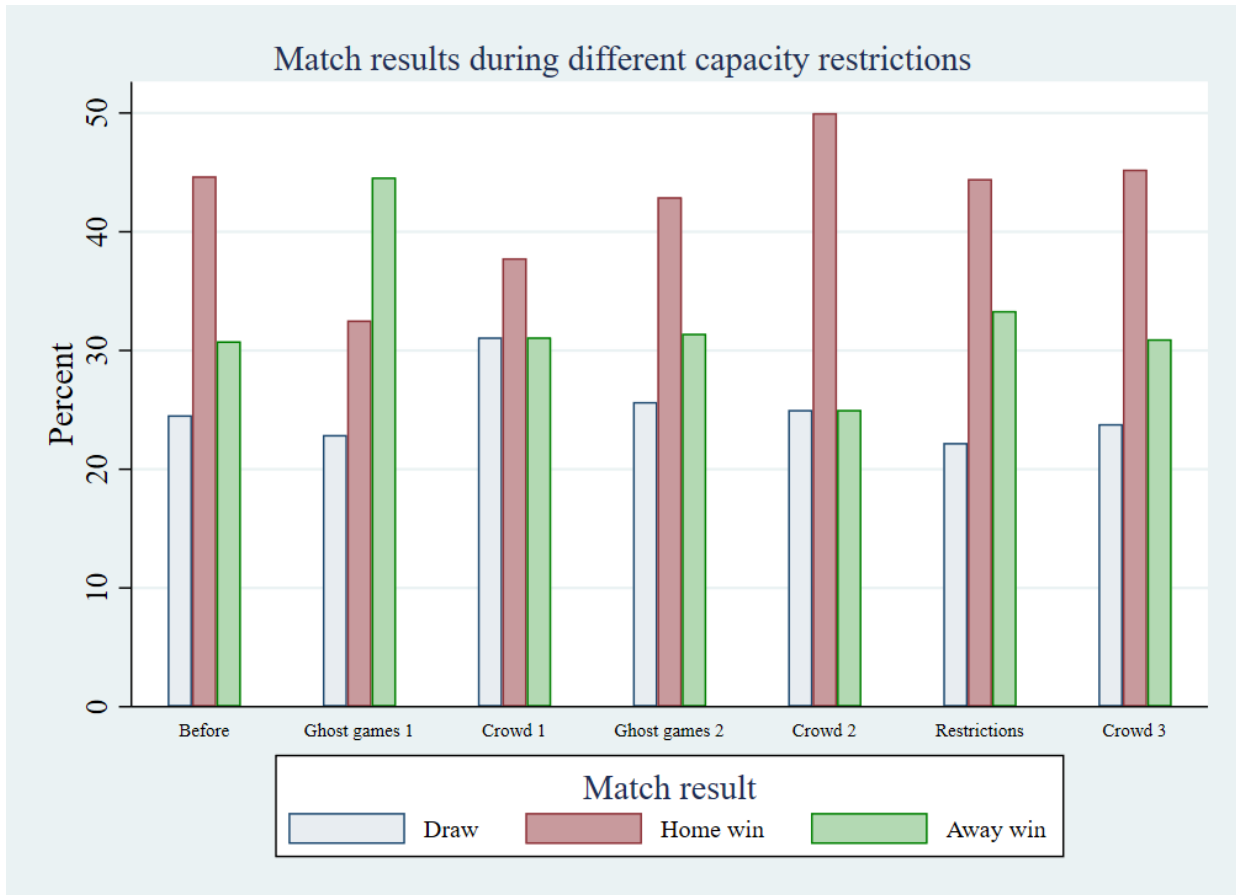
<i>Variable</i>	<i>Mean</i>	<i>SD</i>	<i>Min</i>	<i>Max</i>
<i>Match results</i>				
Home win	0.439	0.496	0	1
Away win	0.314	0.464	0	1
Point difference	0.376	2.577	-3	3
<i>Match statistics</i>				
Home yellow cards	1.673	1.294	0	8
Away yellow cards	1.923	1.289	0	7
Home red cards	0.051	0.226	0	2
Away red cards	0.078	0.276	0	2
Home fouls	11.840	3.861	2	28
Away fouls	12.346	3.951	2	29
Home shots	13.986	5.021	1	35
Away shots	11.802	4.839	1	32

<i>Variable</i>	<i>Mean</i>	<i>SD</i>	<i>Min</i>	<i>Max</i>
Home shots on target	5.090	2.682	0	16
Away shots on target	4.327	2.476	0	20
Home corners	5.190	2.864	0	19
Away corners	4.5	2.616	0	15
<i>Team quality</i>				
Average market value difference	0	8.880	-29.76	29.76
Table position difference	-0.148	7.785	-17	17
<i>Geographical factors</i>				
Distance stadiums	298.750	145.984	14.7	639.9
Altitude difference	147.314	143.651	0	495
<i>Match-specific information</i>				
New coach home	0.044	0.205	0	1
New coach away	0.041	0.199	0	1
Derby	0.043	0.203	0	1
During the week	0.069	0.253	0	1
Late match	0.362	0.481	0	1
<i>Stadium-specific information</i>				
Running track	0.067	0.250	0	1
Proportion of standing places	0.274	0.152	0	0.836
Capacity	46,337.3	18,232.7	15,000	81,365
Spectators	27,888.3	23,518.8	0	81,365
Capacity utilization	0.598	0.413	0	1.021
<i>Phases of capacity restrictions</i>				
Phases	2.637	2.074	1	7
Before	0.546	0.498	0	1
Ghost games 1	0.054	0.227	0	1
Crowd 1	0.029	0.169	0	1
Ghost games 2	0.171	0.376	0	1
Crowd 2	0.071	0.256	0	1
Restrictions	0.047	0.212	0	1
Crowd 3	0.082	0.275	0	1

Sample size $N = 1,530$. Note that the capacity utilization value exceeds 1 for 10 observations. However, the results do not change if these observations are dropped.

