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# Does Crowd Support Drive the Home Advantage in Professional Soccer? 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 professional soccer. For that purpose, we make use of a unique "natural experiment": so-called ghost games in the three top divisions of German professional soccer during the Corona pandemic. We find that there is a reduced home advantage in the first division, whereas no change can be observed in the second and third division. Our regression analysis indicates that the decrease in the home advantage and the different effects across the three divisions are not sensitive to a variety of performance, location, and team covariates and most suitably explained by the lower occupancy rate in the stadia. Hence, the decrease in the occupancy rates to zero at the ghost games has been less dramatic for teams that have been used to low occupancy rates. Put differently, the more a team has been used to a full stadium, the more severe is the loss of home advantage. The ghost game effect decreases over time, however, implying that players adapt and get used to the new situation. Our analysis also sheds light on potential drivers of home advantage such as stadium tracks, travel distance, derbies and within-week matches.

**Keywords:** Home Advantage, Corona Pandemic, Professional Soccer, Stadium Occupancy

**JEL Codes:** Z20, Z21

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# 1 Introduction

The home advantage is a frequently discussed issue in the sports literature, as the phenomenon is rather persistent in many sports (Courneya & Carron 1992, Jamieson 2010)[1]. Soccer is one of the sports where the largest home advantage has been documented in the literature (Jamieson 2010, Pollard & Pollard 2005) - even though there are differences both across countries (Pollard 2006*b*) and between men and women leagues (Pollard & Gomez 2012). Although the home advantage is widespread and well-known, its drivers and their magnitudes are still subject to intense debate.

The literature largely agrees, however, that the home advantage is not driven by a single source, but due to many factors that also affect each other. Among the factors discussed are, apart from home crowd support, the familiarity with the location, referee bias, physical factors such as the lack of travel necessity for the home team, and also psychological explanations such as the motivation to defend one's home turf. This paper contributes to this discussion by assessing the effect of attendance on the home team's performance in professional soccer. For that purpose, we examine the so-called ghost games in Germany that took place after Germany, following the Corona-induced shut down in March 2020, re-started as the the first country its professional football leagues in May 2020. Thereby, the saying that "football is nothing without fans" can be literally put to a test. While the games' atmosphere has been much less lively, these ghost games provide a rare natural experiment to study and understand the impact of crowd support on soccer team performance. The ghost games in the three top divisions mainly took place between May and July 2020, with the exception of one ghost game already being played in March. We use this unique opportunity to analyse (i) whether the home advantage has been affected by the introduction of ghost games, (ii) potential reasons for a change in the home advantage, (iii) how persistent ghost game effects on home advantage are over time, and (iv) whether absolute or relative crowd size matters more for the home advantage.

The remainder of the paper is now structured as follows: Following a summary of relevant literature in the next section, we present our empirical strategy, the data used, and results in sections 3 and 4, before we discuss our findings and conclude our paper.

# 2 Literature Review

There are probably not many phenomena that attract attention from so many scientific disciplines as the study of home advantage in sports. Whereas psychological and medical perspectives include emotional and

[1] A rare exception is table tennis (Klein-Soetebier et al. 2014). Soccer (Jamieson 2010, Pollard 1986) and handball (Strauss & Bierschwale 2008) are two sports where the effect has been found to be rather substantial. Furthermore, Schwartz & Barsky (1977) state that indoor sports exhibit a more substantial home advantage than outdoor sports although conditions usually vary less inside. Moreover, sports with fewer breaks and pauses (e.g., soccer compared to baseball) tend to have a larger home advantage.

hormone differences between home and away games (Bray et al. 2002, Neave & Wolfson 2003, Terry et al. 1998) or territoriality effects (Neave & Wolfson 2003, Pollard & Pollard 2005), economic research has focussed on changes of the teams' production technology depending on the location of a match (Carmichael & Thomas 2005), the role of expectations for the final match outcomes, and social pressure (Dohmen 2008*b*, Dohmen & Sauermann 2016, Garicano et al. 2005). Interestingly enough, there is no consensus though on the origins and the sources of the home advantage even though the literature has pointed out a number of sources for the home advantage. Typically it is argued that various factors interact in their impact and that they mediate each other (Courneya & Carron 1992, Jamieson 2010, Pollard & Pollard 2005), so that there are multiple channels for the effects. The factors discussed include (i) territoriality/psychological reasons, (ii) familiarity with the location, (iii) referee bias, (iv) crowd support, and (v) other physical reasons. This paper focuses on the role of crowd support, even though we will also briefly discuss other factors.

Territoriality factors refer to the fact that home teams want to defend their home turf in a competition. From a metaphorical viewpoint or from a psychological perspective away teams may be regarded as "invaders", causing home team players to energize additional resistance forces, measured, e.g., through higher testosterone levels in home players (Neave & Wolfson 2003, Carre et al. 2006) and also more stress for those players (Carre et al. 2006). Pollard & Pollard (2005) try to address this issue by showing that differences in home advantage across countries may, to a certain extent, be explained by history. If there has been a civil war in a country in history, rivalries appear to be more severe and the territoriality effect stronger. Apart from that, Terry et al. (1998) and Waters & Lovell (2002) find higher self-esteem and self-efficiacy for home team players. Those emotional differences between teams are not fully exogenously given, but can be partially acquired and taught over time. Staufenbiel et al. (2018) suggest that the awareness of the mechanisms behind the home advantage are less present with younger players.

