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Abstract

This paper examines the relation between crowd support and home advantage in professional football in making use of a unique "natural experiment" induced by restrictions due to the Corona pandemic: so-called ghost games in the top three German football divisions during 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 division. 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 best explained by 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. The ghost game effect decreases over time, however, implying that players adapt and get used to the new situation. 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. We rather assess psychological reasons to be of higher importance.

JEL-Codes: Z200, Z210.

Keywords: home advantage, Corona pandemic, professional soccer, stadium occupancy.

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1 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 2006*b*) and between men and women leagues (Pollard & Gomez 2012, Pollard et al. 2017). Although the home advantage is well-known, its variation and drivers are still subject to intense debate (Pollard 2006*a*, 2008, Pollard et al. 2017).

The literature, however, agrees that the home advantage is not driven by a single source, but many factors that also affect each other, e.g. crowd support and location familiarity (Courneya & Carron 1992, Pollard 2006*a*). This paper contributes to this discussion by quantifying the effect of attendance on home performance in professional football. For that, we examine so-called ghost games in the top three German divisions that took place after Germany, following the Corona-induced shut-down, re-started as the first country its professional leagues in May 2020. While the games' atmosphere has been much less lively, these ghost games 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 analyse (i) whether the home advantage was affected by ghost games, (ii) reasons for and impact channels of a changing home advantage, (iii) how persistent ghost game effects are over time, and (iv) whether absolute attendance or occupancy better explains the home advantage.

Generally, there are few phenomena that attract attention from as many scientific disciplines as 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 focussed 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). Interestingly enough, there is no consensus on origins and sources of home advantage. Among frequently named reasons are (i) territoriality/psychological reasons, (ii) location familiarity, (iii) referee bias, (iv) crowd support, and (v) 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 (Neave & Wolfson 2003, Carre et al. 2006), 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 why home teams perform worse following constructions of new stadia (Pollard 2002). Clarke & Norman (1995) object by showing that promoted teams do not reveal higher home advantages.

The referee bias is one channel via which crowd support may affect home advantage, as crowds may influence referee partiality. Besides 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 home advantage to decrease over time (Nevill et al. 2013). Additionally, this bias also depends on the existence of a running track and on the guest crowd's size (Dohmen 2008) which could explain why home advantage falls 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 only increases with crowd size up to 20,000 visitors in Australian football (Goumas 2014). Peeters & van Ours (2020), Pollard & Gomez (2014), Nevill et al. (1996), and van Damme & 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 & 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 neglect the mental adaption to different crowd sizes as players' reference points.

Moreover, also other issues could play a role for the home advantage, such as travel fatigue (Clarke & Norman 1995, Goumas 2014, Pollard & Gomez 2014), altitude differences (van Damme & Baert 2019), the three-point-rule (Pollard 1986), or TV coverage (Koyama & Reade 2008). Additionally note, that the home advantage also always is mediated by the competitive balance of the opposing teams. Literature tries to control for that in measuring ELO values (Reade et al. 2020), table rankings (Ponzo & Scoppa 2018) or market values (Dilger & Vischer 2020). Similarly, literature 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. The latter finding supports Krumer & Lechner (2017).

As typically every sports competition welcomes supporters, there is almost no research on spectator-free events before 2020. van den Ven (2011) and Pettersson-Lidbom & Priks (2010) analyzed twenty 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 less home wins and mainly refer this to the referee bias.

When having a look at studies on Corona ghost games, Scoppa (2020) presents cross-league evidence for a reduced home advantage. Bryson et al. (2020) construct the largest dataset on almost 1,500 ghost games revealing about three percentage points less home wins and also less away team yellow cards. Endrich & Gesche (2020) analyse German matches and also find more yellow cards and fouls for home relative to away teams. Finally, Dilger & Vischer (2020) agree to the German findings and additionally argue that player performance remained unchanged - supporting broader findings by Bryson et al. (2020).

This paper's objective is to shed light on the crowd's importance for the home advantage, players' behavioral response towards 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 quantify the crowd's relevance. Given that the exclusion of spectators has sometimes been handed 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. Considering that the three German divisions attract quite some interest in terms of visitors - with e.g. the Bundesliga having the highest average attendance of a football league worlwide 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. (2020)).

2 Methods

How to test the above stated hypotheses will be explained subsequently.

