COVID-19, Home Advantage in Professional Soccer, and Betting Market Efficiency

Kai Fischer* Justus Haucap†

Düsseldorf Institute for Competition Economics (DICE)

May 2021

Abstract

Fan support has often been considered to be a main driver of the home advantage in sports. Using the natural experiment of ghost games during the COVID-19 pandemic in German professional soccer, we test this claim. Indeed, we identify a reduction in the home performance - though with much heterogeneity across leagues. We moreover observe the home advantage to recover over time. In analysing whether betting markets anticipated this drop in the home advantage and its recovery, we test the efficient market hypothesis. We find that betting odds do not properly reflect the effect of ghost games regarding changes in the home advantage. Furthermore, we present evidence for a slow to non-existent adaptation process with respect to new match results, indicating a lack of semi-strong efficiency. Based on these findings, we show how simple betting strategies could have exploited the discussed phenomenon.

Keywords: Home Advantage, Betting Market, Efficient Market Hypothesis, Ghost Games

JEL Codes: G14, Z20, Z21, Z23

*DICE, University of Düsseldorf, Universitätsstrasse 1, 40225 Düsseldorf, Germany, kfischer@dice.hhu.de

†DICE, University of Düsseldorf, Universitätsstrasse 1, 40225 Düsseldorf, Germany, haucap@dice.hhu.de

1 Introduction

Betting markets have been analyzed rather frequently - often with the purpose to obtain a better understanding of prediction markets and the expectation formation on such. As every bet has a specific point of termination when all uncertainty is resolved (Thaler & Ziemba 1988), betting markets can be regarded as natural laboratories to study future markets. Many papers have been dealing with the efficiency of information processing and various forms of the efficient market hypothesis, which states that asset prices reflect all relevant information and that it is, by and large, impossible to outperform the market in a systematic fashion. In its weak form, the efficient market hypothesis suggests that asset prices reflect all information on past events. The semi-strong form follows the idea that all public information on past, current and future events is reflected in an asset's current price, while the strong form states that public and private information is contained in prices (Fama 1970, Malkiel 1973).

The analysis of sports betting markets and their efficiency has continuously found a number of biases such as the favorite-longshot bias or the sentiment bias (Thaler & Ziemba 1988, Sauer 1998, Vaughan Williams 1999). While such studies have often taken a static approach to market efficiency in focusing on weak-form inefficiencies that have been prevailing over some time, the present paper also contributes to the understanding of expectation adaptation in betting markets in the presence of an unforeseen exogenous shock. We study betting odds for German professional soccer matches before and after the introduction of ghost games during the COVID-19 pandemic. As ghost games have been a rare phenomenon before the pandemic and have never been conducted in succession, the COVID-19 induced ghost game series provides a unique natural experiment. In particular, after more than one year of ghost games in Germany[1], we investigate whether there is a reduction in the home advantage during ghost games as teams' better performance at home often is associated with fan support. Based on these results, we test whether betting markets anticipated these patterns and rationally updated expectations over time.

During the first ghost matches, we find a clear drop in the home advantage in the first German tier ("Bundesliga") whereas no change is observed in the second tier ("Bundesliga 2"). Over time, the home advantage recovers in the former division and especially teams which were used to high fan attendance suffer during ghost games as they need longer to recover. For a small number of COVID-19 matches, which have been played with a limited number of spectators, we find a higher home advantage than for ghost games.

Betting markets severely underestimated the loss in home advantage in Bundesliga soccer during the first ghost matches while markets overestimated it for the Bundesliga 2. Expectations on the overall loss of the home advantage have been similar for both divisions but were driven by different factors between divisions which market participants assumed to drive ghost games' match outcomes - such as an increasing relevance of the table ranking in the Bundesliga and rising importance of player ability in Bundesliga 2. In addition, we can only identify very weak, insufficient adaptation of expectations over time in the Bundesliga and none in the Bundesliga 2 although match outcomes deviated strongly from bettors' beliefs during the first ghost game matchdays. The lack of updating expectations may be seen as a violation

[1] The first ghost game took place on March 11, 2020, right before the lockdown break.

of semi-strong market efficiency. Hence, unfamiliar 'first time ever' shocks can cause relevant inefficiencies which may apparently also persist for some time. Consequently, we identify a number of profitable betting strategies.

The remainder of this paper is organized as follows: In section 2, we provide an overview of related literature, before we present our empirical approach and results in sections 3 and 4. Section 5 discusses the robustness and section 6 the general relevance of our findings. Section 7 concludes.

2 Literature Review

We contribute to two different strands of literature as we add to the documentation of the home advantage in professional soccer and additionally discuss its relevance for betting markets. Works on the former issue mainly discuss reasons for and drivers of the home advantage. This literature primarily discusses travel fatigue and altitude changes for away teams (Oberhofer et al. 2010, van Damme & Baert 2019), psychological and mental circumstances in home matches (Bray et al. 2002, Neave & Wolfson 2003, Pollard & Pollard 2005, Terry et al. 1998), social pressure and crowd support (Dohmen 2008, Garicano et al. 2005, Goumas 2014, Nevill et al. 2002, Peeters & van Ours 2021, Sutter & Kocher 2004, Unkelbach & Memmert 2010), and location familiarity (Clarke & Norman 1995, Pollard 2002) as potential mediators of the home advantage. Regarding ghost games, recent studies have found that ghost games reduce the home advantage. Reade, Schreyer & Singleton (2020) find that the home advantage is affected by changing referee behavior without crowd pressure on the referee. Their results are consistent with for example Bryson et al. (2021), Dilger & Vischer (2020), Endrich & Gesche (2020), Ferraresi & Gucciardi (2020), Pettersson-Lidbom & Priks (2010), and Scoppa (2021) who also focus on the impact of empty seats on referee decisions. Nevertheless, these papers mostly focus on the few matchdays of the 2019/2020 season and hence only detect very short-term effects. To our knowledge, we are the firsts to extend the analysis to more than a year and a complete season of data which implies for example 43 instead of just nine analysed matchdays for the leagues we discuss. Hence, we can also overcome studying only short-term dynamics and are able to understand long-run adaptations of players and expectations on the betting market. Moreover, we focus on heterogeneity across divisions and potential underlying causes for this.

In general, there exists a broad literature on sports betting markets and soccer betting in particular. However, most studies take a static approach to betting markets and their inefficiencies, as they mainly focus on behavioral biases such as the favorite-longshot bias, sentiment bias or mispricing of the home advantage. Especially the favorite-longshot bias, namely that bets on clear favorites are more profitable than bets on underdogs, has attracted much attention (Angelini & De Angelis 2019, Cain et al. 2000, 2003, Deschamps & Gergand 2007, Oikonomidis et al. 2015, Reade, Singleton & Vaughan Williams 2020). However, there is also evidence of markets without any, with only a weak, or even with a reversed longshot pattern (Angelini & De Angelis 2019, Angelini et al. 2020, Elaad et al. 2020, Forrest & Simmons 2008, Franck et al. 2011, Goddard & Asimakopoulos 2004, Kuypers 2000, Oikonomidis et al. 2015). Potential reasons for the longshot bias can be risk-hedging pricing strategies of betting providers against insider trading (Cain et al. 2003, Shin 1991, 1992, 1993), bettors' overconfidence or image effects (Direr 2011, Golec & Tamarkin 1995, Sauer 1998, Vaughan Williams 1999) and odd salience.