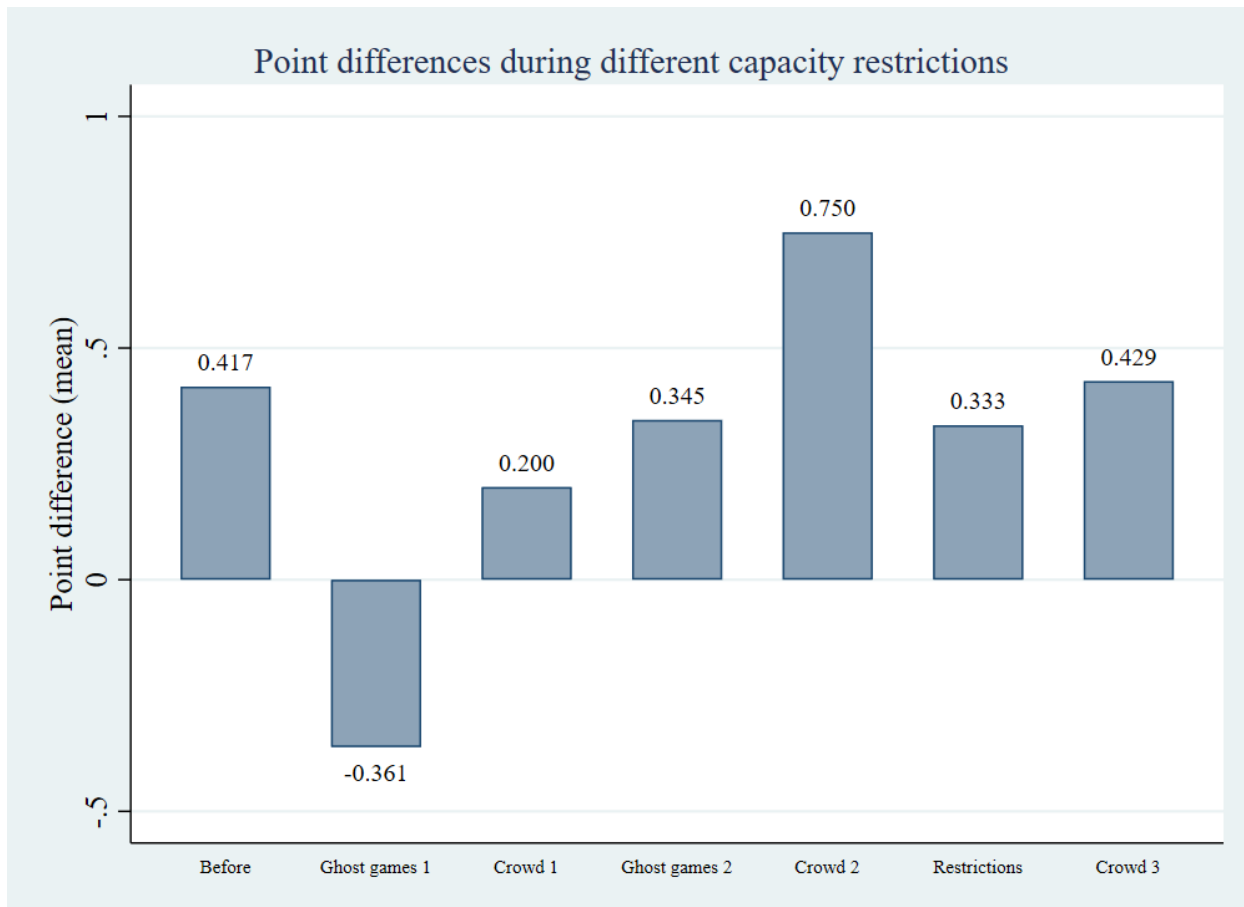
Figure 2 shows the match results during the seven phases of capacity restrictions. It reveals that, at least descriptively, both previous research results on ghost games and our hypotheses on the post-pandemic period can be confirmed. In the pre-pandemic period, there are more home than away wins. While this home advantage even turns into home disadvantage during the first ghost game period, agents seem to adjust to empty stadiums in the second ghost game period. In the period following the second spectator-free phase, there is initially an increase in home advantage, but over time the level approaches the pre-pandemic level again. Drawn matches are relatively constant over time.

FIGURE 2
MATCH RESULTS DURING DIFFERENT CAPACITY RESTRICTIONS



The development of the mean values of the point differences illustrated in Figure 3 confirms the trend described above. If the mean value of the point difference is greater than zero, there is a home advantage. Here too, it can be observed descriptively that in the first ghost game period the home advantage disappears completely, whereas it exists again in the second. It can also be clearly seen that immediately following the second phase of empty spectator stands, the home advantage rises sharply and then approaches pre-pandemic levels. In the following section we present the results of regression analyses to test these descriptive findings for statistical significance.

FIGURE 3
POINT DIFFERENCES DURING DIFFERENT CAPACITY RESTRICTIONS



Regression Analysis

Before examining the development of home advantage within the different restriction phases over time, the home advantage in each period is first examined in comparison to the home advantage in the pre-pandemic period. Table 4 presents the results of the regressions including the control variables. In this first model, there is only a statistically significant effect in the first ghost game period. The missing spectators decrease the probability of a home win by 14.8 percentage points and increase the probability of an away win by 16.7 percentage points. Contrary to expectations from the descriptive analysis, the second ghost game period and the periods after the ghost games show no significant difference to the pre-pandemic home advantage.

TABLE 4
THE INFLUENCE OF SPECTATORS ON HOME ADVANTAGE

	(1) Home win	(2) Away win	(3) Point difference
Ghost games 1	-0.148** (0.069)	0.167*** (0.059)	-0.749*** (0.261)
Crowd 1	-0.114 (0.081)	-0.009 (0.065)	-0.304 (0.297)
Ghost games 2	-0.015 (0.031)	0.010 (0.034)	-0.052 (0.141)
Crowd 2	0.018 (0.064)	-0.022 (0.051)	0.085 (0.238)
Restrictions	0.019 (0.052)	0.026 (0.067)	-0.039 (0.270)
Crowd 3	0.018 (0.049)	0.002 (0.042)	0.031 (0.207)
Average market value difference	0.001 (0.002)	-0.001 (0.002)	0.007 (0.011)
Table position difference	-0.033*** (0.003)	0.032*** (0.003)	-0.172*** (0.013)
Distance stadiums	-0.000 (0.000)	-0.000 (0.000)	0.000 (0.000)
Altitude difference	0.000 (0.000)	0.000 (0.000)	-0.000 (0.000)
New coach home	0.112* (0.059)	-0.032 (0.039)	0.339 (0.206)
New coach away	-0.139** (0.055)	0.122* (0.064)	-0.658** (0.241)
Derby	0.016 (0.071)	0.073 (0.073)	-0.173 (0.312)
During the week	0.001 (0.054)	0.017 (0.048)	-0.084 (0.228)
Late match	0.033 (0.029)	-0.031 (0.031)	0.174 (0.122)
Running track	-0.051 (0.040)	-0.038 (0.034)	-0.000 (0.140)
Proportion of standing places	0.137* (0.073)	-0.127 (0.126)	0.651 (0.397)
ln(Capacity)	0.040 (0.034)	0.024 (0.055)	-0.018 (0.175)
Constant			0.338 (1.854)
<i>N</i>	1,530	1,530	1,530
<i>(Pseudo) R</i> ²	0.179	0.217	0.287

