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Does Crowd Support Drive the Home Advantage in Professional Football? Evidence from German Ghost Games during the COVID-19 Pandemic

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Abstract

This paper examines the relation between crowd support and home advantage in men's professional football in making use of a unique "natural experiment" induced by restrictions due to the COVID-19 pandemic: the so-called ghost games in the top three German football divisions at the end of the 2019/2020 season. We find that there is a reduced home advantage in the first division, whereas no change is observed in the second and third divisions. Our regression analysis indicates that the decrease in the home advantage and the heterogeneity across divisions are not sensitive to a variety of performance, location, and team covariates and are best explained through the lower occupancy rate in the stadia. Hence, the decrease in occupancy to zero at the ghost games has been less dramatic for teams that have been used to low occupancy rates. We cannot find strong evidence for a change in referee behavior or teams' tactics as main impact channels of occupancy rates on the home advantage. Hence, we argue that psychological reasons are of higher importance.

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Introduction

The home advantage is frequently discussed in the sports literature, as the phenomenon is rather persistent in most sports (Courneya & Carron, 1992; Gomez et al., 2011; Jamieson, 2010; Jones, 2013; Nevill & Holder, 1999; Pollard et al., 2017), with only rare exceptions (Klein-Soetebier et al., 2014). Football is one of the sports with the largest home advantage (Jamieson, 2010; Pollard & Pollard, 2005), though there are differences across countries (Pollard, 2006b) and between men and women leagues (Pollard & Gomez, 2014a; Pollard et al., 2017). Although the home advantage is well known, its variation and drivers are still subject to intense debate (Pollard, 2006a, 2008; Pollard et al., 2017).

The literature, however, agrees that the home advantage is not driven by a single, but many factors that also affect each other, such as crowd support and location familiarity (Courneya & Carron, 1992; Pollard, 2006a). This paper contributes to this discussion by quantifying the effect of attendance on home performance in men's professional football. We examine the so-called ghost games in the top three German divisions that took place after Germany, following the Corona-induced shut-down, restarted as the first country its professional football leagues in May 2020. While the games' atmosphere has been much less lively, these ghost games, induced by the COVID-19 pandemic, provide a rare "natural experiment" to study crowd impact on player performance. The ghost games took place between May and July 2020, with the exception of one ghost game already being played in March. We use this unique setup to analyze (a) whether the home advantage was affected by ghost games, (b) reasons for and impact channels of a changing home advantage, and (c) whether absolute attendance or occupancy better explains the home advantage.

Generally, there are few phenomena that attract attention from as many scientific disciplines as the home advantage in sports. Whereas psychological and medical perspectives include emotional and hormone differences between home and away games (Bray et al., 2002; Neave & Wolfson, 2003; Pollard & Pollard, 2005; Terry et al., 1998), economic research has focused on location impact on teams' production technologies (Carmichael & Thomas, 2005), the role of expectations for match outcomes, and social pressure (Dohmen, 2008; Dohmen & Sauermann, 2016; Garicano et al., 2005; Sutter & Kocher, 2004). In general, there is a wide spectrum of sources for the home advantage. Five of the most frequently named include (a) territoriality/psychological reasons, (b) location familiarity, (c) referee bias, (d) crowd support, and (e) physical factors.

While this paper focuses on the crowd's role, we briefly discuss other factors subsequently.

Firstly, territoriality refers to home teams' willingness to defend their turf in competitions (Pollard & Pollard, 2005) causing home players to energize resistance forces (Carre et al., 2006; Neave & Wolfson, 2003), feel stress (Carre et al., 2006) or show higher self-esteem and self-efficacy (Terry et al., 1998; Waters & Lovell, 2002).

Location familiarity assumes home teams to be more used to local circumstances (e.g., climate, field length, lawn texture). That could be the reason why home teams perform worse following constructions of new stadia (Pollard, 2002), even though Clarke & Norman (1995) provide contrasting evidence.

The referee bias is one channel via which crowd support may affect home advantage, as crowds may influence referee partiality. Apart from experimental studies (Nevill et al., 2002; Unkelbach & Memmert, 2010), field research (Dohmen, 2008; Garicano et al., 2005) provides evidence for a referee home bias. The latter two studies show that the bias increases the closer and more important a match is. Still, better referee training could have caused the referee bias to decrease over time (Nevill et al., 2013). Additionally, the bias has also been found to depend on the existence of a running track and on the guest crowd's size (Dohmen, 2008) which may explain why home advantage decreases in derbies (Pollard, 1986; Ponzo & Scoppa, 2018; Seckin & Pollard, 2008).

Our focus is on the crowd's role, as there is inconclusive evidence on its importance. The ambiguity in previous studies' findings may result from different ways of proxying home support (e.g., occupancy rate or absolute attendance) or various degrees of control for covariates (Goumas, 2014; Nevill & Holder, 1999; van den Ven, 2011). In addition, several functional forms have been tested. For example, the home advantage has been found to only increase with crowd size up to 20,000 visitors in Australian football (Goumas, 2014). Nevill et al. (1996), Peeters and van Ours (2021), Pollard and Gomez (2014b), and van Damme and Baert (2019) also document the relation between crowd size and home advantage. The latter examine individual matches from international club competitions, whereas the former three papers focus on seasonal team-specific home advantage measures. In contrast, Clarke and Norman (1995) and Pollard (1986) argue the home advantage measured in different football divisions does not vary much, even though the crowd size increases steadily from amateur to professional levels. This argument may ignore the mental adaption to different crowd sizes as players' reference points. In particular, a player may form different expectations to the number of spectators he is used to. A deviation from typical visitor numbers then may cause changes in the home advantage as the familiarization with the circumstances vanishes.