Data: We built a dataset including all matches (N = 2,976) from the past three seasons (2017/18-2019/20) in the three German 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-specific, 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 2020) and use home wins before and during ghost games as measure of the home advantage. A second figure of interest is the difference in points earned by home and guest team in a match which we use to cross-check our results. This is 3 for a home win, 0 for a draw, and -3 for an away win. This differentiates draws from away wins which is not the case for the first measure, purely home win or not. If there are significantly more home than away

wins and a point difference between home and away team 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, 2006*b*). Table 1 provides a snapshot on the home advantage before and during ghost games with p-values of two-sided t-tests.

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

	Home Win			Δ Points		
	Before	During	p-value	Before	During	p-value
Overall	42.56%	39.05%	0.259	0.371	0.175	0.227
Bundesliga	44.67%	32.53%	0.028**	0.417	-0.361	0.011**
2. Bundesliga	41.58%	43.21%	0.779	0.387	0.556	0.553
3. Liga	41.65%	40.91%	0.881	0.320	0.300	0.936

As shown, there is hardly any difference in pre-Corona home advantage between leagues, an observation consistent with Pollard (2006*a*) or Leite & 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. The fact, that the home advantage only is reduced in the division with the best trained referees, contradicts current suggestions (Bryson et al. 2020, Dilger & Vischer 2020, Endrich & Gesche 2020, Reade et al. 2020). Overall, the remaining point 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 minus three percentage points less home wins as in Bryson et al. (2020)'s cross-country study.

Obviously, such a conclusion 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 could have been very different so that our findings would be artificial.

Covariates: To avoid this, we use four categories of covariates. Firstly, we use ability covariates to control for heterogeniety in team strength. Among these, there is the difference in the average player's market value between home and away team (Δ Player Value), the difference between the table ranking of home and away team (Δ Table), the difference in the teams' rest pause since the last match (Δ Pause), and the difference in the points earned in the three preceeding matches (Δ Shape). 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 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 (New 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 in the Appendix.

Statistical Analysis: To control for all factors, we rely on the following before-after-approach:

$$Y_{it} = \alpha + \beta Corona_t + \gamma' X + \epsilon_{it} \tag{1}$$

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

3 Results

We start by analyzing home advantage changes and their relation to the crowd. We then determine channels via which a reduced occupancy finally affects match outcomes.

3.1 Match Outcome

Subsequently, 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. Increasing Δ Player 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, Δ Table is significant across all divisions. If Δ Table 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 Bundesliga reveals the largest effect. We also find that the rest time (Δ Pause) matters in the third division, where one more rest day increases the win probability by two percentage points which is substantial considering that the average rest time difference is 0.89 days in our sample. Finally, Δ Shape is found to be a driver for the 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 determinants 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.