(1) and (2): Average marginal effects of probit regressions. (3): Coefficients of OLS regression. Cluster-robust standard errors in parentheses, clustered on home team level. *Pseudo R*² for probit regressions, *R*² for OLS regression.

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

The statistically significant control variables behave as expected. If the difference between the table positions decreases by one, the home team becomes better positioned relative to the away team, the probability of a home win increases by 3.3 percentage points. Interestingly, team quality is fully explained by the table position difference, the average market value difference becomes insignificant once the table position difference is included in the regression. New coaches positively affect the winning probability in the short-run already (i.e. during the first three matches). A new coach of the home team increases the probability of a home win by 11.2 percentage points, a new coach of the away team decreases the probability of a home win by 13.9 percentage points. Last but not least, a one percentage point increase in the proportion of standing places leads to a 0.137 percentage point increase in the probability of a home win. Even though the coefficient is only significant at the 10% level, it could still be argued that the more intense atmosphere associated with a higher proportion of standing places impacts home advantage.

In order to examine the development of home advantage within the restriction phases over time, the interactions of the phase dummies with the respective matchday within the phase were included in Table 5. Considering the development over time, significant negative effects on the probability of winning at home can be identified in both ghost game periods. However, in both periods the home advantage increases over time, i.e. the negative effect of missing spectators on home advantage decreases over time. Taking into account the results of the previous model, it can be concluded that the negative effect becomes smaller in the first ghost game period, whereas in the second ghost game period, it seems to disappear completely. Thus, during the 2020/21 season ghost games, the home advantage increases over time to pre-pandemic levels.

Although the descriptive analysis points towards a significant increase in home advantage at the beginning of the 2021/22 season compared to the pre-pandemic level, a significantly increased home win probability is only found in the last spectator phase. As in the second ghost game period, the positive effect of spectators on home advantage is limited to the beginning of the phase; the effect disappears over time and the home advantage approaches the pre-pandemic home advantage.

TABLE 5
THE DEVELOPMENT OF HOME ADVANTAGE WITHIN THE DISTINCT RESTRICTION PHASES OVER TIME

	(1) Home win	(2) Away win	(3) Point difference
Ghost games 1	-1.227*** (0.399)	0.638* (0.327)	-1.605*** (0.485)
Crowd 1	-0.298 (0.361)	0.405 (0.473)	-0.663 (0.429)
Ghost games 2	-0.470** (0.212)	0.207 (0.211)	-0.618* (0.325)
Crowd 2	-0.193 (0.252)	-0.120 (0.280)	-0.114 (0.295)
Restrictions	0.464 (0.354)	-0.174 (0.492)	0.531 (0.772)
Crowd 3	0.440** (0.188)	-0.190 (0.269)	0.532 (0.367)
(Ghost games 1)×(#Matchday)	0.160** (0.067)	-0.037 (0.060)	0.175* (0.099)
(Crowd 1)×(#Matchday)	-0.002 (0.114)	-0.148 (0.145)	0.120 (0.131)

	(1) Home win	(2) Away win	(3) Point difference
(Ghost games 2)×(#Matchday)	0.028** (0.011)	-0.012 (0.013)	0.038* (0.019)
(Crowd 2)×(#Matchday)	0.036 (0.045)	0.007 (0.045)	0.031 (0.065)
(Restrictions)×(#Matchday)	-0.094 (0.071)	0.057 (0.093)	-0.127 (0.145)
(Crowd 3)×(#Matchday)	-0.052** (0.024)	0.026 (0.035)	-0.067 (0.045)
Control variables	Yes	Yes	Yes
<i>N</i>	1,530	1,530	1,530
(<i>Pseudo</i>) <i>R</i> ²	0.188	0.219	0.293

(1) and (2): Coefficients of probit regressions. (3): Coefficients of OLS regression. Cluster-robust standard errors in parentheses, clustered on home team level. *Pseudo R*² for probit regressions, *R*² for OLS regression.

* *p* < 0.1, ** *p* < 0.05, *** *p* < 0.01.

Robustness Checks

We conducted several robustness checks to check the robustness of the previous results and test potential explanations for the effects. Table 6 shows the results of an alternative regression analysis where each match was divided into two observations and a dummy variable for home matches was included (e.g. Endrich & Gesche, 2020; Fischer & Haucap, 2021, 2022; McCarrick et al., 2021; Scoppa, 2021).

The dependent variables are either a dummy variable for a win or the number of points gained in the match. The regression analysis shows that the negative effect on home advantage diminishes over time, especially in the second ghost game period, confirming the previous models' results. However, contrary to what we found before, the spectator return in the 2021/22 season has no significant impact on home advantage using the alternative regression model.

As already described in the theoretical foundations, the literature suggests two explanations for the influence of spectators on home advantage: their motivational effect on players of the home team and their influencing effect on refereeing decisions. Both potential explanations are briefly examined below (Fischer & Haucap, 2021, 2022).