Secondly, the sentiment bias addresses the issue that odds do not always efficiently account for heterogeneity in teams' fan support or popularity (Feddersen et al. 2017, Forrest & Simmons 2008, Na & Kunkel 2019). As the sentiment mainly affects betting demand for specific match outcomes, betting providers react by using inefficient odds to ensure a balanced betting volume across the different options or to attract betting volume from highly supported teams by raising their odds.

Lastly and most relevant for our analysis, some studies offer evidence for a persistent mispricing of the home advantage. Elaad (2020) finds an overpredicted home advantage in some English soccer divisions. Vlastakis et al. (2009) provides supporting evidence for European matches. However, Elaad et al. (2020) and Franck et al. (2011) do not find any inefficiencies with regard to home performance. Forrest & Simmons (2008), on the contrary, argue that the home advantage is underestimated in data for Spanish and Scottish soccer.

In contrast to those static, backward-oriented perspectives on market efficiency, we can study the adaptation process of match-related expectations due to new experiences - implying an evaluation of the market's semi-strong efficiency from a dynamic, belief-updating point of view. To analyze this approach to efficiency, the literature has mainly focused on within-match news and their immediate or delayed effects in within-match betting. Angelini et al. (2020), Choi & Hui (2014), Croxson & Reade (2014), and Gil & Levitt (2007) identify that the surprisingness of events - such as unexpected goals - drive odd changes during matches. Less surprising goals, on the other hand, even tend to be underpriced at the beginning with an improving accuracy throughout the following minutes. From this literature, we conjecture that potentially very strong decreases of the home advantage may even lead to an overreaction in the odds, if the effect size is rather unexpected[2].

Finally, note that there are two recent papers with a similar research purpose to ours. Deutscher et al. (2021) and Meier et al. (2020) both analyze betting market efficiency in the presence of ghost games. While both papers reveal an overestimation of the probability of home wins, the latter finds an improving accuracy in the betting odds over time. We will find contradicting results later on and consider the better accuracy of betting odds at the end of the 2019/2020 season not to be related to an improving estimation of betting providers but purely to the return of the home advantage. We further shed more light on division heterogeneity while also analysing the determinants of the miscalculation of odds. Lastly, we extend the analysis to the 2020/2021 season which enables us to also study long-run reaction on betting markets.

3 Empirical Strategy

For our primary analysis of changes in the home advantage during COVID-19 ghost games, we build a dataset including all matches (N = 2,448) from the past four seasons (2017/18-2020/21). There were a total of 776 matches (Bundesliga: 389, Bundesliga 2: 387) played with zero or only few spectators after the first lockdown in spring 2020 which we consider

[2]Further, there is also evidence of time-sensitive inefficiencies at the beginning (Deutscher et al. 2018) and the end of soccer seasons (Goddard & Asimakopoulos 2004) as well as after coach dismissals (Bernardo et al. 2019).

to be matches during COVID-19. The dataset further includes match-specific and team-specific data such as the teams' table ranking or their players' average market value. Descriptive statistics of all data used are attached in Table A1 of the Appendix.

To estimate effects of potential shocks on the home advantage, we follow a regression approach like Ponzo & Scoppa (2018) or van Damme & Baert (2019). In particular, we treat every match as two observations - from each team's perspective once. We then determine COVID-19 effects by using ordered probit regressions

$$Points_{tm} = \beta_0 + \beta_1 Home_{tm} + \beta_2 Home_{tm} \times COVID19_m + X'_{tm}\gamma + \epsilon_{tm}$$

where $Points_{tm}$ gives the number of points (zero for loss, one for draw, three for win) which team t earned in match m. $Home_{tm}$ and $COVID19_m$ are dummies which characterise whether a team played at home and whether matches took place during the COVID-19 period. Hence, β_2 is our coefficient of interest. By including X_{tm}, we control for other factors which drive match outcomes like team ability. We later on extend this analysis to for example study the effects' development over time.

To better understand the timing of the analysis, we provide Figure 1 which gives precise information on important events. The last matches under usual conditions took place between March 6th and 9th, 2020. After that, the first lockdown was in place which also caused professional football to take a break. From May 16th onwards, football return in the form of ghost games with minor exceptions in late summer and autumn 2020 where some matches were played in front of visitors. These matches account for 8.8% percent of all COVID-19 matches in our sample, have experienced a maximum of 25% occupancy and are carefully taken into consideration in our later regression analysis.

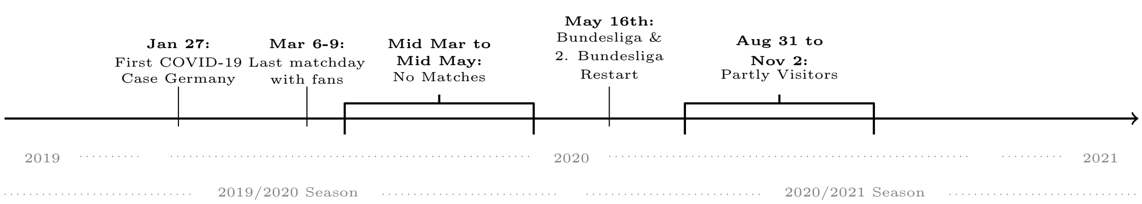

Figure 1: Time Setting of the Analysis

In a second step, we then study the reaction of the betting market. For that, we make use of a betting provider's closing odds for matches of the two German top soccer divisions - Bundesliga and 2. Bundesliga.

To scrutinize the betting market empirically, we rely on a standard regression design as used in previous literature (Deutscher et al. 2018, Forrest & Simmons 2008, Franck et al. 2011) though our regression analysis differs from those former works in the implementation of a test for semi-strong efficiency. As can be seen later on, we therefore introduce time-sensitive inefficiency terms into the regression model.

In general, it is assumed that efficient betting odds include all relevant information and hence on average perfectly predict all match outcomes. As we use closing odds, the betting provider had the opportunity to adapt odds throughout the days and hours before the match. Those adaptations should reflect demand for all three betting options - home win, draw, away win - and hence should account for public and private market information. The odds used are European decimal odds which give the revenue for the case of a successful bet. If the odd is 2.50 for a home win, this implies that one earns a revenue of 2.50 if one's bet was a home win and 0 otherwise. All bets refer to a wager of 1. We suggest that the odds o_{jm} for match m's outcomes $j \in \{H, D, A\}$ represent implicit probabilities p_{jm}:

$$p_{jm} = \frac{\frac{1}{o_{jm}}}{\sum\limits_{j \in \{H,D,A\}} \frac{1}{o_{jm}}}$$

Efficient odds include all relevant information, so that they should optimally forecast match outcomes. Thus, when regressing the implicit probabilities on the match outcomes, no other added variable should be significant in such a regression as information on the other variables should already be included in p_{jm}. Hence, we run the following probit regression for the two divisions:

$$Win_{tm} = \delta_0 + \delta_1 p_{tm} + \delta_2 Home_{tm} \times COVID19_m + \delta_3 Home_{tm} \times COVID19_m \times (\#Matchday_m) + C'_{tm}\eta + u_{tm}$$

where Win_{tm} is a dummy which turns one if team t won match m and is zero otherwise. p_{tm} gives the implicit probability - extracted from the odds - how likely a win of team t in match m is. $COVID19_m$ is a dummy variable which indicates matches played during COVID-19. We also interact this variable with a running time index $\#Matchday_m$ which should identify a potential adaptation process over time, as it indicates the number of ghost gamedays that have been played until match m. C_{tm} are further covariates which are match- and team-specific and which should control for other biases in the betting market such as the sentiment bias and a general mispricing of the home advantage. We consider the betting market to be efficient if δ_1 is not significantly different from 1 as this would be in line with a directly proportional relationship between odds and match outcome. Further, all other covariates have to be insignificant as this implies that the odds already include all relevant information. If we find that δ_2 or δ_3 are significantly different from 0, we interpret this as an indicator for mispricing and an inefficient expectations with regard to ghost games.