Moreover, other issues could also play a role for the home advantage, such as travel fatigue (Clarke & Norman, 1995; Goumas, 2014; Pollard & Gomez, 2014b), altitude differences (van Damme & Baert, 2019), the three-point rule (Pollard, 1986), or TV coverage (Koyama & Reade, 2008). In addition, note that the home

advantage is mediated by the competitive balance of the opposing teams. Various papers try to control for that in measuring ELO values (Reade et al., 2020), table rankings (Ponzo & Scoppa, 2018), or market values (Dilger & Vischer, 2020). Similarly, it has been analyzed whether heterogeneity in teams' rest pauses and hence fitness recovery drives match outcomes. Scoppa (2015) emphasizes that pauses matter more with decreasing athletic preparation but that pauses lost importance over the last decades due to improving fitness. Krumer and Lechner (2017) neither find robust evidence for rest pauses to matter for team success in football competitions but emphasizes the structure of contests (e.g., in World Cups) to be of higher importance for match outcomes.

As every sports competition typically welcomes supporters, there is almost no research on spectator-free events before 2020. Pettersson-Lidbom and Priks (2010) and van den Ven (2011) analyzed 20 Italian ghost games. The latter find referees' behavior to be sensitive to banning spectators. Further, Reade et al. (2020) examine 160 pre-Corona ghost games. They find 10 percentage points fewer home wins and mainly refer this to the referee bias. Colella et al. (2021) discuss Argentinian matches where away spectators were banned and find away teams to perform worse without their fans' moral support.

With respect to Corona ghost games, Ferraresi and Gucciardi (2020) and Scoppa (2021) presents cross-league evidence for a reduced home advantage. Bryson et al. (2021) and Cueva (2020) construct the largest datasets on almost 1,500 and more than 2,000 ghost games revealing about 3–4 percentage points fewer home wins and also changed referee behavior toward a smaller home bias. While these global studies focus on the aggregated effect of ghost games or partly distinguish between divisions on international level (Scoppa, 2021), we are the first to analyze within-country variation in the home advantage across divisions. This enables us to better understand the dynamics and relevance of spectators and their support for teams' performances as the framework mainly remains unchanged. Similar to us, Endrich and Gesche (2020) analyze German matches and also find more yellow cards and fouls for home relative to away teams. Finally, Dilger and Vischer (2020) reconstruct the German findings and additionally argue that player performance remained unchanged, supporting broader findings by Bryson et al. (2021).

This paper's objective is to shed light on the crowd's importance for the home advantage, players' behavioral response toward ghost games as well as division heterogeneity in ghost game effects. While keeping other drivers (e.g., stadia, travel distance) constant, the "natural experiment" of ghost games serves to determine the crowd's relevance. Given that the exclusion of spectators has previously been used out as a severe, not only financial, punishment, we expect the home advantage to decrease with a reduced audience. Further, we expect changes in players' reactions to ghost games with increasing ghost game experience, as this should shift the players' reference points and expectations to visitor numbers. Hence, also their expectations with regard to fans support change. Considering that the three German divisions attract quite some interest in terms of visitors, with the

Bundesliga, for example, having the highest average attendance of a football league worldwide in recent years with more than 40,000 visitors (EPFL, 2018; Statista, 2020), we expect ghost game effects to exceed values from worldwide samples (cf., Bryson et al., 2021). In the run of this paper, we will show that especially pre-Corona occupancy levels, to which players have been used to, matter for the strength of the ghost game effect.

Methods

Sample

We built a dataset including all matches (N = 2,976) from the past three seasons (2017/2018–2019/2020) in the three German men's top divisions ("Bundesliga", "2. Bundesliga", "3. Liga") with the participating teams, results, match dates, and locations. There were a total of 274 ghost games (Bundesliga: 83, 2. Bundesliga: 81, 3. Liga: 110). The dataset further includes match-, stadium-, and team-specific data to avoid any omitted variable bias in later regressions.

Home Advantage Calculation

We follow standard practice (Ponzo & Scoppa, 2018; Scoppa, 2021) and use the likelihood of a home win before and during ghost games as measure of the extent of the home advantage. A second and third measure of interest is the share of away wins and the difference in points earned by home and guest teams which we use to cross-check our results. This allows us to study the effect of all outcomes' likelihood (win, draw, loss). For the point difference, this number is 3 for a home win, 0 for a draw, and −3 for an away win. This distinguishes draws from away wins which is not the case for the first (binary) measure, home win or not. If there are significantly more home than away wins and a point difference between home and away teams which significantly exceeds zero, this is evidence for home advantage. Note that other studies also evaluate home advantage on a more aggregate level than on the individual match level (Pollard et al., 2017; Pollard, 1986, 2006b). Table 1 provides a snapshot on the home advantage before and during ghost games with p values of two-sided t-tests.

As shown, there is hardly any difference in pre-Corona home advantages between leagues, an observation consistent with Pollard (2006a) or Leite and Pollard (2018). During ghost games, only the Bundesliga shows a significant reduction of home advantage. In fact, away teams even outperformed home teams in collecting *more* points than their hosts, something not observed in the two other leagues. It is evident that this effect is driven by an increase in away wins instead of draws. The fact that the home advantage only is reduced in the division with the best trained referees is in contrast to current suggestions (Bryson et al., 2021; Dilger & Vischer, 2020; Endrich & Gesche, 2020; Reade et al., 2020). Overall, the remaining point

Table 1. Two-Sided *t*-Test Analysis of Changed Home Advantage.