TABLE 6
THE DEVELOPMENT OF HOME ADVANTAGE WITHIN THE DISTINCT RESTRICTION
PHASES OVER TIME – ALTERNATIVE MODEL

	(1) Win	(2) Win	(3) Points	(4) Points
Home	0.350*** (0.066)	0.351*** (0.066)	0.352*** (0.065)	0.352*** (0.065)
(Home)×(Ghost games 1)	-0.328** (0.152)	-1.080*** (0.343)	-0.351** (0.137)	-0.811*** (0.272)
(Home)×(Crowd 1)	-0.174 (0.194)	-0.259 (0.448)	-0.094 (0.165)	-0.325 (0.392)
(Home)×(Ghost games 2)	-0.042 (0.090)	-0.460*** (0.170)	-0.033 (0.081)	-0.357** (0.142)
(Home)×(Crowd 2)	0.148 (0.129)	0.084 (0.262)	0.148 (0.118)	0.143 (0.225)

	(1) Win	(2) Win	(3) Points	(4) Points
(Home)×(Restrictions)	0.000 (0.155)	0.229 (0.332)	-0.040 (0.145)	0.143 (0.330)
(Home)×(Crowd 3)	0.025 (0.121)	0.270 (0.242)	0.004 (0.111)	0.191 (0.227)
(Home)×(Ghost games 1)×(#Matchday)		0.147** (0.058)		0.095* (0.051)
(Home)×(Crowd 1)×(#Matchday)		0.028 (0.133)		0.077 (0.113)
(Home)×(Ghost games 2)×(#Matchday)		0.028*** (0.009)		0.022*** (0.008)
(Home)×(Crowd 2)×(#Matchday)		0.010 (0.035)		0.001 (0.030)
(Home)×(Restrictions)×(#Matchday)		-0.051 (0.066)		-0.040 (0.064)
(Home)×(Crowd 3)×(#Matchday)		-0.033 (0.028)		-0.025 (0.026)
Control variables	Yes	Yes	Yes	Yes
<i>N</i>	3,060	3,060	3,060	3,060
<i>Pseudo R</i> ²	0.016	0.021	0.011	0.013

(1) and (2): Coefficients of probit regressions. (3) and (4): Coefficients of ordered probit regressions. Cluster-robust standard errors in parentheses, clustered on match level.

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Table 7 shows the influence of spectators on refereeing behavior. During the first ghost game period, referees award 0.5 more yellow cards and 1 more foul to players of the home team compared to matches with spectators before the pandemic. In the last spectator phase, both home and away teams receive fewer red cards. Overall, there are significant effects of (missing) spectators on refereeing decisions, but given the size of the effects, it is unlikely that changes in refereeing behavior are the only reason for the changes in home advantage.

TABLE 7
THE INFLUENCE OF SPECTATORS ON REFEREEING DECISIONS

	(1) Home yellow cards	(2) Away yellow cards	(3) Home red cards	(4) Away red cards	(5) Home fouls	(6) Away fouls
Ghost games 1	0.503*** (0.159)	-0.019 (0.123)	0.034 (0.037)	-0.009 (0.032)	1.014** (0.453)	-0.065 (0.470)
Crowd 1	0.351* (0.194)	0.163 (0.188)	-0.015 (0.027)	-0.027 (0.035)	-0.196 (0.582)	0.567 (0.557)
Ghost games 2	0.103 (0.086)	-0.132 (0.084)	-0.019 (0.022)	-0.027 (0.019)	0.488 (0.365)	0.095 (0.317)
Crowd 2	0.124 (0.169)	0.066 (0.128)	-0.028* (0.016)	0.001 (0.031)	-0.044 (0.397)	0.390 (0.529)

	(1) Home yellow cards	(2) Away yellow cards	(3) Home red cards	(4) Away red cards	(5) Home fouls	(6) Away fouls
Restrictions	-0.028 (0.138)	-0.279*** (0.093)	-0.047*** (0.016)	-0.052 (0.033)	-0.779 (0.530)	-1.214 (0.737)
Crowd 3	-0.049 (0.152)	-0.162 (0.116)	-0.034* (0.017)	-0.059*** (0.018)	-0.338 (0.350)	0.026 (0.465)
Control variables	Yes	Yes	Yes	Yes	Yes	Yes
<i>N</i>	1,530	1,530	1,530	1,530	1,530	1,530
<i>R</i> ²	0.045	0.022	0.012	0.010	0.060	0.050

Coefficients of OLS regressions. Cluster-robust standard errors in parentheses, clustered on home team level.

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Table 8 shows the influence of spectators on team performance. The estimates imply that the number of shots the home team takes decreases in both ghost game periods (by 1.1 and 1.7, respectively). Moreover, the home team wins 0.7 fewer corner kicks in the second ghost game period. But again, these effects are too small to explain the effect of spectators on home advantage.

Even if we also consider the development over time by including the interactions of the phase dummies with the respective matchday (results not reported here), neither changes in refereeing behavior nor changes in team performance explain the development of home advantage over time. Consequently, the lack of statistically significant coefficients, especially in the last spectator phase, suggests that other reasons must exist for the observed effects. In the following section we argue that these reasons appear to be mainly psychological.

TABLE 8
THE INFLUENCE OF SPECTATORS ON TEAM PERFORMANCE

	(1) Home shots	(2) Away shots	(3) Home shots on target	(4) Away shots on target	(5) Home corners	(6) Away corners
Ghost games 1	-1.071** (0.459)	0.047 (0.566)	-0.200 (0.260)	0.214 (0.349)	-0.058 (0.317)	0.061 (0.388)
Crowd 1	-0.491 (0.822)	-0.660 (0.549)	-0.010 (0.288)	-0.072 (0.445)	-0.082 (0.396)	-0.052 (0.452)
Ghost games 2	-1.653*** (0.383)	-0.097 (0.456)	-0.247 (0.192)	0.147 (0.164)	-0.706*** (0.194)	-0.056 (0.160)
Crowd 2	-0.157 (0.511)	-0.343 (0.590)	0.144 (0.231)	-0.194 (0.314)	-0.182 (0.263)	-0.213 (0.217)
Restrictions	-0.273 (0.440)	0.402 (0.609)	0.296 (0.224)	0.510* (0.294)	0.257 (0.347)	0.198 (0.393)
Crowd 3	-0.527 (0.593)	-0.478 (0.387)	-0.051 (0.275)	-0.031 (0.223)	-0.350 (0.381)	0.022 (0.248)
Control variables	Yes	Yes	Yes	Yes	Yes	Yes
<i>N</i>	1,530	1,530	1,530	1,530	1,530	1,530
<i>R</i> ²	0.221	0.203	0.182	0.176	0.103	0.120

Coefficients of OLS regressions. Cluster-robust standard errors in parentheses, clustered on home team level.