Location familiarity means that home teams are more used to conditions and physical circumstances which are typical of their home location. This includes better knowledge of weather conditions and local (micro) climate during the match or specific physical issues such as field length or lawn texture. In more detail, this means that the stadium is of high importance for soccer and, indeed, e.g. Pollard (2002) finds that home teams perform worse following the construction of a new stadium, indicating a reduction of the familiarity advantage. However, in the case of teams which have just been promoted and are new to a league no relative disadvantage has been observed for their guest teams even though they should be less familiar with the new team's stadium (Clarke & Norman 1995). The latter result is backed by anecdotal evidence provided by Moore & Brylinski (1995) who document that a university's basketball team which had to play in alternative venues did not perform worse than in their usual home venue.

A referee bias can occur in sports in which purely objective decisions are not always possible (figureskating,

gymnastics, and also soccer in contrast to, e.g., bowling). It is an important channel via which crowd support may affect home advantage, as a (large) crowd's presence may influence how partial a referee is[2]. Nevill et al. (2002) and Unkelbach & Memmert (2010) have shown experimentally that crowd noise biases referees' decisions in favour of the home team. As more noise seems to increase the bias, clubs with a large and loud fan community should tend to have a larger home advantage. Still, Nevill et al. (2002) find that with increasing referee experience, the bias is reduced. Complementary results suggest that better referee training may be a reason for the observed decrease in home advantage over the last decades in soccer (Nevill et al. 2013). Although German referees are professionals, Dohmen (2008*b*) provides evidence for a referee home bias in the German first division, finding that the bias increases the closer a match is, thereby supporting former findings by Garicano et al. (2005)[3]. Additionally, the strength of referee bias also depends on whether a stadium has a running track or not, as it affects the field's distance from the audience. Dohmen (2008*b*) also documents that the number of guest fans affcets the extent of the bias, as more guest fans counterbalance the home fans' noise[4]. A review on the referee bias is available in Dohmen & Sauermann (2016).

Our focus is on the role of the crowd, as there is inconclusive evidence on the importance of supporters. The ambiguity in the results of previous studies may also result from different measures used for proxying home support (e.g., occupancy rate, absolute audience numbers, the relative number of visitors in relation to the season's mean at the team level) and they may also be due to various degrees of control for covariates used in former studies (Goumas 2014*b*, Nevill & Holder 1999, van den Ven 2011). In addition, various functional forms have been tested[5]. For example, the home advantage has only been found to increase with crowd size until up to 20,000 visitors in Australian soccer (Goumas 2014*b*). Peeters & van Ours (2020), Pollard & Gomez (2014), Nevill et al. (1996) and van Damme & Baert (2019) are some examples documenting the relation between crowd size and home advantage. The latter examine individual matches from international club competitions in Europe, whereas the former three papers focus on British and worldwide seasonal team-specific home advantage measures or seasonal averages, respectively. In contrast, Pollard (1986) argues the home advantage measured in different soccer divisions does not vary very much, even though the crowd size increases steadily from amateur to professional levels. This argument may neglect the mental adaption to

[2]The interaction of referee decisions and the crowd is only one interaction of the named factors which sum up to the overall detected home advantage. Another could e.g. be the mediation of psychological effects (e.g. players' self-confidence) by the presence of the crowd.

[3]Garicano et al. (2005) further underline that the referee bias changes the more important the match is for the home team. All in all, they suggest at least 2.5% of all match outcomes in their sample are affected by the referee bias.

[4]This could for example also explain why the home advantage is less distinct in derbies (Pollard 1986, Ponzo & Scoppa 2018, Seckin & Pollard 2008) as a lot of away fans are in the stadium, too. In combination with less travel fatigue for the away team, this exceeds the home advantage-boosting effect that home teams should feel increased rivalry and territoriality against derby opponents (Jamieson 2010).

[5]Non-monotonic influence of the crowd size on the home team's performance is especially subject to the literature on choking which deals with deteriorating home team performances due to increasing mental pressure with a larger home crowd. For a start point s. e.g. Dohmen (2008*a*).

different crowd sizes as players' reference points may be important. Clarke & Norman (1995) do not find a division effect either and, therefore, support Pollard (1986)'s hypothesis. Jamieson (2010) generalizes this observation and argues that there is no difference in home advantage between amateur and professional sports for various types of sports. To examine whether crowd size matters for the home advantage and whether absolute or relative measures of crowd attendance are important for an home advantage in soccer is still an open question.

Finally, a number of various other issues seem to play a role for the home advantage, such as the burden of traveling for away teams (Goumas 2014*b*). The improving comfortability of travel may be one cause for the decreasing trend in home advantage over time. Although, there is mainly evidence for (Clarke & Norman 1995, Goumas 2014*b*, Pollard & Gomez 2014) the travel burden hypothesis, there is also against it (Pollard & Pollard 2005, Pollard 1986). For the German first division, Oberhofer et al. (2010) observed that increasing travel distances for guest teams are associated with a rising home advantage. The effect peaks at a linear travel distance of about 450 km and shows a non-monotonic pattern. In addition vertical distances also seem to matter, as e.g. van Damme & Baert (2019) find altitude differences to be even more important than travel distances.

Moreover, there is also literature on the effect of the introduction of the three-point-rule (Pollard 1986) and the role of TV coverage of soccer matches for the home advantage (Koyama & Reade 2008).

To deepen our understanding of the role of the crowd size in soccer, this paper studies the unique natural experiment provided by the Corona crisis. As typically every sports competition enjoys the presence of supporters - even at the lowest amateur level - there is almost no evidence for an home advantage at spectator-free events, and hence hardly any studies of such competitions. In fact, we have only found a small number of - mainly anecdotal - discussions of matches without audience. The first by Moore & Brylinsky (1993) refers to less than a dozen basketball matches, where the home team apparently even performed better with respect to throw accuracy and points. Similarly, van den Ven (2011) has analyzed twenty Italian soccer matches without spectators (home teams again perform better without fans), but the examination again lacks statistical power due to the low number of observations and missing controls. Pettersson-Lidbom & Priks (2010) use the same Italian natural experiment and find referees' behavior to be sensitive to the exclusion of spectators. Lastly, Reade et al. (2020) offer an overview on 160 ghost games throughout the last two decades across European soccer competitions. They find a decreasing home advantage of on average 10 percentage points and mainly refer this change to a decreasing referee bias.