	Home win			Away win			ΔPoints		
	Before (%)	During (%)	*p* value	Before (%)	During (%)	*p* value	Before	During	*p* value
Overall	42.56	39.05	.259	30.20	33.21	.314	0.371	0.175	.227
Bundesliga	44.67	32.53	.028**	30.78	44.58	.018**	0.417	−0.361	.011**
2. Bundesliga	41.58	43.21	.779	28.67	24.69	.434	0.387	0.556	.553
3. Liga	41.65	40.91	.881	30.98	30.91	.989	0.320	0.300	.936

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

difference of 0.175 points per ghost game is not statistically different from zero ($p = 0.256$). Hence, Table 1 shows that especially the Bundesliga strongly deviates from the minus three to four percentage points fewer home wins, as in Bryson et al. (2021)'s and Cueva (2020)'s cross-country studies. For further information on the development of the home advantage in all three divisions over time, we also provide Figure 1. There for example can also be identified that the null effects in the second or third division are not driven by outliers.

Obviously, clear conclusions from simple *t*-tests would be premature, as we have not yet controlled for a number of other factors. In theory, the composition of games before and after the Corona-break in spring 2020 could have been very different so that our findings would be artificial.

Covariates

To control for other factors, we use four categories of covariates. Firstly, we use ability covariates to control for heterogeneity in team strength. Among these, there is the difference in the average player's market value between home and away team (ΔPlayer Value), the difference between the table ranking of home and away team (ΔTable), the difference in the teams' rest pause since the last match (ΔPause), and the difference in the points earned in the three preceeding matches (ΔShape). For the latter variable, we also tested to use only the last, the last four, five, or eight matches (as, e.g., in Ponzo & Scoppa, 2018) which however does not qualitatively change our findings. Secondly, we control for geographical factors like travel distance and altitude differences between the teams' stadia. Thirdly, we include dummies for the three first matches of a new home coach

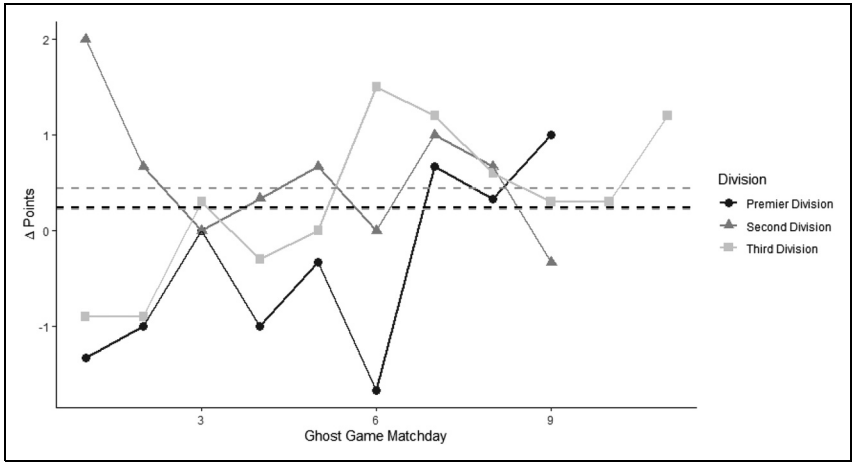

Figure 1. Development of home advantage with increasing ghost game experience.

(New Home Coach), matches with a travel distance below 50 km (Derby), matches on Tuesday to Thursday (Within-Week Match), and matches after 6.00 pm (Night Match). Finally, stadium fixed effects control for the existence of a running track, the share of standing places and the stadium capacity. An overview of sources and descriptive statistics can be found in Tables A1 and A2 of the Appendix.

Statistical Analysis

To control for all factors, we rely on the following before–after approach:

$$Y_{it} = \alpha + \beta(Ghost\ Games)_t + X'_{it}\gamma + \epsilon_{it} \quad (1)$$

where Y_{it} gives team i's performance (dummy for wins or point difference between home and away team) in time t. $(Ghost\ Games)_t$ indicates ghost games as a before–after dummy and X_{it} is a matrix of covariates.

Results

We start by analyzing home advantage changes and their relation to the crowd, before we examine the channel, through which reduced occupancy rates affect match outcomes.

Match Outcome

In the following, we present results from multivariate regressions. We first analyze the robustness of ghost game effects by controlling for covariates unrelated to crowd support. We then examine potential changes in the effect over time before we finally argue that the effect and time-variant fluctuations are best explained with stadium occupancy.

First of all, we augment the naive analysis from Table 1 by controlling for covariates in Table 2. Firstly, all ability controls show the expected effect. An increasing ΔPlayer Value indicates a competitive advantage for home teams, so that a one million Euro increase in the average player's value increases the home win probability by 1.7 percentage points in the overall sample. This effect is mostly robust across all divisions. Marginal effects are higher for lower divisions, as the absolute difference in market values is smaller. Also, ΔTable is significant across all divisions. If ΔTable falls by one (indicating a better positioned home team), the probability of a home win increases by 0.7 percentage points in the overall sample. The largest effect can be observed in the Bundesliga. We also find that the rest time (ΔPause) matters in the third division, where one more rest day increases the win probability by 2 percentage points which is substantial considering that the average rest time difference is 0.89 days in our sample. Finally, ΔShape is found to be a driver for the

Table 2. Regression Analyses with Ability, Geographical, Specific Match, and Stadium Covariates.