4 Results

4.1 Home Advantage

Recent papers (e.g., Bryson et al. (2021), Deutscher et al. (2021), Dilger & Vischer (2020), Fischer & Haucap (2020) and Santana et al. (2021)) find that the home advantage fell drastically for the first few Bundesliga ghost matchdays of the season 2019/2020. Less is known about Bundesliga 2 and the development of the home advantage in the 2020/2021 season. We now shed light on effects across the whole sample of 43 ghost matchdays under COVID-19. Table 1 presents descriptive t-test comparisons of the share of home wins and points of home teams before and during COVID-19. As shown, there is hardly any difference in pre-COVID-19 home advantages between leagues, an observations consistent with Pollard (2006) and Leite & Pollard (2018). We clearly see that the home advantage shrank in the Bundesliga at the end of the 2019/2020 season after the restart as home performance was significantly higher than in pre-COVID-19 times. For example, the probability of a home win seems to have decreased by over 12 percentage points. This exceeds the three to four percentage point loss which Bryson et al. (2021) found in an extensive, international sample. With regard to the effect on the difference of points between home and away team (Δ Points) one can even say, that the home advantage completely vanished as away teams performed better. Interestingly, the reduction in the home advantage vanishes in the 2020/2021 season. Opposingly, there is no change (even an insignificant increase) at the first glance in Bundesliga 2.

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

	Home Win			Δ Points		
	Before	During	p-value	Before	During	p-value
End of 2019/2020 Season						
Overall	43.12%	37.80%	0.184	0.402	0.091	0.140
Bundesliga	44.67%	32.53%	0.028^{**}	0.417	−0.361	0.011^{**}
Bundesliga 2	41.58%	43.21%	0.779	0.387	0.556	0.553
Complete 2020/2021 Season						
Overall	43.12%	43.63%	0.829	0.402	0.368	0.777
Bundesliga	44.67%	42.16%	0.448	0.417	0.324	0.586
Bundesliga 2	41.58%	45.10%	0.289	0.387	0.412	0.886

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

We subsequently present our findings from multivariate regressions which can be found in Table 2. In particular, we control for the teams' difference in market value per player, table ranking, collected points throughout the last four matches and their rest pause from the last match on the match level[3].

Indeed, our descriptive results from above are confirmed in the regression output (s. baseline model (I)). Firstly, we observe a highly significant home advantage in both divisions before COVID-19. Home teams earn more than 0.35 points more than their guests. Moreover, we do not see a clear drop in home advantage during COVID-19 in the Bundesliga and in Bundesliga 2.

Still in models (I), we do not account for time-sensitive development such as the observed pattern of a recovered home advantage in the Bundesliga in 2020/2021. It is an open question whether Bundesliga home players adjust to the unknown situation as an explanation of a return of home wins. If the latter was the case, the ghost game effect should decrease over time. This hypothesis is tested in models (II) of Table 2 where we interact $COVID19_m$ with a running index for ghost matchdays. In particular, we find that the drop in the Bundesliga home advantage was extensive at the beginning of the ghost games (almost half a point). But the home advantage recovered over time with an increase of 0.016 points per

[3] As a robustness check, we also controlled for different other factors which have been named to be potential drivers of match outcomes and the home advantage. These are travelling distance (squared) (Oberhofer et al. 2010), altitude differences (van Damme & Baert 2019), a new coach (van Ours & van Tuijl 2016), kick-off time and weekday Goller & Krumer (2020), Krumer (2017), Krumer & Lechner (2018), derbies (Ponzo & Scoppa 2018, Seckin & Pollard 2008), stadium capacity, existence of stadium track (Dohmen 2008) and share of standing places. This did not change our results.

Table 2: Regressions on COVID-19 and Home Advantage

	# Points							
	Bundesliga				Bundesliga 2			
	(I)	(II)	(III)	(IV)	(I)	(II)	(III)	(IV)
Home	0.373***	0.373***	0.373***	0.374***	0.366***	0.366***	0.366***	0.366***
	(0.053)	(0.053)	(0.053)	(0.053)	(0.051)	(0.051)	(0.051)	(0.051)
× COVID-19	−0.117	−0.467***	−0.469***	−0.530***	0.028	0.102	0.101	0.013
	(0.072)	(0.128)	(0.128)	(0.134)	(0.070)	(0.124)	(0.124)	(0.134)
× COVID-19 × (# Matchday)		0.016***	0.167**	0.129**		−0.003	−0.015	−0.013
		(0.005)	(0.063)	(0.063)		(0.005)	(0.040)	(0.040)
× COVID-19 × (# Matchday) × $\ln(\text{Attendance}_{2019/2020})$			−0.011*	−0.011*			0.001	0.001
			(0.006)	(0.006)			(0.004)	(0.004)
× COVID-19 × ln(1+Attendance)				0.050*				0.047*
				(0.030)				(0.027)
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	2,448	2,448	2,448	2,448	2,448	2,448	2,448	2,448
McFadden R^2	0.083	0.085	0.086	0.086	0.022	0.022	0.022	0.023

Note: *p<0.1; **p<0.05; ***p<0.01. Ordered probit regressions with heteroskedasticity-robust standard errors. Marginal effects at the variables' means. Controls are Δ Table, Δ Market Value, Δ Points Last Four Match, Δ Pause.

matchday which we interpret as a familiarization process with empty stadia. Considering that 43 COVID-19 matchdays have taken place by now, the Bundesliga's home advantage seems to have more than fully recovered. These findings fit Figure 2 which documents the recovery of the home advantage over time[4]. Again, there is no effect on Bundesliga 2 matches. Interestingly, Bryson et al. (2021) do not find a familiarization process over time in cross-country data. We argue this can be explained with the Bundesliga's very high average attendance and occupancy in contrast to other leagues, so that players elsewhere have not been affected as drastically. Similarly, this could explain the zero effect in the Bundesliga 2.

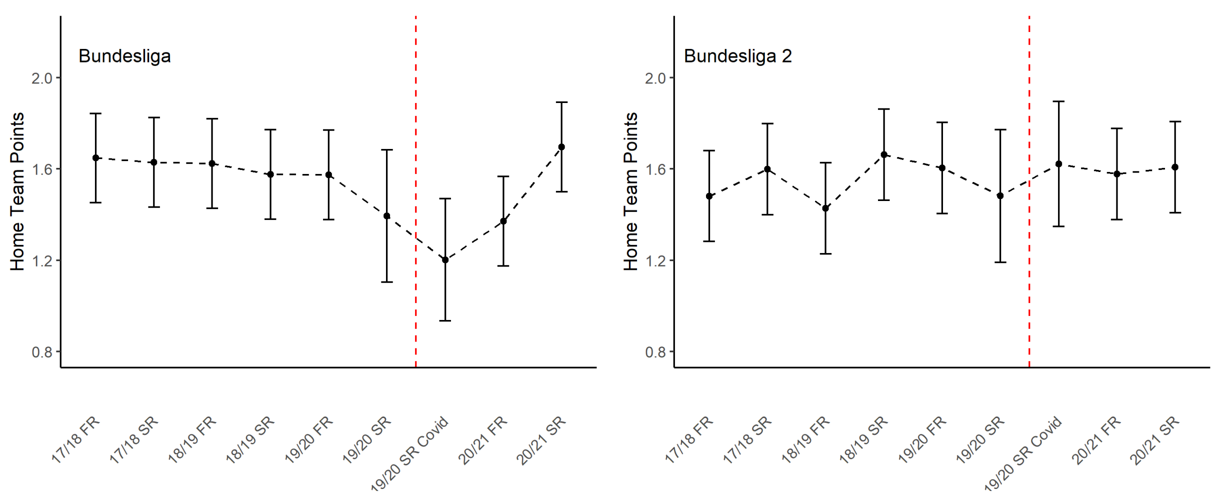

Figure 2: Development of Home Team Points over Time
Estimates are calculated from an OLS regression of collected points of each team on the above mentioned time group fixed effects interacted with a dummy for home teams. We control for performance and team strength covariates such as table position or market value. FR implies first round (first seventeen matchdays of the season), SR means second round. Error bars give the 90% confidence interval.