Given that the requirement to exclude spectators has sometimes been handed out as a form of severe competitive - not only financial - punishment for soccer teams, we also expect that the home advantage in soccer should decrease with a reduced audience. We want to contribute to the discussion on the home advantage

as we analyse a larger number of games without audience and are able to investigate the players' adaption process to ghost games over time.

# 3 Data and Empirical Strategy

To control for a variety of factors which typically affect match outcomes and to further analyse variation between the three German leagues, we have built a data set including all matches from the past three seasons (2017/18-2019/20) across the three top divisions ('Bundesliga', '2. Bundesliga', '3. Liga'). For an overall number of $N$ = 2,976 matches the participating teams, results and match date and location have been recorded. Across all three divisions, there were a total of 274 ghost games (first division: 83, second division: 81, third division: 110)[6]. The data further includes match-specific information such as the most recent performance ("shape") of the competing teams measured by points obtained in the three preceding games. Also, stadium data such as capacity, spectator numbers, and existence of a running track and team-specific data such as a team's total market value and squad size have been collected. The latter is used to ensure that fitness and talent do not bias our findings about any potential home advantage. An overview of variables included in the data set and respective sources as well as descriptive statistics can be found in Tables A1 and A2 in the Appendix.

All three German professional soccer leagues attract quite some interest in terms of visitors. The first German league, the Bundesliga, has been the soccer league with the second highest total attendance numbers in the world for the last ten years, with only the English Premier League drawing more visitors to its games in total. More importantly for our analysis, the Bundesliga has the highest *average* number of visitors in the world, with an average attendance of more than 40,000 per game in recent years. This implies that the effects of ghost games on home advantage may be more substantial in Germany than in other countries that have lower attendance rates[7]. While the German second and third leagues are less popular, even the third division usually has reasonably high attendance levels[8].

Table 1 provides a first snapshot on the home advantage before and after the start of ghost games. We follow standard practice (see, e.g., Ponzo & Scoppa (2018)) and calculate the probability of a home win before and after the Corona-induced lockdown. A second number of interest may be the difference in points earned by

[6]Note that there also has been a small number of other ghost games in Germany (relegation matches, throphy matches). We do not include those in the data as e.g. teams from different division competed against each other. Further, relegation and throphy matches differ from league matches in their end game effect which affects tactics, results and the home advantage (Pollard 1986, Pollard & Pollard 2005). Hence, our results would have been biased otherwise.

[7]However, this could be compensated by a more aggressive and stronger identification of fans with clubs, so that smaller crowds could show effects of similar size in other countries. Further, we suggest that players in other countries could adapt more quickly to the ghost game scenario as they could experience the atmosphere from German ghost matches as Germany re-started its league as the first country. Losses in the home advantage would be less dramatic then.

[8]Average numbers of spectators in the season 2019/2020 before the introduction of ghost games are: Bundesliga (40,895), 2. Bundesliga (20,369) and 3. Liga (8,674).

the home and the guest team.

Table 1: t-Test Analysis of Changed Home Advantage

| | Home Win | | | Δ Points | | |
|---|---|---|---|---|---|---|
| | Before | After | p-value | Before | After | 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 the pre-Corona numbers reveal, there is hardly any difference in home advantage between the three leagues, a finding largely consistent with previous findings for Germany by Pollard (2006*a*) or Leite & Pollard (2018) and which may be due to comparative levels of competitive balance (Koyama & Reade 2008). After the Corona break, only the Bundesliga shows a significant reduction of home advantage. In fact, away teams have even outperformed home teams and collected *more* points than their hosts in Bundesliga ghost games, something not observed in the second and third league. The 2. Bundesliga even shows a slightly higher share of home team wins throughout the ghost game period, but this is statistically not significant. For teams in the 3. Liga there is no significant difference in the home advantage between pre-Corona matches and the latter ghost games either[9]. Overall, the remaining point difference of 0.175 points per match after the Corona break is not statistically different from zero ($p = 0.256$), so that the home advantage has completely vanished during ghost games. As we will see below, this is largely due to Bundesliga teams losing their home advantage, while not much has changed in the lower two leagues.

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 finding of a reduced home bias would be artificial. In fact, the teams' match schedules before and after the break were obviously different. Hence, we have to control for multivariate differences, as factors such as the teams' abilities and fitness measures (length of the rest pauses between matches, squad size), the strength of their opponents and other variables may vary. Fitness values may be important, as the the schedule after the Corona break was much tighter, with approximately two matches per week and, accordingly, shorter recovery periods[10]. Hence, we need to control for these factors in order not to bias our results, as they affcet

[9]The fact, that the home advantage only is reduced in the division where referees are trained best, contradicts Reade et al. (2020) who consider the referee bias to be the main driver of reduced home advantage in ghost games.

[10]An extreme example is Dynamo Dresden, a team from the second division, which had to play eight matches in only 22 days. The team had been quarantined, so that they had to delay matches to the already densely filled June 2020.

match outcomes. For our multivariate analysis, we therefore rely on the following before-after-approach:

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

where $Y_{it}$ measures home team performance (either a dummy variable for home wins, or point differences between home and away team) and fluctuates with time $t$ and home teams $i$. $Corona_t$ indicates the introduction of ghost games as a before-after dummy and $X$ gives a matrix of covariates which are partly constant over time (e.g., stadium fixed effects) or time-variant (e.g., league table positions). In our analysis below, we also interact $Corona_t$ with other variables.