	Home win				Away win				ΔPoints			
Δ = Home-Away	(Overall)	(BL)	(2BL)	(3L)	(Overall)	(BL)	(2BL)	(3L)	(Overall)	(BL)	(2BL)	(3L)
Ghost games	−0.039	−0.153**	0.014	0.020	0.026	0.158**	−0.040	−0.014	−0.185	−0.824***	0.173	0.093
	(0.033)	(0.057)	(0.060)	(0.055)	(0.031)	(0.063)	(0.052)	(0.050)	(0.176)	(0.255)	(0.319)	(0.298)
Ability covariates												
ΔPlayer value	0.017***	0.016***	0.069**	0.191	−0.020***	−0.018***	−0.066**	−0.297**	0.094***	0.088***	0.403***	1.380**
	(0.002)	(0.003)	(0.031)	(0.126)	(0.002)	(0.003)	(0.027)	(0.122)	(0.012)	(0.012)	(0.146)	(0.573)
ΔTable	−0.007***	−0.010***	−0.006**	−0.005**	0.006***	0.009**	0.002	0.007***	−0.040***	−0.059***	−0.021	−0.034***
	(0.001)	(0.003)	(0.003)	(0.002)	(0.002)	(0.004)	(0.003)	(0.002)	(0.007)	(0.017)	(0.015)	(0.008)
ΔPause	0.013**	−0.001	0.004	0.020**	−0.00005	0.007	0.009	−0.006	0.036	−0.018	−0.012	0.076*
	(0.006)	(0.017)	(0.011)	(0.009)	(0.006)	(0.016)	(0.010)	(0.008)	(0.031)	(0.060)	(0.052)	(0.045)
ΔShape	0.004	−0.003	−0.008	0.019***	−0.00003	−0.001	0.004	−0.002	0.011	−0.017	−0.045	0.071***
	(0.003)	(0.006)	(0.006)	(0.005)	(0.002)	(0.004)	(0.004)	(0.003)	(0.017)	(0.028)	(0.040)	(0.021)
Geographical factors												
Distance	0.0001	−0.001	0.001	−0.0001	0.0003	0.001*	−0.0005	0.0004	−0.001	−0.004*	0.003	−0.001
	(0.0003)	(0.001)	(0.001)	(0.0004)	(0.0003)	(0.001)	(0.0005)	(0.0004)	(0.001)	(0.002)	(0.003)	(0.002)
Distance^2 $('0000)^{-1}$	−0.001	0.012	−0.010	−0.0004	−0.006	−0.016*	0.006	−0.007	0.016	0.072**	−0.047	0.020
	(0.004)	(0.009)	(0.008)	(0.006)	(0.004)	(0.008)	(0.007)	(0.006)	(0.020)	(0.031)	(0.041)	(0.034)
$\lvert\Delta\text{Altitude}\rvert$ $('00)^{-1}$	0.011	0.005	0.014	0.010	−0.007	−0.002	0.002	−0.016	0.044	0.0002	0.036	0.078
	(0.007)	(0.014)	(0.013)	(0.012)	(0.007)	(0.013)	(0.012)	(0.011)	(0.036)	(0.056)	(0.058)	(0.061)
Specific matches FE												
New home coach	−0.026	0.015	−0.029	−0.054	−0.002	−0.026	0.004	0.014	−0.060	0.124	−0.076	−0.206
	(0.032)	(0.065)	(0.056)	(0.050)	(0.029)	(0.057)	(0.052)	(0.047)	(0.160)	(0.307)	(0.199)	(0.293)

(continued)

Table 2. (continued)

	Home win				Away win				ΔPoints			
Δ = Home-Away	(Overall)	(BL)	(2BL)	(3L)	(Overall)	(BL)	(2BL)	(3L)	(Overall)	(BL)	(2BL)	(3L)
Derby	0.056	0.082	−0.099	0.107	0.033	0.091	0.094	−0.092	0.065	0.012	−0.594	0.601
	(0.063)	(0.105)	(0.118)	(0.109)	(0.060)	(0.106)	(0.118)	(0.087)	(0.326)	(0.467)	(0.546)	(0.551)
Within-week match	−0.019	−0.007	0.052	−0.084	0.029	0.009	−0.029	0.085	−0.133	−0.038	0.246	−0.510
	(0.037)	(0.073)	(0.071)	(0.058)	(0.036)	(0.069)	(0.060)	(0.060)	(0.200)	(0.321)	(0.461)	(0.335)
Night match	−0.002	0.015	−0.014	−0.004	−0.014	−0.047	0.029	−0.032	0.032	0.167	−0.142	0.091
	(0.023)	(0.039)	(0.039)	(0.042)	(0.021)	(0.035)	(0.035)	(0.039)	(0.110)	(0.142)	(0.141)	(0.304)
Home stadium FE												
Track	−0.058*	−0.109	−0.070	−0.037	0.009	−0.002	0.025	0.001	−0.190	−0.280	−0.287**	−0.109
	(0.030)	(0.070)	(0.056)	(0.044)	(0.028)	(0.065)	(0.053)	(0.041)	(0.162)	(0.186)	(0.138)	(0.277)
Share standing places	0.171***	0.156	0.223*	0.158**	−0.096*	−0.009	−0.396***	0.012	0.767***	0.408	1.762***	0.428
	(0.055)	(0.140)	(0.122)	(0.074)	(0.050)	(0.132)	(0.115)	(0.066)	(0.238)	(0.527)	(0.531)	(0.362)
ln(Capacity)	0.053***	0.062	0.034	0.037	−0.033*	0.009	−0.081*	−0.038	0.218***	0.076	0.321	0.225
	(0.020)	(0.054)	(0.052)	(0.036)	(0.019)	(0.053)	(0.047)	(0.033)	(0.084)	(0.211)	(0.282)	(0.215)
Observations	2,976	918	918	1,140	2,976	918	918	1,140	2,976	918	918	1,140
(McFadden) R^2	0.042	0.098	0.022	0.038	0.048	0.129	0.027	0.032	0.068	0.165	0.036	0.052

Note. Ordinary least squares regressions with clustered and heteroskedasticity-robust standard errors. Clusters on home team level.
All coefficients represent estimators of the respective regressions. Marginal effects of probit regressions at the variables' means.
* $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$.

home advantage, but again only in the third division. If the home team has earned one point more than the guests over the preceeding three matches, the probability of a home win increases by 1.8 percentage points.