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

	Home Win				Δ Points			
	(Overall)	(BL)	(2BL)	(3L)	(Overall)	(BL)	(2BL)	(3L)
Corona	−0.039	−0.153**	0.014	0.020	−0.185	−0.824***	0.173	0.093
	(0.033)	(0.057)	(0.060)	(0.055)	(0.176)	(0.255)	(0.319)	(0.298)
Ability Covariates								
Δ Player Value	0.017***	0.016***	0.069**	0.191	0.094***	0.088***	0.403***	1.380**
	(0.002)	(0.003)	(0.031)	(0.126)	(0.012)	(0.012)	(0.146)	(0.573)
Δ Table	−0.007***	−0.010***	−0.006**	−0.005**	−0.040***	−0.059***	−0.021	−0.034***
	(0.001)	(0.003)	(0.003)	(0.002)	(0.007)	(0.017)	(0.015)	(0.008)
Δ Pause	0.013**	−0.001	0.004	0.020**	0.036	−0.018	−0.012	0.076*
	(0.006)	(0.017)	(0.011)	(0.009)	(0.031)	(0.060)	(0.052)	(0.045)
Δ Shape	0.004	−0.003	−0.008	0.019***	0.011	−0.017	−0.045	0.071***
	(0.003)	(0.006)	(0.006)	(0.005)	(0.017)	(0.028)	(0.040)	(0.021)
Geographical Factors								
Distance	0.0001	−0.001	0.001	−0.0001	−0.001	−0.004*	0.003	−0.001
	(0.0003)	(0.001)	(0.001)	(0.0004)	(0.001)	(0.002)	(0.003)	(0.002)
Distance^2 ('0000)$^{-1}$	−0.001	0.012	−0.010	−0.0004	0.016	0.072**	−0.047	0.020
	(0.004)	(0.009)	(0.008)	(0.006)	(0.020)	(0.031)	(0.041)	(0.034)
|Δ Altitude| ('00)$^{-1}$	0.011	0.005	0.014	0.010	0.044	0.0002	0.036	0.078
	(0.007)	(0.014)	(0.013)	(0.012)	(0.036)	(0.056)	(0.058)	(0.061)
Specific Matches FE								
New Coach	−0.026	0.015	−0.029	−0.054	−0.060	0.124	−0.076	−0.206
	(0.032)	(0.065)	(0.056)	(0.050)	(0.160)	(0.307)	(0.199)	(0.293)
Derby	0.056	0.082	−0.099	0.107	0.065	0.012	−0.594	0.601
	(0.063)	(0.105)	(0.118)	(0.109)	(0.326)	(0.467)	(0.546)	(0.551)
Within-Week Match	−0.019	−0.007	0.052	−0.084	−0.133	−0.038	0.246	−0.510
	(0.037)	(0.073)	(0.071)	(0.058)	(0.200)	(0.321)	(0.461)	(0.335)
Night Match	−0.002	0.015	−0.014	−0.004	0.032	0.167	−0.142	0.091
	(0.023)	(0.039)	(0.039)	(0.042)	(0.110)	(0.142)	(0.141)	(0.304)
Stadium FE								
Track	−0.058*	−0.109	−0.070	−0.037	−0.190	−0.280	−0.287**	−0.109
	(0.030)	(0.070)	(0.056)	(0.044)	(0.162)	(0.186)	(0.138)	(0.277)
Share Standing Places	0.171***	0.156	0.223*	0.158**	0.767***	0.408	1.762***	0.428
	(0.055)	(0.140)	(0.122)	(0.074)	(0.238)	(0.527)	(0.531)	(0.362)
ln(Capacity)	0.053***	0.062	0.034	0.037	0.218***	0.076	0.321	0.225
	(0.020)	(0.054)	(0.052)	(0.036)	(0.084)	(0.211)	(0.282)	(0.215)
Observations	2,976	918	918	1,140	2,976	918	918	1,140
(McFadden) R^2	0.042	0.098	0.022	0.038	0.068	0.165	0.036	0.052

Note: *p<0.1; **p<0.05; ***p<0.01. OLS 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.

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 (Seckin & Pollard 2008, Ponzo & Scoppa 2018). Still, it has to be mentioned that 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 (Δ Visitors $\approx$ 8,236, $p < 0.001$). Moreover, within-week and night matches do not significantly lower the home advantage which contrasts Goller & Krumer (2020), Krumer & 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) concerning the referee bias, the existence of a track reduces the probability of home wins by almost six percentage points 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 behaviour.

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 (see Table 1) to 15.3 percentage points.

Let us now double-check the effect's existence and insensitivity in Table 3 where we follow the regression approach by van Damme & Baert (2019) and Ponzo & Scoppa (2018) 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 $Corona_t$. Results confirm findings from above.

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×Corona	−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: *p<0.1; **p<0.05; ***p<0.01. OLS 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.

We also see that all divisions 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 division whereas the Bundesliga's original home advantage vanishes completely, so that the points gathered by home teams during ghost games are comparable to those by away teams in

pre-Corona matches.

While we have quantified ghost game effects, it remains an open question now whether home players adjust to the unknown situation by adapting their reference point. If this was the case, the ghost game effect should decrease over time. This hypothesis is tested in Table 4 where we interact $Corona_t$ with a running index for ghost matchdays.

Table 4: Development of Ghost Game Effect over Time

	Home Win				Δ Points			
	(Overall)	(BL)	(2BL)	(3L)	(Overall)	(BL)	(2BL)	(3L)
Corona	-0.147^{**}	-0.357^{***}	0.075	−0.110	-0.726^{**}	-1.711^{***}	0.924^{**}	-0.887^{*}
	(0.059)	(0.072)	(0.125)	(0.099)	(0.293)	(0.454)	(0.390)	(0.529)
Corona×(# Matchday)	0.021^{**}	0.056^{**}	−0.012	0.022	0.101^{**}	0.182^{*}	-0.150^{**}	0.164^{**}
	(0.010)	(0.023)	(0.021)	(0.015)	(0.045)	(0.097)	(0.071)	(0.066)
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	0.043	0.103	0.023	0.039	0.069	0.169	0.039	0.056

Note: *p<0.1; **p<0.05; ***p<0.01. OLS 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.