# 4 Results

In this section, we present our results from multivariate regressions on the home advantage. While we later show that the fall in occupancy is the main driver of the reduced home advantage in the first division, we first analyze the robustness of any ghost game effect by controlling for covariates unrelated to measures of crowd support. We then examine potential changes in the effect size over time before we finally argue that the effect and the time-variant fluctuations can be best explained with regards to stadium occupancy.

First of all, we augment the naive analysis provided in Table 1 by controlling for ability differences between home and away teams, geographical factors, match-specific determinants and stadium characteristics. Results are provided in Table 2.

Firstly, ability measures are important determinants for the outcome of a match. Therefore, we include the difference betweeen the average player value of the home and the away team to proxy quality differences. Furthermore, we add the difference in the teams' current position in the league table to control for the teams' performance differences throughout the matches already played in the current season which also affects psychological measures like self-confidence. We also use the difference between the points earned by the home and away team over the past three matches in order to reflect the teams' most recent shape. Additionally, the difference in the teams' rest time is used as a further covariate to control for fitness inequality. All ability controls show the expected impact on match outcome. An increasing difference between the home team's and the away team's average player value indicates a growing competitive advantage for the home team, so a home win becomes more likely[11]. This effect is by and large robust across all three top divisions in Germany. Marginal effects are higher for lower divisions, as the absolute difference in market values between teams

[11] If the home team's average player value exceeds the one of the guest team by one million Euro, this will increase the probability of a home win by approximately 1.7 percentage points in the overall sample.

is smaller[12]. Also, the difference in the table positions is significant across all divisions. A lower number (which indicates that the home team is better positioned) increases the probability to win. This largest effect is found for the first division, as competitive and ability differences are somewhat higher than in the lower two divisions so that the match outcome reacts more strongly to table ranks[13]. We also find that the rest time matters in the third division[14]. This appears rather plausible, as this league's season has 38 matches (in comparison to 34 in the two higher leagues) but teams have simultaneously smaller squad sizes due to financial constraints compared to teams from the two higher divisions[15]. Therefore, rest pauses are of higher importance in the third league. One more rest day in the third division increases the winning probability by two percentage points. Finally, the teams' shape over the last three matches is found to be a driver for the home advantage, but only in the third division. If the home team has earned one point more than the guest team over the last three games, the probability of a home win increases by 1.8 percentage points. The results do not qualitatively differ between the dependent variables used and seem to be robust.

Secondly, we also include geographical determinants in the regressions to control for travel distance and differences in altitude and, hence, the necessity of acclimatisation and potential travel stress. Moreover, we include a dummy variable which captures the first three home matches after the home team has changed coaches so as to ensure that match outcomes are not biased due to new coach effects. Additionally, we distinguish between weekday matches (Tuesday, Wednesday, Thursday) in contrast to more common weekend matches. There has been some evidence that weekday matches exhibit a smaller home advantage in the German first division (Krumer & Lechner 2018). For a similar reason we include a dummy for late matches after 6.00 pm since evening matches have often been less highly occupied in the past. While those factors can affect home advantage and match outcomes in general, we see no reasons to expect a priori that these factors change the effects of ghost games, as these covariates do not directly relate to the crowd as a factor for a team's success. In addition, we use stadium fixed effects (capacity, share of standing places, existence of track) as these can drive stadium atmosphere which affects the home advantage, e.g., through the referee bias channel (Dohmen 2008*b*).

Our regression results provide some interesting insights into the general factors driving home advantage. First, travel fatigue of guest teams does not appear to benefit home teams. This finding is in contrast to

[12]For that, see the standard deviations of the variable $\Delta$ Player Value in the season 2019/2020 in million Euro: 9.84 (1. Bundesliga), 0.65 (2. Bundesliga), 0.19 (3. Liga).

[13]Increasing $\Delta$ Table by 1 reduces the probability of a home win by one percentage point in the premier division.

[14]Scoppa (2015) finds that differences in rest time during world cups and European championships do matter more with decreasing athletic preparation. Hence, the more professional a team is, the less important the role of rest time should be what we find in our results, too. Further, he states that fitness improved throughout the last years, so that rest time matters less in today's soccer which could explain the variables insignificance for the premier and second division.

[15]In the season 2019/2020, the average squad sizes in the three observed divisions have been: 29.83 (first division), 29.06 (second division), 28.20 (third division). A t-test which compares the average squad size between the premier and third league gives that the latter has a significantly smaller squad size ($p = 0.084$).

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. Marginal effects of probit regressions at the variables' means.

Oberhofer et al. (2010) and may possibly be due to more comfortable travel options today, as we analyse recent matches that were played more than a decade later than the observations in Oberhofer et al. (2010). Similarly, altitude does not matter in German soccer which is very plausible, as even the highest located stadium in the data, the stadium of 1. FC Heidenheim, is barely over 550m above sea level[16]. Considering specific match characteristics, we do not find any evidence for any (short-run) positive effect of a new coach,

[16]Nevertheless, all coefficients of |Δ Altitude| are positive implying a change in the altitude - no matter whether up- or downwards - could at least weakly benefit the home team.

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 where we consider matches as derbies if the linear distance between two teams' stadia does not exceed 50 km[17]. Moreover, within-week matches do not significantly lower the home advantage which contrasts Krumer & Lechner (2018)[18]. Evening games do not seem to affect the home advantage either.