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

DISCUSSION

Interpretation of Results

The results of the empirical analysis are consistent with previous research. The home advantage in the German Bundesliga disappears during the first ghost game period in the 2019/20 season. In the second ghost game period, there is a negative effect of missing spectators on home advantage, decreasing over time. Hence, the home advantage increases over time to pre-pandemic levels in the 2020/21 season. Changes in referee bias and team performance are of limited relevance in both ghost game periods.

Hypotheses 1 and 2 are partially supported. Only in the last spectator phase at the end of the 2021/22 season, there is some evidence for a positive effect of spectators on home advantage, which diminishes over time despite increasing spectator numbers. The hypotheses are only partially confirmed, since the last spectator phase does not begin immediately after the ghost games, but after the period of capacity restrictions in the winter of the 2021/22 season. Contrary to expectations from the descriptive analysis, there is no significant effect in the spectator phase immediately after the second ghost game period. Refereeing behavior and team performance are not significantly affected by the increasing spectator numbers in the 2021/22 season.

One possible explanation for the significant effect of spectators on home advantage in the last spectator phase is that this phase immediately followed the period of restricted spectator numbers, whereas an off-season break occurred between the second ghost game period and the following spectator phase. Psychologically, it could be argued that abrupt changes in spectator numbers are perceived stronger than changes with an interruption between the two periods.

Furthermore, the results reveal that the effect of ghost games (especially the first ghost game period) on home advantage is more pronounced than the effect of spectators being allowed back in stadiums. This result can be plausibly explained by the psychological phenomenon of negativity bias, according to which negative events have a greater impact on agents than positive events, even if they are of equal intensity (Baumeister et al., 2001). This phenomenon is also reflected in the concept of loss aversion in behavioral economics (Kahneman & Tversky, 1979). Moreover, it can be argued that despite the restrictions and the spectator-free matches, the memory of full stadiums is still present. Consequently, the pre-pandemic crowds can serve as an additional reference point and it can be assumed that players adapt more quickly to increasing spectator numbers than to empty stadiums.

Another important factor that should be considered when looking at our results is the composition of crowds, which has been identified as a potential driver of crowd influence on home advantage (Humphreys et al., 2022; Singleton et al., 2023). Despite increasing attendance, both spectator phases in the 2021/22 season were still subject to restrictions. For instance, supporters of the visiting teams were not admitted until the third matchday, distances had to be maintained, standing places were limited and face masks were mandatory (Sportbuzzer, 2021). This certainly affected the atmosphere in the stadiums and may have reduced the influence of fans on players and referees.

The results also show that in both ghost game periods, the home advantage increases over time and players adapt to empty stadiums. Hence, other factors compensate for the negative effect of missing spectators over time. This is an indication that multiple factors interact and contribute to home advantage (Courneya & Carron, 1992; Fischer & Haucap, 2021; Pollard, 2008).

Limitations

The results obtained in the empirical analysis are subject to several limitations. First, it must be noted that the last spectator phase only significantly affects the probability of a home win, but has no significant effect on the point difference (Table 5). Furthermore, spectator return does not significantly affect home advantage when using the alternative regression model (Table 6). Taken together, we cannot rule out that increasing spectator numbers in the 2021/22 season has no significant effect on home advantage in the German Bundesliga.

In the regressions for the examination of changes in refereeing behavior (Table 7), the coefficients of determination R^2 are relatively small. Although this is consistent with the small values reported in Fischer

and Haucap (2021, 2022) and Scoppa (2021), and referee bias is found to be of limited relevance in our context, future research could still further investigate the influence of spectator return on referee behavior. In particular, it might be interesting to examine leagues where the effects of ghost games on referee bias appear to be more pronounced. While our analysis uses OLS, future research should also consider alternative regression models such as Poisson regressions (e.g. Benz & Lopez, 2023; McCarrick et al., 2021).

Despite the inclusion of control variables, the analysis may still suffer from an omitted variable bias. In particular, differences between the teams after the pandemic break could bias the results (e.g. different training conditions during the break, resulting in different fitness levels). In this context, another issue concerns data granularity regarding stadium spectators. Specifically, the composition of spectators in the 2021/22 season could not be accounted for in the analysis. Our data does not include the ratio of home to away fans and the actual proportion of standing places per match. We were only able to include the proportion of standing places in each stadium under normal conditions. The results of Humphreys et al. (2022), however, indicate that the crowd composition has an impact on home and away performances of teams. Therefore, future research should also try to include variables that reflect crowd composition into the analysis of effects of spectator return on home advantage. Additionally, it is important to note that the spectator numbers in our data reflect the number of tickets sold, but actual attendance may be lower due to no-shows. For instance, the studies by Schreyer (2019) and Schreyer and Däuper (2018) have demonstrated that no-show behavior also plays a role in the German Bundesliga.

Moreover, it cannot be excluded that a general ‘COVID-19 effect’ is measured instead of the effect of (missing) spectators on home advantage, especially since psychological factors seem to play an important role in the development of the home advantage and a general impact of the pandemic on psychological states is likely to occur. Therefore, a general COVID-19 effect could mean that other factors that are otherwise responsible for the home advantage (e.g. self-confidence or familiarity with the environment) were influenced by the general uncertainty of people in the context of the pandemic situation. The interplay between the factors influencing home advantage, and in particular the analysis of the underlying psychological mechanisms, is one of the challenges for future research.

Another limitation concerns the circumstances of the fan return in the Bundesliga. To comprehensively understand the impact of spectators on home advantage, both spectator loss and fan return to stadiums should be examined. Due to capacity restrictions in the 2021/22 season, we were only able to look at the effect of gradually increasing attendance on home advantage. It would be interesting, however, to study the effect of full stadiums immediately following ghost games.

Since home advantage was particularly affected by empty stadiums in the Bundesliga, we focused on the effect of increasing spectator numbers on home advantage in this league. The results of our study apply exclusively to the first division of German soccer and cannot be transferred to lower divisions in Germany or leagues in other countries, nor to other sports.