Secondly, geographical factors like travel distance or altitude (travel fatigue) do not have a significant impact on match outcomes, contradicting Oberhofer et al. (2010)'s Bundesliga findings a decade ago.

Thirdly, considering specific match characteristics, we do not find evidence for (short-run) positive effects of new home coaches, which is consistent with former literature findings (for an overview see, e.g., Table 2b in van Ours & van Tuijl, 2016). We neither find evidence for derby effects which is not in line with previous derby literature (Ponzo & Scoppa, 2018; Seckin & Pollard, 2008). Still, those papers mainly refer to same-stadium or same-city derbies whereas this paper's approach relaxes this definition in dealing with a maximum distance. To argue that 50 km is a suitable measure, a simple *t*-test shows that such matches show higher attendance than the remaining matches in pre-Corona times ($\Delta\text{Visitors} \approx 8{,}236$, $p < 0.001$). Moreover, within-week and night matches do not significantly lower the home advantage which contrasts Goller and Krumer (2020), Krumer and Lechner (2018), and Krumer (2020). While these variables could have had an influence on match outcomes, we do not expect them to have influence on the ghost game effect as these variables are not related to the crowd.

Finally, we find stadium fixed effects to significantly drive match outcomes. As proposed in Dohmen (2008), the existence of a track reduces the probability of home wins by almost 6 percentage points on the 10% significance level in the overall sample. Furthermore, capacity and share of standing places both increase home advantage as they affect atmosphere and sound level which may also impact referee and player behavior. Intuitively, we find reverse signs for the most important variables in the away win regressions (e.g., see ability covariates or stadium FE). The Bundesliga's reduction in home wins is almost perfectly balanced out by additional away wins.

Overall, we see that ghost game effects are rather insensitive to including covariates, as the Bundesliga's effect on home wins even increased from 12.3 (Table 1) to 15.3 percentage points.

Let us now double-check the effect's existence and sensitivity in Table 3 where we follow the regression approach by, for example, Ponzo and Scoppa (2018), van Damme and Baert (2019), and Scoppa (2021) who use every match as two observations, one from each team's perspective, and implement a home team dummy indicating the home advantage. We interact this dummy with $(\textit{Ghost Games})_t$. Results confirm findings from above.

We also see that all three leagues show a home advantage of similar extent before the Corona break with approximately 12–14 percentage points more home than away wins. There is no Corona-induced effect on home wins in the second and third divisions, whereas the Bundesliga's original home advantage vanishes completely, so that the points gathered by home teams during ghost games are comparable with

Table 3. Control Regression Analyses with Home Dummy.

	Win				Points			
	(Overall)	(BL)	(2BL)	(3L)	(Overall)	(BL)	(2BL)	(3L)
Home	0.130***	0.142***	0.131***	0.119***	0.375***	0.387***	0.389***	0.350***
	(0.013)	(0.024)	(0.023)	(0.021)	(0.044)	(0.064)	(0.097)	(0.079)
Home×(Ghost games)	−0.038	−0.131**	0.017	−0.007	−0.100	−0.370**	0.075	−0.011
	(0.030)	(0.050)	(0.055)	(0.048)	(0.088)	(0.155)	(0.163)	(0.134)
Ability covariates	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	5,952	1,836	1,836	2,280	5,952	1,836	1,836	2,280
(McFadden) R^2	0.051	0.112	0.025	0.034	0.077	0.165	0.040	0.054

Note. Ordinary least squares regressions with clustered and heteroskedasticity-robust standard errors. Clusters on home team level.
All coefficients represent estimators of the respective regressions. Marginal effects of probit regressions at the variables' means.
* $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$.

those by away teams in pre-Corona matches. While we have quantified ghost game effects, it remains an open question now whether home players heterogeneously adjust to the unknown situation with regard to their former experiences of full stadia. In other words, it may matter whether players have typically played in front of very few or many spectators in their home matches. Although it is obvious that the change in home advantage is related to reduced attendance, it is unclear which measure of attendance most suitably captures this effect. We propose that the main driver is not the absolute spectator number, but rather stadium occupancy. We suggest that it may matter more how well-filled a stadium is than how many visitors there are in absolute terms. Consider, for example, a half-filled Berlin Olympic Stadium with 37,300 visitors in contrast to a 90%-occupied stadium in Bremen that counts roughly the same visitors (37,800) or even to a sold out stadium in Hamburg St. Pauli with only 29,000 visitors. Although the absolute numbers are equivalent or even higher in Berlin, the atmosphere usually will be less intense. In Table 4, we interact the ghost game effect with each home team's mean occupancy rate in the pre-Corona phase of the 2019/2020 season and also test whether the change in the effect size over time is explained by the usual occupancy level. If the interaction of $(Ghost\ Games)_t$ with the occupancy and this term's interaction with a running matchday index is significant, this would be evidence for the occupancy rate being the decisive measure explaining the decrease in the Bundesliga's home advantage. This time, we do not provide estimates for away win effects as occupancy is home-team specific.