Finally, we find that stadium fixed effects are relevant for the extent of the home advantage. The existence of a track reduces home advantage as already claimed in Dohmen (2008*b*) - however not always significantly. Furthermore, capacity and share of standing places both increase the home advantage as they drive the atmosphere and sound level which again could affect matches through channels such as the referee bias. Also, capacity can be assumed to be a proxy for a club's financial potential which correlates with team success measures.

Overall, we see that the ghost game effect is rather insensitive to the inclusion of a variety of additional covariates, as the effect size even increased from 12.3 (see Table 1) to 15.3 percentage points for the probit regressions on the probability of a home win.

Let us now double-check the existence of the ghost game effect and its 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 dummy indicating home teams to identify the home advantage. We interact this dummy with the before-after ghost game dummy.

The results confirm our findings from above with an only slightly smaller ghost game effect in the first division. We also see that all divisions show a home advantage of a similar size before the structural Corona break due to ghost games. There is no significant change in the home advantage following the introduction of ghost games in the second and third division whereas the original home advantage in the first division vanishes completely, so that the number of points gathered by home teams during ghost games is comparable to those collected by away teams in pre-corona matches. When comparing these results with the "naive" analysis from Table 1, we further underline the robustness of the effect and its estimated size relative to the previously present home advantage.

[17]The non-existence of a derby effect 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 derbies or same-city derbies whereas this paper's approach refers to a more flexible definition of derbies in dealing with a maximum distance. To argue that 50 km is a suitable measure, a simple t-test shows that derbies following this definition reveal to have higher visitor numbers than the rest of the observed matches across all divisions in the pre-Corona period ($\Delta$ Visitors $\approx$ 8,236, $p < 0.001$).

[18]Obviously, the changed variation in the databases used by Krumer & Lechner (2018) compared to the dataset used in this paper is the reason for the different findings. In their descriptive statistics, Krumer & Lechner (2018) present that away teams on average earn 0.1 points more in matches on weekdays. In our dataset, premier division home teams earn 0.369 points more than away teams. Still, we want to highlight that a reduced home advantage for within-week games as found by the authors named could originate from on average lower occupancy rates as this is an important driver for the home advantage as will be shown later. The occupancy rate within the week - before ghost games - in the premier division is about six percentage points lower than for weekend matches in our sample ($p = 0.020$).

Table 3: Control Regression Analyses with Home Dummy

| | Home 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. Marginal effects of probit regressions at the variables' means.

Hence, the home advantage appears to almost vanish in the first division, whereas no effect can be found for the two lower leagues when controlling for a variety of non-crowd-related covariates. While we have now identified an overall ghost game effect for the first division on average across all game days after the lockdown, it remains an open question now whether home team players may be able to adjust to the previously unknown situation. When we assume that home players' performance may be related to a certain reference point - giving e.g. the occupancy a player is used to - this adaption process over time is quite plausible. If this was the case, the ghost game effect should decrease over time. This hypothesis is tested in the regressions in Table 4 where we interact the before-after dummy of ghost games with a running index for the number of matchdays after the structural break.

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. Marginal effects of probit regressions at the variables' means.

Indeed, we find some evidence for such 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. We have also tested this hypothesis using a quadratic term of this variable which did not show qualitatively different results. Hence, we argue that the pattern of a reduced home advantage is quite persistent in the first division during the first matchdays, but the home advantage appears to return with more ghost games experience (Figure 1 gives another impression of the development where the dashed lines represent the average home advantage before the Corona break[19][20]). For the first division, the coefficients show that the ghost game effect with regard to the probability of a win vanishes after matchday 6.4 which actually can also be seen in figure 1. A similar pattern can be observed for the third division while second division games are heavily affected by the outlayer of the first ghost gameday after Corona[21].

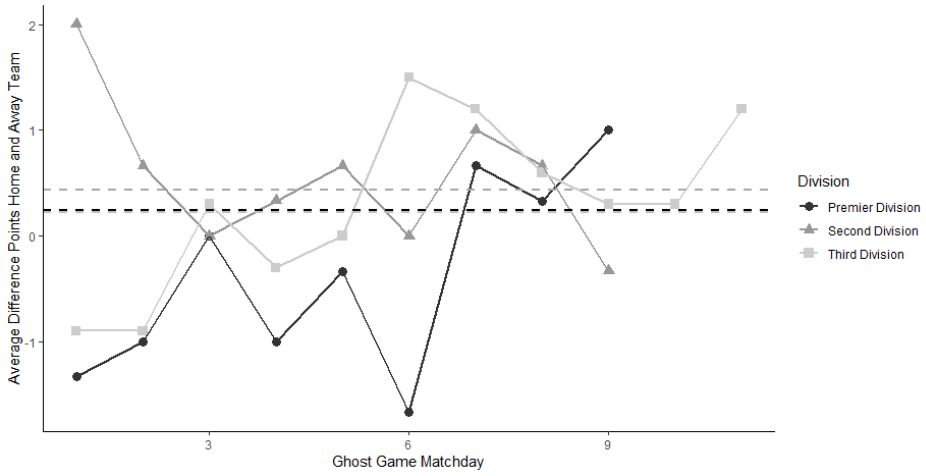


Figure 1: Development of Home Advantage with Increasing Ghost Game Experience

As ghost game effects change over time - possibly related to home players becoming more used to play without fans - the question arises which variables drive that change. Whereas it is obvious that the change in the home advantage is related to reduced visitor numbers, it is not clear which measure of crowd attendance most suitably captures this effect. We propose that the main driver is not the absolute number of visitors, but rather that the stadium's occupancy rate is decisive, implying that occupancy rates may serve as players' reference points. We suggest that it may matter more for a team how well filled a stadium is than how many visitors there are in absolute terms. Consider, for example, the Berlin Olympic Stadium which would count about 37,300 visitors if half-filled in contrast to a stadium in Bremen that counts roughly the same number of visitors (37,800) if 90 percent are filled or even to a sold out stadium in Hamburg St. Pauli with only

[19]Note that in this figure - in contrast to the regressions - it is not controlled forany covariates.
[20]Note as well that all divisions already reached their former average home advantage again during the last matchdays.
[21]This shows that although we did not find a significant ghost game effect for the third division above, this does not mean that there has not been an effect during the first post-Corona matchdays.