Indeed, we find evidence for a familiarization process with empty arenas. Hence, it appears that there has initially been a negative effect on the home advantage during the first ghost games, but that the home advantages has "recovered" over time. Interestingly, the Bundesliga seems to be unique in this pattern as Bryson et al. (2020) do not find similar patterns in cross-country data. We argue that this can be explained with the Bundesliga's very high occupancy in contrast to other leagues, so that players over there have not been affected as drastically. We also tested this adaption hypothesis using a quadratic interaction term which did not show qualitatively different results. Figure 1 underlines our empirical results (Dashed lines represent the pre-Corona average home advantage). For the Bundesliga, the coefficients show that the ghost game effect with regard to the win probability vanishes after matchday 6.4 which fits to the trend in Figure 1. A similar pattern can be observed for the third division while second division games are heavily affected by the first ghost gameday's outlayer. Note that the non-significant ghost game effect for the third division in Table 2 does not precludes an effect during the first post-Corona matchdays.

As ghost game effects change over time, the question arises which variables drive that change. Whereas it is obvious that the change 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

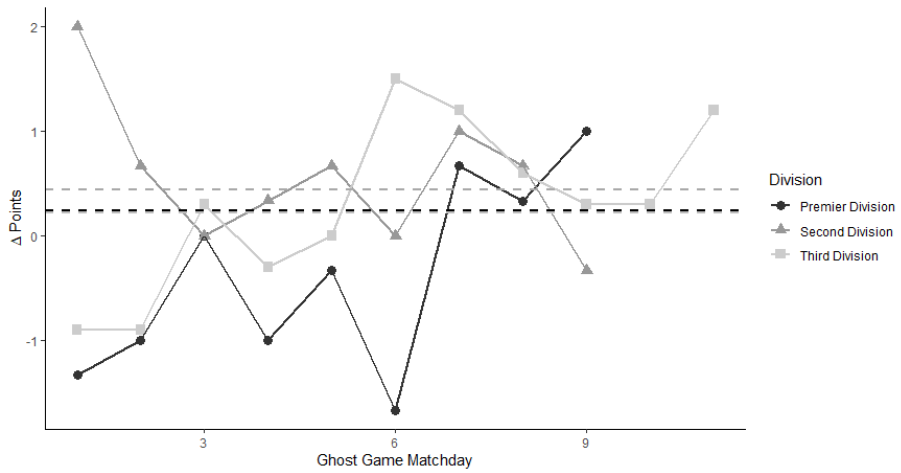

Figure 1: Development of Home Advantage with Increasing Ghost Game Experience

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 5, we interact the ghost game effect with each home team's mean occupancy rate in the pre-Corona phase of the 2019/20 season and also control whether the change in the effect size over time is explained by the usual occupancy level. If the interaction of $Corona_t$ with the occupancy and this term's interaction with the running matchday index is significant, this would be evidence for the occupancy rate being the decisive measure explaining the fall in the Bundesliga's home advantage.

And that is exactly what we find. This observation suggests that the overall Corona 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 suffer from a reduced home advantage (measured in Δ Points) due to ghost games on their first matchday when the occupancy rate throughout the pre-Corona season was above 67 percent. On the season's last matchday (9th ghost game), this margin arrived at literally 103 percent occupancy - implying that the ghost game effect vanished for all teams. This perfectly fits to Table 4 and Figure 1. Hence, the reduction in the ghost game effect over time is driven by the shrinking importance of the pre-Corona occupancy. Players appear to adapt.

Also note that the interaction of the average absolute spectator numbers' logarithm during pre-Corona 2019/20 home matches and $Corona_t$ is robustly insignificant, which supports our claim that the absolute attendance does not drive ghost game effects.

Table 5: Regression Analyses on the Role of Occupancy

	Home Win				Δ Points			
	(Overall)	(BL)	(2BL)	(3L)	(Overall)	(BL)	(2BL)	(3L)
Corona	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)
Corona×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)
Corona×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)
Corona×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: *p<0.1; **p<0.05; ***p<0.01. OLS 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.

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. Throughout, our results remain robustly. For details, see our discussion paper (Fischer & Haucap 2020).