Implications

Several implications regarding the importance of fans in professional soccer can be drawn from the results. As already confirmed by previous studies, our empirical analysis has shown that ghost games can have two adverse effects on clubs. In addition to the missing revenue from ticket sales, missing spectators also have an impact on the sporting success of a club. Therefore, since the negative influence of missing spectators on match results is particularly short-term, spectator exclusions can be used as an effective sanction against clubs (e.g., following spectator misconduct or crowd violence). This is in line with the study by Singleton et al. (2023), who find that banning crowds following crowd violence in the Egyptian Premier League reduced home advantage. While ghost games can be used as a powerful sanctioning tool, at the same time it is important for clubs to avoid such sanctions. Therefore, measures can be considered to prevent violence in stadiums, such as excluding fans or fan groups that have attracted negative attention. However, those fan groups are often the main driver of the intense stadium atmospheres, which can positively impact home advantage. Furthermore, they help clubs generate higher income by being an

essential part of broadcasts since they are one target group for hospitality offers. It should therefore be considered whether a credible threat of such a measure could already be sufficient.

We have argued that the influence of spectators on players is particularly psychological. In order to reduce the home advantage of opposing teams and increase the performance of own players, clubs could create incentives for fans to attend away matches (Leitner et al., 2022). This implication is also consistent with the findings of Humphreys et al. (2022), who recently examined home and away attendances at soccer matches. Their results indicate that the crowd composition impacts home and away teams' performances. On a more general note, the overall stadium atmosphere seems highly important for fans' positive effect on match outcomes. Even under normal conditions, i.e. without pandemic-related constraints, measures can be taken to improve the atmosphere and create greater intensity. Such measures may include artificial fan chants, the establishment of a fan culture, closer relationships between players and fans and affordable matches (Edensor, 2015).

Although it cannot be ruled out that the negative psychological effect on the players is not the result of the lack of spectators, but rather the result of the general stress associated with the pandemic, it can nevertheless be concluded that the players' mental health plays an important role. When looking at the effect of spectators, it became clear that the negative effects of ghost games are more pronounced than the positive effects of spectator return. This negativity bias is likely to occur not only in the context of effects of crowd on players, but also in other circumstances. Clubs should therefore try to avoid negative external influences on players, such as negative media coverage or disagreements at club level, which might negatively influence player performances. We conclude that it is important for clubs, beyond exceptional situations such as in the context of the pandemic, to consider not only players' physical but also mental health. In fact, psychologists are already used at many Bundesliga clubs. For instance, Julian Nagelsmann, who coached FC Bayern Munich in the 2021/22 and 2022/23 seasons, transferred together with the team psychologist from his previous club. The psychologist collaborates with the coach and supports the players, for example in dealing with defeats or pressure to perform (Sport1, 2021). Similarly, Borussia Dortmund hired former goalkeeper Philipp Laux as a psychologist to support both coaches and players during the pandemic crisis (SPOX, 2020).

Lastly, our results also demonstrated the limited relevance of effects of spectator return on refereeing behavior in the German Bundesliga, which was also found to be of limited importance in ghost games. It is likely that the introduction of video assistant referees (VAR) in the 2017/18 season is the main reason for referees being less sensitive to external influences (e.g. Fischer & Haucap, 2021).

CONCLUSIONS

Our study aimed to investigate the development of home advantage after the pandemic-related ghost games in the first division of German soccer. The empirical analysis considered five seasons from 2017/18 to 2021/22. The results of previous studies on home advantage during ghost games were confirmed: While the home advantage disappears during the first ghost game period in the 2019/20 season, the home advantage increases over time to pre-pandemic levels in the second ghost game period in the 2020/21 season. In the 2021/22 season, after a short period of stricter capacity restrictions, there is some evidence for a significantly larger home advantage compared to the pre-pandemic period. Despite increasing spectator numbers, the above-average positive effect of spectators in this last period disappears over time.

Overall, our empirical analysis was able to further highlight the ability of spectators to affect sporting success. Positive psychological effects on the home team players were identified as the main reason for the influence of fans on home advantage.

REFERENCES

- Almeida, C.H., & Leite, W.S. (2021). Professional football in times of COVID-19: Did the home advantage effect disappear in European domestic leagues? *Biology of Sport*, 38(4), 693–701. <https://doi.org/10.5114/biolsport.2021.104920>
- Baumeister, R.F., Bratslavsky, E., Finkenauer, C., & Vohs, K.D. (2001). Bad is stronger than good. *Review of General Psychology*, 5(4), 323–370. <https://doi.org/10.1037/1089-2680.5.4.323>
- Benz, L.S., & Lopez, M.J. (2023). Estimating the change in soccer's home advantage during the Covid-19 pandemic using bivariate Poisson regression. *Advances in Statistical Analysis*, 107(1–2), 205–232. <https://doi.org/10.1007/s10182-021-00413-9>
- Bilalić, M., Gula, B., & Vaci, N. (2021). Home advantage mediated (HAM) by referee bias and team performance during covid. *Scientific Reports*, 11(1), Article 21558. <https://doi.org/10.1038/s41598-021-00784-8>
- Bryson, A., Dolton, P., Reade, J.J., Schreyer, D., & Singleton, C. (2021). Causal effects of an absent crowd on performances and refereeing decisions during Covid-19. *Economics Letters*, 198, 109664. <https://doi.org/10.1016/j.econlet.2020.109664>
- Correia-Oliveira, C.R., & Andrade-Souza, V.A. (2022). Home advantage in soccer after the break due to COVID-19 pandemic: Does crowd support matter? *International Journal of Sport and Exercise Psychology*, 20(4), 1245–1256. <https://doi.org/10.1080/1612197X.2021.1934716>
- Courneya, K.S., & Carron, A.V. (1992). The home advantage in sport competitions: A literature review. *Journal of Sport and Exercise Psychology*, 14(1), 13–27. <https://doi.org/10.1123/jsep.14.1.13>
- Couto, B.P., & Sayers, M.G. (2022). Crowd social pressure in the Brazilian soccer league: Testing home advantage and referees' bias during the COVID-19 pandemic. *International Journal of Sport and Exercise Psychology*, 21(4), 1–16. <https://doi.org/10.1080/1612197X.2022.2084763>
- Cross, J., & Uhrig, R. (2023). Do fans impact sports outcomes? A COVID-19 natural experiment. *Journal of Sports Economics*, 24(1), 3–27. <https://doi.org/10.1177/15270025221100204>
- Destefanis, S., Addesa, F., & Rossi, G. (2022). The impact of COVID-19 on home advantage: A conditional order-m analysis of football clubs' efficiency in the top-5 European leagues. *Applied Economics*, 54(58), 6639–6655. <https://doi.org/10.1080/00036846.2022.2074361>
- Dilger, A., & Vischer, L. (2022). No home bias in ghost games. *Athens Journal of Sports*, 9(1), 9–24. <https://doi.org/10.30958/ajspo.9-1-1>
- Dohmen, T.J. (2008). The influence of social forces: Evidence from the behavior of football referees. *Economic Inquiry*, 46(3), 411–424. <https://doi.org/10.1111/j.1465-7295.2007.00112.x>
- Edensor, T. (2015). Producing atmospheres at the match: Fan cultures, commercialisation and mood management in English football. *Emotion, Space and Society*, 15, 82–89. <https://doi.org/10.1016/j.emospa.2013.12.010>
- Endrich, M., & Gesche, T. (2020). Home-bias in referee decisions: Evidence from “ghost matches” during the Covid19-pandemic. *Economics Letters*, 197, Article 109621. <https://doi.org/10.1016/j.econlet.2020.109621>
- Fischer, K., & Haucap, J. (2021). Does crowd support drive the home advantage in professional football? Evidence from German ghost games during the COVID-19 pandemic. *Journal of Sports Economics*, 22(8), 982–1008. <https://doi.org/10.1177/15270025211026552>
- Fischer, K., & Haucap, J. (2022). Home advantage in professional soccer and betting market efficiency: The role of spectator crowds. *Kyklos*, 75(2), 294–316. <https://doi.org/10.1111/kykl.12291>
- Garicano, L., Palacios-Huerta, I., & Prendergast, C. (2005). Favoritism under social pressure. *Review of Economics and Statistics*, 87(2), 208–216. <https://doi.org/10.1162/0034653053970267>
- Hill, Y., & van Yperen, N.W. (2021). Losing the home field advantage when playing behind closed doors during COVID-19: Change or chance? *Frontiers in Psychology*, 12, 658452. <https://doi.org/10.3389/fpsyg.2021.658452>
- Humphreys, B.R., Reade, J., Schreyer, D., & Singleton, C. (2022). Separating the crowds: Examining home and away attendances at football matches. *SSRN*. <https://doi.org/10.2139/ssrn.4275076>