29,000 visitors. Although the absolute numbers are equivalent or even higher in Berlin, the atmosphere usually will be less intense there if 50 percent of the seats are empty. We test how effects change over time in Table 5 where we interact the ghost game effect with the mean occupancy rate of each home team in the pre-Corona phase of the 2019/20 season[22] and also control whether the change in the effect size over time can be explained by the usual occupancy level.

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. Marginal effects of probit regressions at the variables' means.

Indeed, it can be observed that the reduction in home advantage in the first division is driven by a lower occupancy rate[23] which supports former findings by Goumas (2014*a*). This observation suggests that the overall Corona effect is at least in that sense club-specific, as especially clubs with otherwise high occupancy rates seem to suffer. It can also be seen that first division clubs suffer from a reduced home advantage (measured in the reduced point difference) due to ghost games on their first matchday when the occupancy rate throughout the pre-Corona season was roughly above 67 percent. On the last matchday of the season (9th ghost game), this margin arrived at literally 103 percent - implying that the ghost game effect vanished for all teams, also those which normally play in a sold out stadium. This perfectly fits to findings from 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 rate. Players appear to adapt to the new situation. Again, the

[22]Note that usually there could be a simultaneity issue between occupancy and the probability of a home win as better match outcomes also attract more fans. Here, that is not the case as the mean occupancy rate before the introduction of ghost games is an exogenously given number which is fixed and not influenced by the performance during ghost games.

[23]The finding that a higher occupancy rate can lead to a higher home advantage is in line with anecdotal evidence on so-called lion's dens which are typically stadia with intense atmospheres, but not necessarily many spectators.

two lower divisions are not sensitive to a change in occupancy. One may argue that those players have been used to exceptions with matches in front of smaller crowds before which makes them less sensitive to ghost games. In the third division, there are, for example, also junior teams of major clubs, as is the case for Bayern Munich's junior team. Typically, only a few hundred people attend some of those teams' matches[24]. Also note that the interaction of the logarithm of the average absolute number of spectators during pre-Corona home matches in the 2019/20 season and the $Corona_t$ dummy is insignificant for all regressions, which suports our claim that ist is not the absolute number of pre-Corona visitors per game that drives the ghost game effect.

We also have conducted several robustness checks in which we cross-checked our results with the effect on goals scored by home and away teams (see Table A3 in the Appendix). In addition, we have also used a regression discontinuity design to ensure that the ghost game effect for the first division really originated with the introduction of ghost games and not at a different point in time (Figure A1 in the Appendix)[25]. We have also run an interaction term analysis to ensure that there are no other relevant drivers of the ghost game effect (e.g., fitness measures proxied by the squad size) besides the change in the occupancy rate (Table A4 in the Appendix). We present all of those results in the Appendix. None of these additional analyses changes the findings reported above.

Finally, we also checked whether there were similar effects with respect to the home advantage over the last matchdays of the season in previous years. That is, we tested whether the home advantage also disappeared over the last nine games in the Bundesliga in previous seasons not affected by the Corona pandemic. Probably not very surprisingly, this was not the case. The home advantage did not decrease in previous seasons towards the end of the season.

# 5 Discussions

The finding that the reduction in the home advantage is driven by reduced occupancy rates leaves room for discussions on the implications for sports. For example, the results suggest that potential success and failure spirals may exist. The better a team performs, the higher the subsequent occupancy rate which again results in an increase in the home advantage. The opposite pattern may result for the negative situation. Only a few papers have discussed this self-fulfilling prophecy and negative expectations as a driver of the home advantage (Bray et al. 2002, Carre et al. 2006, Staufenbiel et al. 2015) resulting in self-confidence differences

[24] E.g. the match between Werder Bremen II and VfR Aalen in the season 2017/2018 only had 201 visitors.

[25] Figure A1 shows that there is a significant shock associated with the introduction of ghost games ($p = 0.082$) in the premier division with regard to the probability of a home win. The effect at the cutpoint equals a reduction of 24.9 percentage points at a bandwidth of four matchdays before and after the introduction. The optimal bandwidth is calculated with the method by Imbens & Kalyanaraman (2012). Non-random selection at the cutpoint is not possible as the order of the matchdays is fixed from the season's beginning.

between competitors and the game tactics applied (Carmichael & Thomas 2005)[26]. To break a negative spiral, clubs could lower ticket prices or possibly even hand out free tickets to fill empty seats and overcome the disadvantage of low occupancy rates.

In addition, the loss of home advantage without supporters may raise fairness issues. For example, Werder 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 possibly relevant extent - considering that Werder Bremen was stuck in the relegation battle throughout the whole season as a team with almost 100% pre-Corona occupancy rate (96.95% before the ghost games started) and potentially severe monetary implications, as the distribution of income from the marketing of media rights depends on the final table position in Germany.

An important finding of this paper is also that the home advantage is bounded to previous experiences and by that reference points. Thus, it seems that the absolute spectator number does not directly impact the 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 e.g. 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.

Moreover, the examination of the ghost game effects over time, its dependence on reference points with regard to occupancy rates and the interaction effects with ability measures support arguments by Courneya & Carron (1992), Pollard & Pollard (2005) and others: Home advantage in sports and especially in soccer is a multidimensional issue with interacting factors. How complex the home advantage phenomenon is, is also highlighted by the observation that ghost game effects differ dramatically between the first division on the one hand and the two lower professional leagues on the other hand, even though the competitive framework differs only marginally between the leagues.