And that is exactly what we find. We identify that ghost games themselves have no additional explanatory power for match outcomes beyond the reduction in occupancy. This observation suggests that the overall ghost game effect is at least in that sense club-specific, as especially clubs with high occupancy rates seem to suffer. It can also be seen that Bundesliga clubs experience a reduced home advantage (measured in ΔPoints) due to ghost games on their first matchday when the occupancy rate throughout the pre-Corona season was above 67% . On the season's last matchday (ninth ghost game), this margin arrived at literally 103% occupancy, implying that the ghost game effect vanished for all teams (familiarization effect significant on the 5% level for effect on home wins and on the 10% level for ΔPoints). Hence, we find that heterogeneity in the reduction in the ghost game effect due to differences in pre-Corona occupancy vanishes over time. Hence, there is a shrinking importance of the pre-Corona occupancy for the ghost game effect. Players appear to adapt.

Also note that the interaction of the average absolute spectator numbers' logarithm during pre-Corona 2019/2020 home matches and $(Ghost\ Games)_t$ is robustly not significant, which supports our suggestions that it is not the absolute attendance that drives ghost game effects, but rather the occupancy rate.

We also conducted several robustness checks where we cross-checked results with effects on goals, applied a regression discontinuity design, ran interaction term analyses, and checked for a generally lower home advantage to the end of seasons.

Table 4. Regression Analyses on the Role of Occupancy.

	Home win				ΔPoints			
	(Overall)	(BL)	(2BL)	(3L)	(Overall)	(BL)	(2BL)	(3L)
Ghost games	0.382	0.301	0.558	−0.099	0.799	3.440	−0.763	−3.011
	(0.394)	(1.495)	(0.439)	(0.811)	(2.787)	(7.669)	(4.946)	(4.542)
(Ghost games)×Occupancy	−0.086	−1.479**	0.336	0.026	−1.020	−5.112*	2.359	−2.032
	(0.226)	(0.707)	(0.474)	(0.376)	(1.194)	(2.883)	(2.638)	(1.829)
(Ghost games)×Occupancy×(# Matchday)	0.032**	0.062**	−0.014	0.042	0.121*	0.194*	−0.186*	0.281**
	(0.015)	(0.025)	(0.029)	(0.030)	(0.068)	(0.110)	(0.099)	(0.141)
(Ghost games)×ln(Average attendance)	−0.051	0.057	−0.089	−0.002	−0.073	−0.038	−0.012	0.367
	(0.062)	(0.155)	(0.115)	(0.030)	(0.348)	(0.660)	(0.643)	(0.546)
Ability covariates	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Geographical factors	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Specific matches FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Stadium FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	2,976	918	918	1,140	2,976	918	918	1,140
(McFadden) R^2	0.044	0.106	0.023	0.040	0.069	0.171	0.039	0.056

Note. Ordinary least squares regressions with clustered and heteroskedasticity-robust standard errors. Clusters on home team level.
All coefficients represent estimators of the respective regressions. Marginal effects of probit regressions at the variables' means.
* $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$.

Throughout, our results remain robust. Note that (in line with Figure 1), the empirical analysis also indicates a recovery of the home advantage in the Bundesliga until the end of the season (statistically tested by interacting $(Ghost\ Games)_t$ with a matchday trend). Hence, this may be interpreted as a refamiliarization of players with there stadiums under new circumstances. For further details on these robustness checks, see Fischer and Haucap (2020).

Within-Match Data

By now, we found pre-Corona occupancy to explain the Bundesliga's changed home advantage. Still, it is yet unanswered via which channels occupancy affects matches. Concerning ghost games, the reduced referee bias has been frequently named as relevant channel of crowd support (Bryson et al., 2021; Dilger & Vischer, 2020; Endrich & Gesche, 2020; Pettersson-Lidbom & Priks, 2010; Reade et al., 2020). We check this hypothesis and also assess changes in tactics and player performance as effect channels by analyzing within-match data on the first two divisions.

Referee Behavior

Table 5 provides results on some of in former literature used variables to measure referee decisions: yellow cards and fouls. We restrain from including red cards in the detailed analysis as they typically are rarely and randomly observed, so that our regressions would suffer explanatory power. Still, we observe that home teams receive (insignificantly) fewer red cards than before ghost games which supports later findings of an limitedly relevant referee bias. If the referee bias drives the reduced home advantage in the Bundesliga, we should expect more home team yellow cards and fouls relative to the away team during ghost games. Indeed, we observe that there is an increase of about 0.6 yellow cards and 1.1 fouls, which is consistent with findings of Dilger and Vischer (2020) and Endrich and Gesche (2020).

At first glance, this seems like a reduced referee home bias. But a deeper investigation calls this into question. Firstly, the results are similar in both divisions, 0.6 yellow cards and 1.1 fouls. As we know that there was no decline in the second division's home advantage, this points towards a reduced relevance of referee biases. Secondly, we find relatively small effects. When assuming that the found ghost game effect originates from the referee's changed behavior, it is unlikely that the pre-Corona home advantage completely vanishes, just due to one foul or half a yellow card. Pettersson-Lidbom and Priks (2010) find even about twice as strong effects on yellow cards and a foul difference of 4–4.5 in Italian ghost games. Also, Bryson et al. (2021) find the yellow card difference to increase by 0.3 cards resulting in a home advantage decrease of only three percentage points. Thirdly, when interacting $(Ghost\ Games)_t$ with the ghost game matchday, we cannot identify any time trend in yellow cards or fouls in the Bundesliga. Hence, the referee bias neither explains the home advantage return over time, which an adaption to occupancy may do. From this, we derive that the referee bias seems

Table 5. Referee-Related Within-Match Data.