- Jiménez Sánchez, Á., & Lavín, J.M. (2021). Home advantage in European soccer without crowd. *Soccer and Society*, 22(1–2), 152–165. <https://doi.org/10.1080/14660970.2020.1830067>
- Kahneman, D., & Tversky, A. (1979). Prospect theory: An analysis of decision under risk. *Econometrica*, 47(2), 263–292. <https://doi.org/10.2307/1914185>
- Lee, J., Kim, J., Kim, H., & Lee, J.-S. (2022). A Bayesian approach to predict football matches with changed home advantage in spectator-free matches after the COVID-19 break. *Entropy*, 24(3), 366–378. <https://doi.org/10.3390/e24030366>
- Leitner, M.C., Daumann, F., Follert, F., & Richlan, F. (2022). The cauldron has cooled down: A systematic literature review on home advantage in football during the COVID-19 pandemic from a socio-economic and psychological perspective. *Management Review Quarterly*, 73, 1–29. <https://doi.org/10.1007/s11301-021-00254-5>
- Leitner, M.C., & Richlan, F. (2021). No fans-no pressure: Referees in professional football during the COVID-19 pandemic. *Frontiers in Sports and Active Living*, 3, 720488. <https://doi.org/10.3389/fspor.2021.720488>
- Link, D., & Anzer, G. (2022). How the COVID-19 pandemic has changed the game of soccer. *International Journal of Sports Medicine*, 43(1), 83–93. <https://doi.org/10.1055/a-1518-7778>
- Martins, H.S.R., Duarte, A.R., Barbosa, J.J., & Souza, G.L. (2022). Home team's advantage reduced without crowd support after the COVID-19 outbreak. *Soccer and Society*, 24(5), 636–653. <https://doi.org/10.1080/14660970.2022.2088526>
- Matos, R., Monteiro, D., Antunes, R., Mendes, D., Botas, J., Clemente, J., & Amaro, N. (2021). Home-advantage during COVID-19: An analysis in Portuguese football league. *International Journal of Environmental Research and Public Health*, 18(7), Article 3761. <https://doi.org/10.3390/ijerph18073761>
- McCarrick, D., Bilalić, M., Neave, N., & Wolfson, S. (2021). Home advantage during the COVID-19 pandemic: Analyses of European football leagues. *Psychology of Sport and Exercise*, 56, Article 102013. <https://doi.org/10.1016/j.psychsport.2021.102013>
- Neave, N., & Wolfson, S. (2003). Testosterone, territoriality, and the 'home advantage'. *Physiology and Behavior*, 78(2), 269–275. [https://doi.org/10.1016/S0031-9384\(02\)00969-1](https://doi.org/10.1016/S0031-9384(02)00969-1)
- Nevill, A.M., Balmer, N.J., & Williams, A.M. (2002). The influence of crowd noise and experience upon refereeing decisions in football. *Psychology of Sport and Exercise*, 3(4), 261–272. [https://doi.org/10.1016/S1469-0292\(01\)00033-4](https://doi.org/10.1016/S1469-0292(01)00033-4)
- Nevill, A.M., & Holder, R.L. (1999). Home advantage in sport: An overview of studies on the advantage of playing at home. *Sports Medicine*, 28(4), 221–236. <https://doi.org/10.2165/00007256-199928040-00001>
- Odermatt, R., & Stutzer, A. (2019). (Mis-)predicted subjective well-being following life events. *Journal of the European Economic Association*, 17(1), 245–283. <https://doi.org/10.1093/jeea/jvy005>
- Pollard, R. (2008). Home advantage in football: A current review of an unsolved puzzle. *Open Sports Sciences Journal*, 1(1), 12–14. <https://doi.org/10.2174/1875399X00801010012>
- Ramchandani, G., & Millar, R. (2021). Investigating the “twelfth man” effect in five European domestic football leagues: A COVID-19 induced natural experiment. *Journal of Global Sport Management*, 8(4), 928–942. <https://doi.org/10.1080/24704067.2021.1951614>
- Reade, J.J., Schreyer, D., & Singleton, C. (2022). Eliminating supportive crowds reduces referee bias. *Economic Inquiry*, 60(3), 1416–1436. <https://doi.org/10.1111/ecin.13063>
- Ribeiro, L.d.C., Fonseca, F.d.S., Costa, G.D.C.T., Castro, H.d.O., Da Santos, J.P.V.S., & Figueiredo, L.S. (2022). Did the absence of crowd support during the Covid-19 pandemic affect the home advantage in Brazilian elite soccer? *Journal of Human Kinetics*, 81(1), 251–258. <https://doi.org/10.2478/hukin-2022-0047>
- Santana, H.A.P., Bettiga, O.B., & Dellagrana, R. (2021). An analysis of Bundesliga matches before and after social distancing by COVID-19. *Science and Medicine in Football*, 5(sup1), 17–21. <https://doi.org/10.1080/24733938.2021.1903540>