[4]The figure also documents a drop in home team points of about a fourth of the pre-COVID level during the end of the 2019/2020 season.

To test the latter claim and to determine what exactly drives the recovery of the home advantage, we check whether attendance differences can explain heterogeneity in the loss of the home advantage in the Bundesliga. We suggest that it could take longer to adapt for players which are used to play in front of more fans. Models (III) of Table 2 confirm our hypothesis. There we interact the COVID-19 matchday index with a measure of attendance. In particular, $\text{Attendance}_{2019/2020,m}$ is the mean attendance at home matches of every individual team in the pre-COVID-19 part of the season 2019/2020. Our results show that teams which are used to play in the presence of large crowds were more exposed to an aggregate loss in the home advantage as they recovered at a slower pace.

Lastly, we test the robustness of our results by checking whether findings changes if we account for the small share of matches (approx. 9%) which have been played with visitors. Models (IV) show that there is a significant impact of already a small number of visitors on home team performance in both leagues. This may indicate that there is a kinked, non-linear relation between spectator attendance and home team performance with already relevant effects for only few supporters. Importantly, we also see that our previous results do not change qualitatively.

4.2 Betting Market Efficiency

We now investigate betting market efficiency on basis of these results. Running the regressions explained in our empirical strategy, we arrive at Table 3.

Table 3: Accuracy of Implicit Probabilities

	Win					
	Bundesliga			Bundesliga 2		
	(I)	(II)	(III)	(I)	(II)	(III)
p_{tm}	1.104***	1.111***	1.111***	0.708***	0.708***	0.707***
	(0.072)	(0.082)	(0.082)	(0.141)	(0.134)	(0.134)
Home	0.002	0.001	0.001	0.045	0.045	0.046
	(0.031)	(0.029)	(0.029)	(0.029)	(0.030)	(0.030)
Home×COVID-19	−0.017	−0.165***	−0.182***	0.046	0.038	0.011
	(0.028)	(0.046)	(0.047)	(0.032)	(0.054)	(0.058)
Home×COVID-19×(#Matchday)		0.007***	0.008***		0.0003	0.001
		(0.002)	(0.002)		(0.002)	(0.002)
Home×COVID-19×ln(1+Attendance)			0.016			0.014
			(0.013)			(0.011)
(Δ Average Attendance)$\times 10^{-5}$	−0.007	−0.007	−0.007	0.001	0.001	0.001
	(0.006)	(0.006)	(0.006)	(0.009)	(0.009)	(0.009)
Observations	2,448	2,448	2,448	2,448	2,448	2,448
McFadden R^2	0.121	0.124	0.125	0.034	0.034	0.035

Note: *p<0.1; **p<0.05; ***p<0.01. Probit regressions with heteroskedasticity-robust standard errors clustered on match level. Marginal effects at the variables' means.

Intuitively, we find - for both divisions - that the implicit probability p_{tm} is highly significantly predicting match outcomes. Although this paper focuses on inefficiencies from shocks, also note that Bundesliga 2 odds imply a negative longshot bias, as the coefficient of p_{tm} is significantly smaller than 1. This is consistent with previous results by Forrest & Simmons (2008) on Spanish and Scottish professional soccer, but contrasts earlier findings on the 2. Bundesliga by Oikonomidis et al. (2015). Our finding implies that bettors can outperform the market by betting on low probability wins, hence contradicting the efficient market hypothesis. A (negative) longshot bias cannot be found in the Bundesliga which contrasts Angelini & De Angelis (2019) who have found such a pattern for matches played between 2006 and 2017. The finding is consistent though with Oikonomidis et al. (2015).

In both divisions there is no systematic mispricing of the general home advantage.

With regard to the COVID-19 shock, at first glance the market reaction seems to be efficient, too (s. models (I)). However, Bundesliga bettors misprice the effect of ghost games over time which fits short-run findings by Deutscher et al. (2021). In general, model (II) reveals that the odds imply a probability of a home team win that is 16.5 percentage points higher than it actually was for the case of the first ghost gameday. Furthermore, the effect vanished with time over the ghost game period and disappeared after approximately 23 matchdays. Since it took several matchdays until the inefficiency disappeared, we conclude that expectations only changed rather slowly. Also, the findings imply that betting markets underestimate home performance after the 'break-even point' which implies that the return in the home advantage may have been unexpected. Interestingly enough, comparable patterns cannot be observed for the 2. Bundesliga.

As we cannot infer whether the fluctuation in the efficiency gap originated from an improving accuracy of the market (as assumed in Meier et al. (2020)) or from match outcomes better fitting the odds by coincidence, we cannot finally conclude whether market expectations adapted to ghost games.

Note that we also controlled for a mispricing of the small share of COVID-19 matches which have been played with visitors. No mispricing is evident here. Also, we checked for differences in the average attendance per season[5], as it is one typical proxy used to measure a potential sentiment bias. We do not find any significant effects.

To better understand whether the improved preciseness of betting odds over time originates from a suitable adaptation or just the recovery of the home advantage, we further investigate dispersion of betting odds in the market. For that, we also account for all relevant drivers of match outcomes to avoid an omitted variable bias. Hence, we include several covariates such as ability measures which, for example, capture market value or table ranking differences[6]. Results are listed in Table 4.

We find that the implicit probabilities p_{Hm} of home win odds do not sufficiently account for the decrease of the home advantage in the Bundesliga. Recall that the home advantage dropped by about twelve percentage points at the end of the 2019/2020 season. The implicit probability of an away team win is also only slightly corrected upwards (3.6 percentage points). Moreover, the lack of change in implicit probabilities dramatically ignores the actual development with regard to the interaction $COVID19_m \times Matchday_m$ in probabilities of a home team win. There is no indication for betting odds to consider the improving home team performance. Although we cannot directly conclude that weak-form inefficiency is violated due to the underestimation of ghost game effects on home advantage, as there was no past information, it

[5] For the 2020/2021 season, we also use the pre-COVID-19 attendance from the 2019/2020 season as data.

[6] Other match-specific covariates are e.g. measures for mid-week matches or the change of the head coach as there is evidence on the relevance of such factors (Krumer & Lechner 2018, van Ours & van Tuijl 2016, Flepp & Franck 2020).