3.2 Within-Match Data

By now, we found pre-Corona occupancy to explain the Bundesliga's changed home advantage. Still, it is unanswered via which channels occupancy steers matches. Concerning ghost games, the reduced referee bias has been frequently named as relevant channel of crowd support (Bryson et al. 2020, 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.

Table 6 provides results on some of in former literature used variables to measure referee decisions: Yellow cards and fouls. We stand back 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) less 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 premier division, we should expect more home team yellow cards and fouls relative to the away team during ghost games.

Table 6: Referee-Related Within-Match Data

	Yellow Cards Home		Yellow Cards Away		Fouls Home		Fouls Away	
	(BL)	(2BL)	(BL)	(2BL)	(BL)	(2BL)	(BL)	(2BL)
Corona	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: *p<0.1; **p<0.05; ***p<0.01. OLS regressions with clustered and heteroskedasticity-robust standard errors. Clusters on heam team level. All coefficients represent estimators of the respective regressions.

Indeed, we observe that. There is an increase of about 0.6 yellow cards and 1.1 fouls - which fits Dilger & Vischer (2020) and Endrich & 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 between the premier and second division - 0.6 yellow cards and 1.1 fouls. As we know that there was not a decline in the second division's home advantage, this hints at a smaller importance of referee biases. Secondly, we find relatively small effects. When assuming that the found ghost game effect originates from the referee, it is unlikely that the pre-Corona home advantage completely vanishes - just due to one foul or half a yellow card. Pettersson-Lidbom & Priks (2010) find even about twice as high effects on yellow cards and a foul difference of 4-4.5 in Italian ghost games. Also, Bryson et al. (2020) 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 $Corona_t$ with the ghost gameday, 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. From this, we derive that the referee bias seems to be a potential but nevertheless limitedly relevant ghost game effect driver. This also makes sense when considering the VAR introduction in 2017/2018 causing improved referee decisions (s. 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 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 e.g. more fouls. We test this claim of changing teams' within-match performance by looking at shots and corners (s. Table 7).

Table 7: Within-Match Performance

	Shots Home		Shots Away		Corners Home		Corners Away	
	(BL)	(2BL)	(BL)	(2BL)	(BL)	(2BL)	(BL)	(2BL)
Corona	-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: *p<0.1; **p<0.05; ***p<0.01. OLS regressions with clustered and heteroskedasticity-robust standard errors. Clusters on heam team level. All coefficients represent estimators of the respective regressions.

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 - so more harmful shots - $Corona_t$ 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 coinciding with Scoppa (2020). Those results indicate no drastic change in tactics which supports recent findings by Dilger & 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. When considering the home advantage return over time, it seems as if psychological patterns and the adaption to empty stadia are more important.

4 Discussions

That the reduction in the home advantage is driven by reduced occupancy rates - which fits 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 those players already have been used to exceptional 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 96.95% pre-Corona occupancy and potentially severe monetary implications, as the distribution of income from media

rights depends on the final table position.

Another important finding is the home advantage's boundedness to previous experiences and by that reference points with regard to occupancy rates. Thus, it seems that absolute attendance does not directly impact home advantage. This would imply that - when controlling for ability measures etc. - 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 reference point 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 reference points and the interaction effects with ability measures support statements by Courneya & Carron (1992), Pollard & 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 - e.g., 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. More empirical evidence is needed here.

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 occurence 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 analyse as e.g. contract uncertainty could have impacted performance.

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

5 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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A Appendix

A.1 Data Set

Table A1: Overview on Data Set 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	✓
Sold Out	Kicker.de	✓
Occupancy	Own Calculations	✓
Capacity	Transfermarkt.de	×
Standing Places	Transfermarkt.de	×
Track	Transfermarkt.de	×
Date of Stadium Inauguration	Wikipedia.de	×
Crowd Index	Own Calculations	✓
Others		
Years in Bundesliga	Kicker.de	×
Years in 2. Bundesliga	Kicker.de	×
Tradition Index	Own Calculations	×

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
Sold Out	2,976	0.157	0.364	0	0	0	0	1
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
Match-Specific Information								
Matches $\geq$ 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
Corona	2,976	0.092	0.289	0	0	0	0	1
Team Seasonal Fixed Effects								
Tradition Index	2,976	42.59	38.88	0	8	28	81	113
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