	Yellow cards home		Yellow cards away		Fouls home		Fouls away	
	(BL)	(2BL)	(BL)	(2BL)	(BL)	(2BL)	(BL)	(2BL)
Ghost games	0.564***	0.361**	−0.051	−0.277*	1.100**	0.354	−0.293	−1.148**
	(0.152)	(0.151)	(0.153)	(0.155)	(0.454)	(0.448)	(0.475)	(0.491)
Ability covariates	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Geographical factors	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Specific matches FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Stadium FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	918	918	918	918	918	918	918	918
R^2	0.073	0.061	0.023	0.020	0.074	0.047	0.056	0.019

Note. Ordinary least squares regressions with clustered and heteroskedasticity-robust standard errors. Clusters on home team level.
All coefficients represent estimators of the respective regressions.
* $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$.

to be a potential but nevertheless limitedly relevant ghost game effect driver. This also makes sense when considering the video assistant referee introduction in 2017/2018 causing improved referee decisions (e.g., Lago-Penas et al., 2019) with a potential reduction of referee's pre-Corona home bias.

Moreover, it is unclear whether effects in yellow cards and fouls really originate from adapted referee behavior or altered tactics. Obviously, also the new rule of five instead of three substitutions could have affected cards or player performance. Adapted tactics could result from a more offensive away team putting more pressure on the home team's defense causing for example more fouls.

Player Within-Match Behavior

Following this remark, we test this claim of changing teams' within-match performance by looking at shots and corners (Table 6).

There is no evidence for away teams attacking more often. We only observe a reduction in the number of home shots. Again, this is similar in the 2. Bundesliga. In addition, when looking at shots on target, $(Ghost\ Games)_t$ is not significant at all for home and away teams and the home team still shoots on target more often than guests. Corners are also insensitive to ghost games, not coincinding with Scoppa (2021). Those results indicate no drastic change in tactics which is consistent with recent findings by Dilger and Vischer (2020). Note that we do not reject the referee bias and tactics as drivers of the effects. Still, the results above suggest that there have to be other factors, too, as also shown in Colella et al. (2021) where team performances deteriorate although no changing referee behavior is evident. When considering the home advantage return over time (with regard to occupancy as in Table 4), it seems as if psychological patterns and the adaption to empty stadia are more important.

Discussions

The finding that the reduction in the home advantage is driven by reduced occupancy rates, which is consistent with Goumas (2014), leaves room for discussions on its reasons and implications. For example, one may argue that the two lower divisions are less sensitive to occupancy as players have already been used to matches with small crowds before. In the third division, there are, for example, also junior teams of major clubs. Typically, only a few hundred people attend some of those teams' matches (e.g., 2017/2018: Werder Bremen II against VfR Aalen, 201 visitors).

Further, the loss of home advantage without supporters may raise fairness issues. For example, Bremen had to play six of its home matches as ghost matches while clubs like Wolfsburg and Leverkusen only had four. This could have affected the season's final outcome to a small, but relevant extent, considering that Bremen was stuck in the relegation battle throughout the whole season with 97% pre-Corona occupancy and potentially severe monetary implications, as the distribution of income from media rights depends on the final table position.

Table 6. Within-Match Performance.

	Shots home		Shots away		Corners home		Corners away	
	(BL)	(2BL)	(BL)	(2BL)	(BL)	(2BL)	(BL)	(2BL)
Ghost games	−1.165**	−1.509**	−0.016	−0.113	−0.075	−0.179	0.034	−0.011
	(0.462)	(0.615)	(0.567)	(0.581)	(0.339)	(0.298)	(0.386)	(0.282)
Ability covariates	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Geographical factors	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Specific matches FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Stadium FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	918	918	918	918	918	918	918	918
R^2	0.232	0.078	0.190	0.057	0.134	0.040	0.121	0.040

Note. Ordinary least squares regressions with clustered and heteroskedasticity-robust standard errors. Clusters on home team level.
All coefficients represent estimators of the respective regressions.
* $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$.

Another important finding is that the home advantage appears to be related to previous experiences or reference points (expectations), a phenomenon often studied in behavioral economics, with regard to occupancy rates. As it seems that absolute attendance does not directly impact home advantage, this would imply that, when controlling for ability measures, and so on, the home advantage does not have to be higher for Bayern Munich in a match with 75,000 visitors in comparison to SC Paderborn with 15,000 as those values represent the respective reference points for both teams. What matters seems to be the deviation from this point. This also sheds light on the phenomenon of lion's dens which are typically highly occupied stadia with intense atmospheres, but not necessarily many spectators.

Moreover, the examination of the ghost game effects over time, its dependence on previously experienced occupancies (reference points), and the interaction effects with ability measures support statements by Courneya and Carron (1992), Pollard and Pollard (2005) and others: Home advantage in sports and especially in football is a multidimensional issue. The phenomenon's complexity is also highlighted by the observation that ghost game effects differ dramatically between divisions, even though the competitive framework differs only marginally.

Furthermore, the effect difference between the divisions remind us that the home advantage varies in multiple dimensions, such as geographically (Anders & Rotthoff, 2014; Pollard & Pollard, 2005) and demographically (Staufenbiel et al., 2018). Hence, our results from German professional football may differ from other leagues or amateur matches.

Additionally, it is interesting to see that a detailed examination of potential drivers of the home advantage still cannot explain the majority of the overall fluctuation in the match outcomes. This maybe is what makes football so special to many people: the occurrence of often surprising and hard to predict outcomes.

Finally, we want to emphasize that our findings are still based on a limited number of matches. It should also be mentioned that the circumstances of the ghost games may play an important role. As the Corona situation was new to all teams, it is likely that some clubs have better managed the Corona break from a fitness and psychological perspective or have profited more from the introduction of five substitutions. We recommend to study those differences between teams and the heterogeneity in the handling of ghost games across countries and leagues. The country-specific use of artifical fan chant or carrying out the matches in a neutral location could be important drivers of different ghost game effects which would be interesting to analyze next. Also studying players' individual handling of the situation and its indirect impact on match outcomes would be interesting to analyze as for example contract uncertainty could have impacted performance.