Table 4: Determinants of Implicit Probabilities

	p_{Hm}		p_{Dm}		p_{Am}	
	(BL)	(BL2)	(BL)	(BL2)	(BL)	(BL2)
COVID-19	-0.020^{**}	-0.014^{*}	-0.003	-0.0003	0.036^{***}	0.016^{**}
	(0.009)	(0.007)	(0.003)	(0.002)	(0.009)	(0.007)
COVID-19 × (#Matchday)	-0.0003	-0.0002	0.0005^{***}	-0.0001	-0.0001	0.0003
	(0.0004)	(0.0003)	(0.0001)	(0.0001)	(0.0004)	(0.0003)
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Observations	1,224	1,224	1,224	1,224	1,224	1,224
Adjusted R^2	0.839	0.639	0.645	0.274	0.829	0.638

Note: *p<0.1; **p<0.05; ***p<0.01. OLS Regressions with heteroskedasticity-robust standard errors. Control variables are Δ Table, Δ Market Value, Δ Points Last Four Matches, Δ Pause, Travel Distance (Squared), Altitude Difference, a New Coach, Derby, Kick-off Time and Weekday Effects, Stadium Capacity, Existence of Stadium Track, Share of Standing Places.

should have been evident and plausible that ghost games are less advantageous for home teams when the stadium is empty. Hence, lack of statistical significance of the $COVID19_m$ dummy for p_{Hm} also questions the market's weak-form efficiency. This also holds for inserting an interaction of the quadratic matchday index with the $COVID19_m$ dummy. Note that we can derive from Figure 3 that the decrease in the expected home points is causal. Nevertheless, it can directly be observed that there is no adaptation over time as the treatment effect is constant over time which corresponds to the regression results.

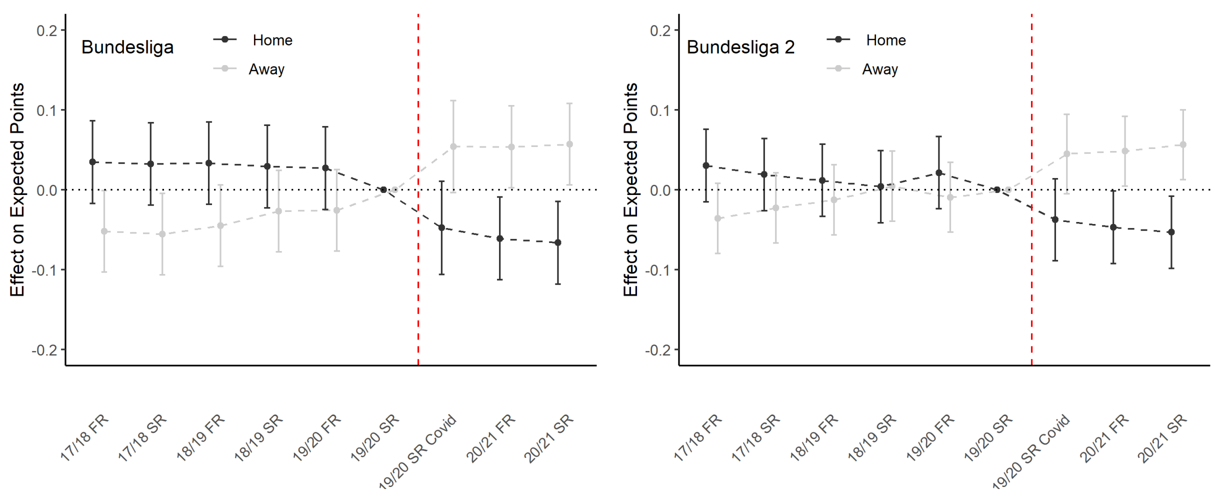

Figure 3: Causal Effects of COVID-19 on Betting Market Expectations

Estimates are calculated from an OLS regression of expected points (weighted sum of points by implicit outcome probabilities) of each team on the above mentioned time group fixed effects. We control for performance and team strength covariates such as table position or market value. FR implies first round (first seventeen matchdays of the season), SR means second round. Error bars give the 90% confidence interval.

Further, this gives us two interesting observations: First, we cannot observe an adaptation in the expected decline of the home advantage after the first ghost game results. That is, although the home advantage drastically decreased during the first ghost gamedays in the Bundesliga and afterwards also showed a positive trend, the market did not significantly update its expectations, as the interactions of the $COVID19_m$ dummy with the actual matchday index are not statistically significant or followed the trend as often typical for financial markets. Since ghost games have been rather rare before the COVID-19 pandemic (Reade, Schreyer & Singleton 2020), an adaptation of the expectations to observed outcomes would have been rational as not much past information has been available. Therefore, we conjecture that the inefficiency in the market also lies in the missing adaptation process over time. Second, we also observe an imperfect pattern in the market reaction to ghost games in the Bundesliga 2: Admittedly the market anticipates correctly the reduction of the home advantage to be smaller than in the Bundesliga, but the expected decrease in the home advantage is still positive and significant (s. p_{Am}) with about 1.6 percentage points more away wins which contradicts our findings of - if at all - more home wins (s. Table 1). When recapitulating that the development of the home advantage strongly differed between Bundesliga and Bundesliga 2, the Bundesliga 2 estimates have been more but still insufficiently accurate. The missing reaction of the market despite the salient results in the Bundesliga throughout the ghost game period is rather surprising and suggests semi-strong inefficiency. Moreover, the negative expected ghost game effect in Bundesliga 2 indicates that the betting market did not correctly assess the role of fan support and attendance for the reduction in the home advantage as a crucial driver of this effect.

After finding different violations of weak and semi-strong market efficiency, it remains an open question why expectations with regards to ghost games actually differed between Bundesliga and Bundesliga 2 as their competitive and administrative background in general are very similar. That is, why does the market ex-ante expect Bundesliga clubs to suffer slightly more from a reduced home advantage than Bundesliga 2 clubs and what drives the expectations? We investigate this by testing several hypotheses of potential explanations of the ghost game effect. For that, we interact the $COVID19_m$ dummy with different variables to analyse whether the betting market expects their importance to change during ghost games which then potentially could explain diverging expectations between divisions. We e.g. test whether betting markets expect player ability to matter more during ghost games which we control for by inserting the interaction term Corona$\times$(Δ Player Value) in the regression. We provide our results of such tests on the impact on the implicit probabilities p_{Hm} in Table A2 of the appendix.

We find that betting odds, and thereby implicit probabilities, include different expectations between Bundesliga and Bundesliga 2. In general, we see that the different consideration of ability measures are one key to explaining the expectation heterogeneity across leagues. Thus, betting markets expected the change in the home advantage to be a team-specific phenomenon which is another finding of our paper. In the Bundesliga, betting markets expected teams with higher player value, better table ranking and good shape throughout the latest matches to suffer more during COVID-19 matches. We find the exact opposing results for Bundesliga 2. Exemplarily, an additional one million Euro difference between the teams' average player value now e.g. implies an increase in the implicit Bundesliga 2 home win probability of 5.6 percentage points on top of the already existing effect size from pre-Corona matches. This implicates an increase of the importance of player ability of more than half in comparison to the market value's relevance before COVID-19. That player ability importance increases during ghost matches implies a reduced competitive balance during ghost games and hence a less present home advantage as the role of home matches is overcompensated by the relevance of player strength. This connotes that betting markets assume Bundesliga 2 supporters to effectively change match outcomes by increasing the surprisingness of match outcomes. That this is not observed in the Bundesliga alludes that Bundesliga player ability is expected to react differently to the appearence of an audience.

Lastly, we note that betting markets reduced Bundesliga home win probabilities for teams which were used to play in highly occupied stadia before COVID-19. This pattern is not appearent for the Bundesliga 2. For the latter league, especially teams with a high share of standing places (proxy for atmosphere) are expected to experience a lower home advantage. Hence, it seems that betting markets considered stadium and fan characteristics but underestimated their role in the Bundesliga and overstated the relevance of standing places in the Bundesliga 2.

Note that those findings across leagues show that betting markets indeed tried to account for ghost games and to some extent considered heterogenous factors - but this then happened partially inefficiently.