Furthermore, the differences in ghost game effects between the three German 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 soccer may differ from other professional leagues or amateur matches. More empirical evidence is needed for a more complete evaluation.

Additionally, it is interesting to see that a quite detailed examination of potential drivers of the home advantage still cannot explain the majority of the overall fluctuation in the match outcomes. This probably is what most would suggest to be the specific flair of soccer that surprising match outcomes are not rare and

[26] Carmichael & Thomas (2005) argue by analysing within match performance (e.g. tacklings and cards) that away teams mainly play more aggressively and defensively.

match ouctomes are hard to predict and can be surprising.

Finally, we want to emphasize that our findings are still based on a limited number of matches even though the number of 274 matches exceeds previous studies by far. 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 substiutions. We recommend to study those differences between different teams and the heterogeneity in the handling of ghost games across countries and leagues in future studies[27]. The country-specific use of artifical fan chant or carrying out the matches in a neutral location could be other important drivers of different ghost game effects which would be interesting to analyze next.

# 6 Conclusion

This paper is one of the first to examine the role of crowd size and occupancy rates for professional soccer teams in affecting the home advantage, using the involuntary natural experiment of ghost games induced by the Corona pandemic. Reduced occupancy is found to be a main driver for a reduced home advantage, while total crowd size is less important. Interestingly enough, this effect is only observed in the first division in Germany. 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. Of course, our paper only provides one potential source for the change in home advantage - variation in the occupancy rate and future research may analyse the exact impact channels. Is it that home players feel less self-confident with lower occupancy rates? Do players experience a loss in familiarity with the location in silent stadia? Or is a reduction in the referee bias the main reason for the ghost game effect? The latter would be surprising, however, given that referees in the first division are better trained than referees in lower divisions. Future research may specifically discuss within-match data on tactics, strategy and referee performance. Furthermore, the examination of other countries' ghost game experience should provide interesting insights into the sources and consequences for home advantage, as the detailed implementation of ghost games differed between countries.

[27] Also players' individual handling of the situation and their capability to distract themselves from the health problems in the surrounding and potential contract uncertainty are important factors influencing the game outcome which we could not control for.

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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 | ✓ |
| **Ability/Fitness Measures** | | |
| Average Player Value | Transfermarkt.de | × |
| Table Standing | Fussball.de | ✓ |
| Rest Time | Own Calculations | ✓ |
| Points Last Three Matches | Own Calculations | ✓ |
| **Physical/Geographical Factors** | | |
| Travel Distance | Own Calculations | ✓ |
| Derby | Own Calculations | ✓ |
| Altitude | Own Calculations | × |
| Squad Size | Transfermarkt.de | × |
| **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(75) | Max |
|---|---|---|---|---|---|---|---|
| **Match Outcome** | | | | | | | |
| Home Win | 2,976 | 0.422 | 0.494 | 0 | 0 | 1 | 1 |
| Points Home | 2,976 | 1.540 | 1.305 | 0 | 0 | 3 | 3 |
| Points Away | 2,976 | 1.187 | 1.268 | 0 | 0 | 3 | 3 |
| Goals Home Team | 2,976 | 1.579 | 1.313 | 0 | 1 | 2 | 8 |
| Goals Away Team | 2,976 | 1.308 | 1.206 | 0 | 0 | 2 | 7 |
| **Stadium-Related Information** | | | | | | | |
| Spectators | 2,976 | 20,049 | 19,304 | 0 | 5,333 | 29,312 | 81,365 |
| Sold Out | 2,976 | 0.157 | 0.364 | 0 | 0 | 0 | 1 |
| Occupancy | 2,976 | 0.610 | 0.331 | 0 | 0.4 | 0.9 | 1 |
| Capacity | 2,976 | 29,510 | 18,634 | 5,500 | 15,000 | 42,100 | 81,365 |
| Track | 2,976 | 0.101 | 0.302 | 0 | 0 | 0 | 1 |
| Share Standing Places | 2,976 | 0.406 | 0.217 | 0 | 0.224 | 0.596 | 0.899 |
| Altitude | 2,976 | 171.7 | 155.4 | 5 | 55.8 | 294 | 555 |
| **Match-Specific Information** | | | | | | | |
| Matches $\geq$ 6.00 pm | 2,976 | 0.323 | 0.468 | 0 | 0 | 1 | 1 |
| Distance | 2,976 | 302.4 | 143.5 | 0 | 192.6 | 401.0 | 669.7 |
| Within-Week Match | 2,976 | 0.090 | 0.287 | 0 | 0 | 0 | 1 |
| New Home Coach | 2,976 | 0.096 | 0.294 | 0 | 0 | 0 | 1 |
| Derby | 2,976 | 0.033 | 0.178 | 0 | 0 | 0 | 1 |
| Table Home | 2,976 | 9.723 | 5.553 | 1 | 5 | 14 | 20 |
| Table Away | 2,976 | 9.490 | 5.559 | 1 | 5 | 14 | 20 |
| Points Last Three Matches Home Team | 2,976 | 3.874 | 2.366 | 0 | 2 | 6 | 9 |
| Points Last Three Matches Away Team | 2,976 | 4.140 | 2.375 | 0 | 3 | 6 | 9 |
| Corona | 2,976 | 0.092 | 0.289 | 0 | 0 | 0 | 1 |
| **Team Seasonal Fixed Effects** | | | | | | | |
| Tradition Index | 2,976 | 42.59 | 38.88 | 0 | 8 | 81 | 113 |
| Player Value | 2,976 | 2.203 | 4.189 | 0.090 | 0.198 | 2.320 | 26.11 |
| Squad Size | 992 | 28.97 | 2.686 | 24 | 27 | 31 | 37 |