Finally, our findings give implications for labor market policies. As it, from a behavioral perspective, takes time to adapt to new conditions, this is new insight to the need of acclimatisation at the work place.

Conclusion and Future Research

This paper is one of the first to examine the role of attendance and occupancy rates for professional football, using Corona-induced ghost games. Reduced occupancy is found to be a main driver for a reduced home advantage, while total crowd size is less important. Interestingly, this effect is only observed in the first German division. The lack of ghost game effects on home advantage may possibly be explained by the fact that players from lower divisions are more used to play in half-empty stadia. Besides the reason for the reduced home advantage, we also analyze potential channels via which occupancy affects match outcomes. We only find weak evidence for the relevance of a change in the referee bias or teams' tactics. So, is it then that home players feel less self-confident with lower occupancy rates? Or do players experience a loss in familiarity in silent stadia? Future research may specifically discuss this psychological background. Furthermore, the disaggregate examination of other countries' ghost game experiences should provide interesting insights into the sources and consequences for home advantage, as the detailed implementation of ghost games differed between countries.

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Appendix

Dataset

Table A1. Overview on Dataset and Sources.

Variable	Source	Match-specific variation
Match information		
Match date/# Matchday	Football-data.co.uk/Kicker.de	✓
Home/Away team	Football-data.co.uk/Kicker.de	✓
Match result	Football-data.co.uk/Kicker.de	✓
Within-match data		
Yellow/Red cards	Football-data-co.uk	✓
Fouls	Football-data.co.uk	✓
Shots (on target)	Football-data.co.uk	✓
Corners	Football-data.co.uk	✓
Ability/Fitness measures		
Average player value	Transfermarkt.de	✘
Table standing	Fussball.de	✓
Rest time	Own Calculations	✓
Points last three matches	Own Calculations	✓
Squad size	Transfermarkt.de	✘
Physical/Geographical factors		
Travel distance	Own Calculations	✓
Derby	Own Calculations	✓
Altitude	Own Calculations	✘
Psychological determinants		
Change of coach	Transfermarkt.de	✓
Weekday matches	Own Calculations	✓
Late games ($\geq$ 6pm)	Own Calculations	✓
Crowd and stadium		
Spectators	Kicker.de	✓
Occupancy	Own Calculations	✓
Capacity	Transfermarkt.de	✘
Standing places	Transfermarkt.de	✘
Track	Transfermarkt.de	✘

Table A2. Descriptive Statistics.

Variable	*N*	*Mean*	*St. Dev.*	*Min*	*Pctl*(25)	*Pctl*(50)	*Pctl*(75)	*Max*
Match outcome								
Home win	2,976	0.422	0.494	0	0	0	1	1
Points home	2,976	1.540	1.305	0	0	1	3	3
Points away	2,976	1.187	1.268	0	0	1	3	3
Goals home team	2,976	1.579	1.313	0	1	1	2	8
Goals away team	2,976	1.308	1.206	0	0	1	2	7
Within-match data								
Shots home	1,836	14.327	4.936	2	11	14	17	35
Shots away	1,836	12.141	4.578	1	9	12	15	32
Shots on target home	1,836	4.978	2.482	0	3	5	7	16
Shots on target away	1,836	4.271	2.352	0	3	4	6	14
Fouls home	1,836	12.524	3.932	2	10	12	15	28
Fouls away	1,836	13.122	4.166	2	10	13	16	29
Corners home	1,836	5.407	2.856	0	3	5	7	19
Corners away	1,836	4.566	2.592	0	3	4	6	15
Yellow cards home	1,836	1.788	1.312	0	1	2	3	8
Yellow cards away	1,836	2.092	1.301	0	1	2	3	8
Red cards home	1,836	0.070	0.265	0	0	0	0	2
Red cards away	1,836	0.100	0.314	0	0	0	0	3
Stadium-related information								
Spectators	2,976	20,049	19,304	0	5,333	13,824	29,312	81,365
Occupancy	2,976	0.610	0.331	0	0.4	0.660	0.9	1
Capacity	2,976	29,510	18,634	5,500	15,000	24,000	42,100	81,365
Track	2,976	0.101	0.302	0	0	0	0	1
Share standing places	2,976	0.406	0.217	0	0.224	0.395	0.596	0.899
Altitude	2,976	171.7	155.4	5	55.8	108	294	555

(continued)

Table A2. (continued)

Variable	*N*	*Mean*	*St. Dev.*	*Min*	*Pctl*(25)	*Pctl*(50)	*Pctl*(75)	*Max*
Match-specific information								
Matches ≥ 6.00 pm	2,976	0.323	0.468	0	0	0	1	1
Distance	2,976	302.4	143.5	0	192.6	305.0	401.0	669.7
Within-week match	2,976	0.090	0.287	0	0	0	0	1
New home coach	2,976	0.096	0.294	0	0	0	0	1
Derby	2,976	0.033	0.178	0	0	0	0	1
Table home	2,976	9.723	5.553	1	5	10	14	20
Table away	2,976	9.490	5.559	1	5	9	14	20
Points last three matches home team	2,976	3.874	2.366	0	2	4	6	9
Points last three matches away team	2,976	4.140	2.375	0	3	4	6	9
Ghost games	2,976	0.092	0.289	0	0	0	0	1
Team seasonal fixed effects								
Player value	2,976	2.203	4.189	0.090	0.198	0.490	2.320	26.11
Squad size	992	28.97	2.686	24	27	28	31	37