Let us now identify some simple but profitable betting strategies based on the findings above. For that purpose, we examine whether it would have been profitable to always bet on the away team in the Bundesliga, if one had been able to predict the reduction in the home advantage. Information on betting returns for various betting strategies are given in Table 5.

Table 5: Return of Simple Betting Strategies

	Bundesliga			**Bundesliga 2**		
	Before COVID-19	End of 2019/2020	2020/2021	Before COVID-19	End of 2019/2020	2020/2021
Home Win	−1.51%	−30.95%	−5.64%	−3.66%	11.74%	5.75%
Draw	2.90%	5.04%	7.04%	7.32%	17.72%	−18.01%
Away Win	−5.73%	16.20%	−15.66%	−4.38%	−17.80%	−12.17%

Indeed, we find it to be highly profitable to follow a simple 'always away win' strategy in the Bundesliga for ghost games - but only in the early matchdays as the home advantage recovered. On the contrary, as there was no decline in the home advantage in the 2. Bundesliga, an 'always home win' strategy would have been overall profitable for second league matches. This also holds for the 2020/2021 season. Whereas short-run strategies could have been hardly predictable in detail, we surprisingly also detect an easy strategy to just bet on draws. In fact, this attempt would have been profitable across all four seasons in the dataset and in both divisions which supports former findings on weak-form inefficiency, e.g., by Deschamps & Gergand (2007). An exception is the negative return to betting on draws in Bundesliga 2 in the 2020/2021. We take those results as further evidence for market inefficiency - during but also partly before ghost games. Also note if a bettor simply had bet symmetrically on all outcomes for all ghost games in both divisions for the matchdays in the 2019/2020 season, no loss would have been realized (revenue of 0.28 percent).

5 Robustness Checks

After having presented results on the violations of the efficient market hypothesis, we also provide an overview on conducted robustness checks. We for example further investigated the heterogeneity in the home advantage drop across divisions. To test whether our hypothesis of an adaptation process of Bundesliga players is correct, we check whether other factors influencing match outcomes changed over time. In particular, we shed light on the referee bias and with-in match performance. The former describes the phenomenon that referees typically are more likely to take decisions in favor of the home team and has been found to drive the reduction of the home advantage during COVID-19 (Reade, Schreyer & Singleton 2020). The latter implies the analysis of match data such as the number of corners or shots to better understand whether the home advantage changed due to adaptations in the playing style. In Table 6, we investigate whether both factors named changed over time. We do not observe an clear trend in the referee behavior and neither in within-match performance data such as corners and fouls. Moreover, the very similar COVID-19 effect on Bundesliga and Bundesliga 2 indicate the small relevance of the referee bias and performance changes on the home advantage in our sample. From that, we conclude that the underlying recovery of the home advantage really is associated with behavioral and psychological adaptations of the players.

Table 6: Potential Drivers of the Home Advantage and their Development over Time

Δ = Home - Away	Δ Yellow Cards		Δ Fouls		Δ Corners		Δ Shots	
	(BL)	(BL2)	(BL)	(BL2)	(BL)	(BL2)	(BL)	(BL2)
COVID-19	0.462***	0.471**	0.682	0.940*	−0.169	−0.023	−1.237	−0.858
	(0.175)	(0.206)	(0.526)	(0.538)	(0.430)	(0.415)	(0.764)	(0.740)
COVID-19 × (# Matchday)	−0.007	−0.003	−0.009	−0.009	−0.014	−0.017	−0.001	0.003
	(0.006)	(0.008)	(0.019)	(0.021)	(0.017)	(0.016)	(0.030)	(0.027)
Observations	1,224	1,224	1,224	1,224	1,224	1,224	1,224	1,224
Adjusted R^2	0.038	0.031	0.036	0.023	0.179	0.024	0.289	0.055

Note: *p<0.1; **p<0.05; ***p<0.01. OLS regressions with heteroskedasticity-robust standard errors. Controls like in Table 4.

In addition, we run identical regressions as in Table 4 for non-closing odds which are collected one or two days in advance of the matches. Here we can make use of data for five additional betting providers, so that we cross-check the findings between providers and hence offer a more disaggregated view. Results do not change. Importantly, no clear adaptation is evident for both divisions in all odds - so that experiences of match outcomes did not change expectations of new matches. Hence, also evidence for an active expectation updating process seems to be limited - also in the 2. Bundesliga.

As results are nearly identical across betting providers, we state that the market is efficient in the sense that ghost games did not create large-scale opportunities for arbitrage trading.

Additionally, we also tested for robustness by including lagged match outcomes instead of the interaction with the matchday running index to the regressions from Table 4. In detail, we calculated the difference between the number of realized and expected home wins, draws and away wins for every matchday. During the ghost game period, lagged values of those variables should be significant determinants of betting odds if odds account for new arriving information on match outcomes and the development of the home advantage. Supporting our former results, we do not find evidence for the relevance of the lagged variables for odds of home and away wins, from which a violation of semi-strong market efficiency and non-optimal updating of expectations can be derived. We also ran the same regressions but interacted the differences of realized and expected match outcomes with the running matchday index, as the relevance of newly arriving information for subsequent matches' odds should decrease over time. We cannot find any evidence for that.

6 Discussions

Our analysis shows that the changes in the home advantage during ghost games have not been anticipated correctly. Only from this fact, we cannot directly conclude market inefficiency as no past data, public or private information has been available on ghost games before. Nevertheless, we detect a violation of efficiency in the run of the ghost games as the already played matches and their results have not been priced in correctly. It is important to notice this distinction.

Further, it is still an open question who exactly misses to adapt to the observed market outcomes - the betting provider or the majority of bettors. It would be very surprising if not a single provider out of the six mentioned in the robustness checks was aware of the drastic decrease in the home advantage in the Bundesliga - or at least understood that this effect could be heterogeneous across divisions. This hints at no reaction in the offered odds due to bettors not changing their behavior and expectations. Betting providers even seem to make use of bettors' inaccurate expectations as e.g. suggested by Levitt (2004). Although the majority of bettors usually are no rookies, most of them rely on their feelings and instinct. Year-long experience of home teams outperforming away teams could have caused a rigidity in bettors' beliefs. This is to some extent what Choi & Hui (2014) refer to as conservatism and overreliance on prior expectations. Still, literature on in-game betting (Angelini et al. 2020, Choi & Hui 2014, Croxson & Reade 2014, Gil & Levitt 2007) finds an adaptation process to in-game exogenous shocks such as goals over time which we hardly observe[7].

Moreover, it is important to transmit the results from betting markets to other markets where new and unknown shocks could occur, too. As it should be a goal to reduce inefficiencies as soon as possible after the shock - at least from a welfare perspective - we therefore make an important note: markets, and human agents on those respectively, do not always update beliefs rationally and at all. Especially the rigidity in expectations over time can be found in several other situations, too - e.g. just consider the disposition effect on financial markets when investors persist in their profit expectations. Still, for individual bettors or investors, this then allows outperforming the median investor. A delayed consideration of unknown shocks in e.g. stock or bond prices can also lead to an intermediate-term discrepancy between intrinsic and observable prices. This involves additional risk and hence uncertainty which is unfavorable in financial markets and could lead to delayed bad surprises when the assets' intrinsic values realize again. As another relevant observation for financial markets, we want to put on record that the weak adaptation over time is insensitive to the degree of the inefficiency. The larger pricing gap in the Bundesliga did not result in a quicker expectation update, so that one cannot always rely on invisible market forces to close at least major mispricing gaps.

[7]Gil & Levitt (2007) document inefficiencies in the sense of arbitrage opportunities for short intervals after goals.