## A.2 Robustness Checks

Table A3: Robustness Checks on Home Advantage Measured in Goal Difference

| | Δ Goals | | | |
|---|---|---|---|---|
| | (Overall) | (BL) | (2BL) | (3L) |
| Corona | −0.076 | −0.579** | 0.130 | 0.191 |
| | (0.139) | (0.241) | (0.242) | (0.204) |
| Ability Covariates | Yes | Yes | Yes | Yes |
| Geographical Factors | Yes | Yes | Yes | Yes |
| Specific Matches FE | Yes | Yes | Yes | Yes |
| Stadium FE | Yes | Yes | Yes | Yes |
| Observations | 2,976 | 918 | 918 | 1,140 |
| $R^2$ | 0.099 | 0.205 | 0.053 | 0.065 |

*Note:* *p<0.1; **p<0.05; ***p<0.01. OLS regressions with clustered and heteroskedasticity-robust standard errors. Clusters on home team level. Marginal effects of probit regressions at the variables' means.

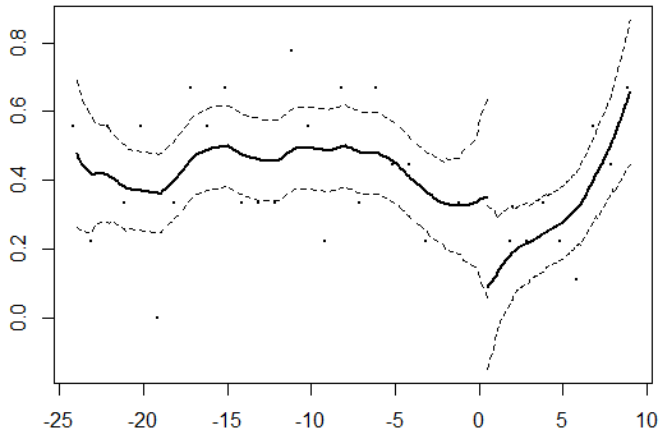


Figure A1: Regression Discontinuity Estimation

Table A4: Robustness Checks with an Interaction Term Analysis

| | Home Win | | | | Δ Points | | | |
|---|---|---|---|---|---|---|---|---|
| | (Overall) | (BL) | (2BL) | (3L) | (Overall) | (BL) | (2BL) | (3L) |
| Corona×(Δ Squad Size) | 0.009 | 0.003 | −0.018 | −0.004 | 0.071* | 0.123 | 0.045 | −0.030 |
| | (0.010) | (0.022) | (0.026) | (0.017) | (0.040) | (0.076) | (0.101) | (0.057) |
| Corona×(Table Home) | −0.003 | −0.008 | −0.032 | 0.018 | 0.002 | 0.036 | −0.186** | 0.075* |
| | (0.009) | (0.020) | (0.022) | (0.013) | (0.037) | (0.064) | (0.074) | (0.043) |
| Corona×Track | 0.267** | 0.535*** | −0.173 | 0.461*** | 1.516*** | 1.983** | 0.858 | 2.299*** |
| | (0.125) | (0.100) | (0.248) | (0.169) | (0.559) | (0.891) | (0.804) | (0.683) |
| Corona×(Share Standing Place) | 0.552*** | 0.476 | 0.489 | 0.777* | 2.401*** | 1.091 | 1.847 | 3.078*** |
| | (0.203) | (0.495) | (0.512) | (0.411) | (0.794) | (2.020) | (1.397) | (1.171) |
| Corona×(Age Stadium) | 0.00005 | 0.002 | −0.005** | −0.0001 | −0.003 | 0.009 | −0.021** | −0.005 |
| | (0.001) | (0.003) | (0.002) | (0.002) | (0.005) | (0.009) | (0.009) | (0.008) |
| Corona×(Δ Tradition Index) | 0.0002 | −0.0002 | 0.005** | 0.003 | 0.002 | −0.002 | 0.018** | 0.012 |
| | (0.001) | (0.001) | (0.002) | (0.002) | (0.004) | (0.007) | (0.007) | (0.008) |
| Corona×(Δ Player Value) | 0.006 | 0.010 | −0.640*** | 0.717* | 0.023 | 0.031 | −2.228*** | 3.318** |
| | (0.008) | (0.015) | (0.214) | (0.431) | (0.031) | (0.038) | (0.683) | (1.626) |
| Corona×(Δ Table) | −0.004 | 0.013 | −0.021 | 0.002 | −0.035 | −0.007 | −0.053 | 0.011 |
| | (0.007) | (0.021) | (0.016) | (0.012) | (0.030) | (0.055) | (0.061) | (0.052) |
| Corona×(Δ Shape) | −0.011 | 0.030 | −0.092*** | 0.008 | −0.064 | 0.073 | −0.268** | −0.031 |
| | (0.012) | (0.024) | (0.030) | (0.021) | (0.050) | (0.089) | (0.110) | (0.075) |
| Corona×(Δ Pause) | −0.006 | 0.051 | −0.0002 | −0.121 | −0.079 | 0.091 | −0.092 | −0.131 |
| | (0.029) | (0.058) | (0.051) | (0.082) | (0.140) | (0.157) | (0.197) | (0.215) |
| 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) $R^2$ | 0.046 | 0.108 | 0.044 | 0.049 | 0.073 | 0.174 | 0.056 | 0.062 |

*Note:* *p<0.1; **p<0.05; ***p<0.01. OLS regressions with clustered and heteroskedasticity-robust standard errors. Clusters on home team level.

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