- Scoppa, V. (2021). Social pressure in the stadiums: Do agents change behavior without crowd support? *Journal of Economic Psychology*, 82, Article 102344. <https://doi.org/10.1016/j.joep.2020.102344>
- Schreyer, D. (2019). Football spectator no-show behaviour in the German Bundesliga. *Applied Economics*, 51(45), 4882–4901. <https://doi.org/10.1080/00036846.2019.1602709>
- Schreyer, D., & Däuper, D. (2018). Determinants of spectator no-show behaviour: First empirical evidence from the German Bundesliga. *Applied Economics Letters*, 25(21), 1475–1480. <https://doi.org/10.1080/13504851.2018.1430314>
- Silva, A.C., Amaral, A.S., Facundo, L.A., Wiprich, M.T., Rechenchosky, L., & Rinaldi, W. (2022). Two years of COVID-19 pandemic: How the Brazilian Serie A championship was affected by home advantage, performance and disciplinary aspects. *International Journal of Environmental Research and Public Health*, 19(16), Article 10308. <https://doi.org/10.3390/ijerph191610308>
- Singleton, C., Reade, J.J., & Schreyer, D. (2023). A decade of violence and empty stadiums in Egypt: When does emotion from the terraces affect behaviour on the pitch? *Empirical Economics*, 65, 1487–1507. <https://doi.org/10.1007/s00181-023-02383-0>
- Sors, F., Grassi, M., Agostini, T., & Murgia, M. (2021). The sound of silence in association football: Home advantage and referee bias decrease in matches played without spectators. *European Journal of Sport Science*, 21(12), 1597–1605. <https://doi.org/10.1080/17461391.2020.1845814>
- Sors, F., Grassi, M., Agostini, T., & Murgia, M. (2022). A complete season with attendance restrictions confirms the relevant contribution of spectators to home advantage and referee bias in association football. *PeerJ*, 10, Article e13681. <https://doi.org/10.7717/peerj.13681>
- Sors, F., Grassi, M., Agostini, T., & Murgia, M. (2023). The influence of spectators on home advantage and referee bias in national teams matches: Insights from UEFA Nations League. *International Journal of Sport and Exercise Psychology*, 21(2), 290–305. <https://doi.org/10.1080/1612197X.2022.2044367>
- Sport1. (2021, November 13). *Das ist Nagelsmanns Spielerflüsterer*. Retrieved from <https://www.sport1.de/news/fussball/bundesliga/2021/11/fc-bayern-dr-maximilian-pelka-ist-der-geheime-joker-von-julian-nagelsmann>
- Sportbuzzer. (2021, December 3). *Die Corona-Chronologie im Fußball: Wie das Virus wieder die Kontrolle übernimmt*. Retrieved from <https://www.sportbuzzer.de/fussball/bundesliga/die-corona-chronologie-im-fussball-wie-das-virus-wieder-die-kontrolle-uebernimmt-6FFACF3DADCB2FFD4B2C72CBE.html>
- Sportschau. (2021, July 6). *Politik erlaubt Fan-Rückkehr im deutschen Profifußball*. Retrieved from <https://www.sportschau.de/fussball/bundesliga/zuschauer-im-profifussball-wieder-erlaubt-100.html>
- SPOX. (2020, May 8). *Borussia Dortmund: Laux als Psychologe zurück beim BVB*. Retrieved from <https://www.spox.com/de/sport/fussball/bundesliga/2005/News/laux-als-psychologe-zueruck-beim-bvb.html>
- SPOX. (2021, August 13). *Bilder zum Saisonauftakt: Endlich wieder Zuschauer*. Retrieved from <https://www.spox.com/de/sport/fussball/bundesliga/2108/Diashows/fan-rueckkehr-bl-zuschauer/saison-auftakt-bayern-gladbach-bvb-frankfurt-leipzig.html>
- Strawiński, P., & Krawczyk, M. (2022). Home advantage revisited: Did COVID level the playing fields? *Central European Economic Journal*, 9(56), 56–67. <https://doi.org/10.2478/ceej-2022-0004>
- Terry, P.C., Walrond, N., & Carron, A.V. (1998). The influence of game location on athletes' psychological states. *Journal of Science and Medicine in Sport*, 1(1), 29–37. [https://doi.org/10.1016/S1440-2440\(98\)80006-6](https://doi.org/10.1016/S1440-2440(98)80006-6)
- Tilp, M., & Thaller, S. (2020). Covid-19 has turned home advantage into home disadvantage in the German soccer Bundesliga. *Frontiers in Sports and Active Living*, 2, 593499. <https://doi.org/10.3389/fspor.2020.593499>

- Vandoni, M., Ferraro, O.E., Gatti, A., Marin, L., Giuriato, M., Silvestri, D., . . . Carnevale Pellino, V. (2022). The role of crowd support on home advantage during COVID-19 restrictions on Italian football competitions: Comparison between 2018-19 and 2020-21 seasons of the Italian Serie A and Serie B championships. *Sports*, 10(2), 17–22. <https://doi.org/10.3390/sports10020017>
- Waters, A., & Lovell, G. (2002). An examination of the homefield advantage in a professional English soccer team from a psychological standpoint. *Football Studies*, 5(1), 46–59.
- Woodman, T., & Hardy, L. (2003). The relative impact of cognitive anxiety and self-confidence upon sport performance: A meta-analysis. *Journal of Sports Sciences*, 21(6), 443–457. <https://doi.org/10.1080/0264041031000101809>
- Wunderlich, F., Weigelt, M., Rein, R., & Memmert, D. (2021). How does spectator presence affect football? Home advantage remains in European top-class football matches played without spectators during the COVID-19 pandemic. *PloS One*, 16(3), Article e0248590. <https://doi.org/10.1371/journal.pone.0248590>