Also importantly, we want to emphasize that there has been media coverage on the drastic decrease in the home advantage in the Bundesliga during the early ghost game period, so that especially experienced bettors should have been aware of this development. This indicates that even improving information transparency over time does not have to better market outcomes immediately. Nevertheless, there is also good news for efficient market pursuers. All betting providers analyzed show similar odds - even after the shock - which do not allow for much arbitrage in such extraordinary times. Moreover, Hegarty (2021) showed that odds' explanatory power in European leagues improved during the COVID-19 time as matches seem to be see less surprises.

Finally, let us mention that our analytical framework is not free of limitations. Ghost games have not been the only important change in the observation period. As a response to many matches being played in a short period of time, two additional substitutions for each team were allowed throughout the ghost game period. Though, there is no clear intuition why more substitutions should have reduced the home advantage.

Finally, we are aware that our research is only partly able to explain the behavioral mechanism behind our results, so that we recommend future research on the question what exactly causes expectation rigidity in the presence of such unfamiliar shocks.

7 Conclusion

Our analysis provides insights to a betting market's reaction to the present COVID-19 pandemic - making use of the introduction of ghost games in German professional soccer. We find that betting markets expected similar small reductions in the home advantage in the two main professional soccer divisions while detecting different drivers of the expectations across the two divisions. The very different match outcomes between the two leagues over the course of the ghost games did not result in a proper adaptation of expectations, pointing at inefficiencies in the market. For bettors, this provided an opportunity to exploit very simple and highly profitable betting strategies. In a broader sense, we believe that these findings are relevant for all types of prediction markets, especially financial markets, where a slow adaptation process of market participants' expectations can result in high losses and inefficient market outcomes. Interestingly, the high media coverage of the reduced home advantage in the Bundesliga did not affect bettors' behavior which suggests that inefficiencies may persist even in the presence of reasonably transparent markets.

References

Angelini, G. & De Angelis, L. (2019), 'Efficiency of Online Football Betting Markets', *International Journal of Forecasting* **35**(2), 712–721.

Angelini, G., De Angelis, L. & Singleton, C. (2020), 'Informational Efficiency and Price Reaction within In-Play Prediction Markets', *Working Paper* .

Bernardo, G., Ruberti, M. & Verona, R. (2019), 'Semi-Strong Inefficiency in the Fixed Odds Betting Market: Underestimating the Positive Impact of Head Coach Replacement in the Main European Soccer Leagues', *The Quarterly Journal of Economics and Finance* **71**, 239–246.

Bray, S. R., Jones, M. V. & Owen, S. (2002), 'The Influence of Competition Location on Athletes' Psychological States', *Journal of Sport Behavior* **25**(3), 231–242.

Bryson, A., Dolton, P., Reade, J. J., Schreyer, D. & Singleton, C. (2021), 'Causal Effects of an Absent Crowd on Performances and Refereeing Decisions During COVID-19', *Economics Letters* **198**, 109664.

Cain, M., Law, D. & Peel, D. (2000), 'The Favorite-Longshot Bias and Market Efficiency in UK Football Betting', *Scottish Journal of Political Economy* **47**(1), 25–36.

Cain, M., Law, D. & Peel, D. (2003), 'The Favorite-Longshot Bias, Bookmaker Margins and Insider Trading in a Variety of Betting Markets', *Bulletin of Economic Research* **55**(3), 263–273.

Choi, D. & Hui, S. K. (2014), 'The Role of Surprise: Understanding Overreaction and Underreaction to Unanticipated Events Using In-Play Soccer Betting Market', *Journal of Economic Behavior and Organization* **107**, 614–629.

Clarke, S. R. & Norman, J. M. (1995), 'Home Ground Advantage of Individual Clubs in English Soccer', *The Statistician* **44**(4), 509–521.

Croxson, K. & Reade, J. J. (2014), 'Information and Efficiency: Goal Arrival in Soccer Betting', *Economic Journal* **124**(575), 62–91.

Deschamps, B. & Gergand, O. (2007), 'Efficiency in Betting Markets: Evidence from English Football', *The Journal of Prediction Markets* **1**, 61–73.

Deutscher, C., Frick, B. & Otting, M. (2018), 'Betting Market Inefficiencies are Short-Lived in German Professional Football', *Applied Economics* **50**(30), 3240–3246.

Deutscher, C., Winkelmann, D. & Oetting, M. (2021), 'Bookmakers' Mispricing of the Disappeared Home Advantage in the German Bundesliga after the COVID-19 Break', *Applied Economics* **53**(26), 3054–3064.

Dilger, A. & Vischer, L. (2020), 'No Home Bias in Ghost Games', *Discussion Paper of the Institute for Organisational Economics 7/2020* .

Direr, A. (2011), 'Are Betting Markets Inefficient? Evidence from European Football Championships?', *Applied Economics* **45**(3), 343–356.

Dohmen, T. (2008), 'The Influence of Social Forces: Evidence from the Behavior of Football Referees', *Economic Inquiry* **46**(3), 411–424.

Elaad, G. (2020), 'Home-Field Advantage and Biased Prediction Markets in English Soccer', *Applied Economics Letters* **27**(14), 1170–1174.

Elaad, G., Reade, J. J. & Singelton, C. (2020), 'Information, Prices and Efficiency in an Online Betting Market', *Finance Research Letters* **35**, 101291.

Endrich, M. & Gesche, T. (2020), 'Home-Bias in Referee Decisions: Evidence from 'Ghost Matches' During the COVID-19 Pandemic', *Economics Letters* **197**, 109621.

Fama, E. F. (1970), 'Efficient Capital Markets: A Review of Theory and Empirical Work', *Journal of Finance* **25**(2), 383–417.

Feddersen, A., Humphreys, B. R. & Soebbing, B. P. (2017), 'Sentiment Bias and Asset Prices: Evidence from Sports Betting Markets and Social Media', *Economic Inquiry* **55**(2), 1119–1129.

Ferraresi, M. & Gucciardi, G. (2020), 'Team Performance and Audience: Experimental Evidence from the Football Sector', *Siep Working Paper No. 760* .

Fischer, K. & Haucap, J. (2020), 'Does Crowd Support Drive the Home Advantage in Professional Soccer? Evidence from German Ghost Games During the COVID-19 Pandemic', *DICE Discussion Paper No. 344* .

Flepp, R. & Franck, E. (2020), 'The Performance Effects of Wise and Unwise Managerial Dismissals', *Economic Inquiry* **59**(1), 186–198.

Forrest, D. & Simmons, R. (2008), 'Sentiment in the Betting Market on Spanish Football', *Applied Economics* **40**(1), 119–126.

Franck, E., Verbeek, E. & Nesch, S. (2011), 'Sentiment Preferences and the Organizational Regime of Betting Markets', *Southern Economic Journal* **78**(2), 502–518.

Garicano, L., Palacios-Huerta, I. & Prendergast, C. (2005), 'Favoritism Under Social Pressure', *Review of Economics and Statistics* **87**(2), 208–216.

Gil, R. & Levitt, S. D. (2007), 'Testing the Efficiency of Markets in the 2002 World Cup', *Journal of Prediction Markets* **1**(3), 255–270.

Goddard, J. & Asimakopoulos, I. (2004), 'Forecasting Football Results and the Efficiency of Fixed-Odds Betting', *Journal of Forecasting* **23**, 51–66.

Golec, J. & Tamarkin, M. (1995), 'Do Bettors Prefer Long Shots Because They are Risk-Lovers, or Are They Just Overconfident?', *Journal of Risk and Uncertainty* **11**(1), 51–64.

Goller, D. & Krumer, A. (2020), 'Let's Meet as Usual: Do Games Played on Non-Frequent Days Differ? Evidence from Top European Soccer Leagues', *European Journal of Operations Research* **286**, 740–754.

Goumas, C. (2014), 'Home Advantage in Australian Soccer', *Journal of Science and Medicine in Sport* **17**(1), 119–123.

Hegarty, T. (2021), 'Information and Price Efficiency in the Absence of Home Crowd Advantage', *Applied Economics Letters* . forthcoming.

Krumer, A. (2017), 'First in First Win: Evidence on Schedule Effects in Round-Robin Tournaments in Mega-Events', *European Economic Review* **100**, 412–427.

Krumer, A. & Lechner, M. (2018), 'Midweek Effect on Soccer Performance: Evidence From the German Bundesliga', *Economic Inquiry* **56**(1), 193–207.

Kuypers, T. (2000), 'Information and Efficiency: An Empirical Study of a Fixed Odds Betting Market', *Applied Economics* **32**(11), 1353–1363.

Leite, W. & Pollard, R. (2018), 'International Comparison of Differences in Home Advantage Between Level 1 and Level 2 of Domestic Football Leagues', *German Journal of Exercise and Sport Research* **48**, 271–277.

Levitt, S. D. (2004), 'Why are Gambling Markets Organised so Differently from Financial Markets?', *Economic Journal* **114**(495), 223–246.

Malkiel, B. G. (1973), *A Random Walk Down Wall Street*, 1 edn, Norton, New York.

Meier, P. F., Flepp, R. & Franck, E. (2020), 'Are Sports Betting Markets Semistrong Efficient? Evidence from the COVID-19 Pandemic', *UZH Business Working Paper No. 387* .

Na, S. & Kunkel, T. (2019), 'Do not Bet on Your Favorite Football Team: The Influence of Fan Identity-Based Biases and Sport Context Knowledge on Game Prediction Accuracy', *European Sport Management Quarterly* **19**(3), 396–418.

Neave, N. & Wolfson, S. (2003), 'Testosterone, Territoriality, and the 'Home Advantage'', *Psychology and Behavior* **78**, 269–275.

Nevill, A. M., Balmer, N. J. & Williams, A. M. (2002), 'The Influence of Crowd Noise and Experience upon Refereeing Decision in Football', *Psychology of Sport and Exercise* **3**, 261–272.

Oberhofer, H., Philippovich, T. & Winner, H. (2010), 'Distance Matters in Away Games: Evidence from the German Football League', *Journal of Economic Psychology* **31**(2), 200–211.

Oikonomidis, A., Bruce, A. C. & Johnson, J. E. V. (2015), 'Does Transparency Imply Efficiency? The Case of the European Soccer Betting Markets', *Economics Letters* **128**, 59–61.

Peeters, T. & van Ours, J. C. (2021), 'Seasonal Home Advantage in English Professional Football; 1973-2018', *De Economist* **169**, 107–126.

Pettersson-Lidbom, P. & Priks, M. (2010), 'Behavior under Social Pressure: Empty Italian Stadiums and Referee Bias', *Economics Letters* **108**(2), 212–214.

Pollard, R. (2002), 'Evidence of a Reduced Home Advantage When a Team Moves to a New Stadium', *Journal of Sports Sciences* **20**, 969–973.

Pollard, R. (2006), 'Home Advantage in Soccer: Variations in its Magnitude and a Literature Review of the Inter-Related Factors Associated with its Existence', *Journal of Sport Behavior* **29**, 169–189.

Pollard, R. & Pollard, G. (2005), 'Home Advantage in Soccer: A Review of its Existence and Causes', *International Journal of Soccer and Science* **3**(1), 28–38.

Ponzo, M. & Scoppa, V. (2018), 'Does the Home Advantage Depend on Crowd Support? Evidence From Same-Stadium Derbies', *Journal of Sports Economics* **19**(4), 562–582.

Reade, J. J., Schreyer, D. & Singleton, C. (2020), 'Eliminating Supportive Crowds Reduces Referee Bias', *Working Paper* .

Reade, J. J., Singleton, C. & Vaughan Williams, L. (2020), 'Betting Markets for English Premier League Results and Scorelines: Evaluating a Forecasting Model', *Economic Issues* **25**(1), 87–106.

Santana, H. A. P., Bettega, O. B. & Dellagrana, R. A. (2021), 'An Analysis of Bundesliga Matches Before and After Social Distancing by COVID-19', *Science and Medicine in Football* . forthcoming.

Sauer, R. D. (1998), 'The Economics of Wagering Markets', *Journal of Economic Literature* **36**(4), 2021–2064.

Scoppa, V. (2021), 'Social Pressure in the Stadiums: Do Agents Change Behavior without Crowd Support?', *Journal of Economic Psychology* **82**, 102344.

Seckin, A. & Pollard, R. (2008), 'Home Advantage in Turkish Professional Soccer', *Perceptual and Motor Skills* **107**(1), 51–54.

Shin, H. S. (1991), 'Optimal Betting Odds Against Insider Traders', *Economic Journal* **101**(408), 1179–1185.

Shin, H. S. (1992), 'Prices of State Contingent Claims with Insider Traders, and the Favorite-Longshot Bias', *Economic Journal* **102**(411), 426–435.

Shin, H. S. (1993), 'Measuring the Incidence of Insider Trading in a Market for State-Contingent Claims', *Economic Journal* **103**(420), 1141–1153.

Sutter, M. & Kocher, M. G. (2004), 'Favoritism of Agents - The Case of Referees' Home Bias', *Journal of Economic Psychology* **25**(4), 461–469.

Terry, P. C., Warlond, N. & Carron, A. V. (1998), 'The Influence of Game Location on Athletes' Psychological States', *Journal of Science and Medicine in Sport* **1**(1), 29–37.

Thaler, R. H. & Ziemba, W. T. (1988), 'Anomalies: Parimutuel Betting Markets: Racetracks and Lotteries', *Journal of Economic Perspectives* **2**(2), 161–174.

Unkelbach, C. & Memmert, D. (2010), 'Crowd Noise as a Cue in Referee Decisions Contributes to the Home Advantage', *Journal of Sport and Exercise Psychology* **32**, 483–498.

van Damme, N. & Baert, S. (2019), 'Home Advantage in European International Soccer: Which Dimension of Distance Matters?', *Economics E-Journal* **13**(50), 1–17.

van Ours, J. C. & van Tuijl, M. A. (2016), 'In-Season Head-Coach Dismissals and the Performance of Professional Football Teams', *Economic Inquiry* **54**(1), 591–604.

Vaughan Williams, L. (1999), 'Information Efficiency in Betting Markets: A Survey', *Bulletin of Economic Research* **51**(1), 1–39.

Vlastakis, N., Dotsis, G. & Markellos, R. N. (2009), 'How Efficient is the European Football Betting Market? Evidence from Arbitrage and Trading Strategies', *Journal of Forecasting* **28**, 426–444.

A Appendix

Table A1: Descriptive Statistics

	Bundesliga					2. Bundesliga				
	N	Mean	St. Dev.	Min	Max	N	Mean	St. Dev.	Min	Max
Corona	1,224	0.318	0.466	0	1	1,224	0.316	0.465	0	1
Home Win	1,224	0.432	0.496	0	1	1,224	0.426	0.495	0	1
Ability Covariates										
Δ Player Value	1,224	−0.001	9.021	−30.100	30.100	1,224	0.001	0.610	−2.650	2.650
Δ Table Ranking	1,224	0.173	7.123	−17	17	1,224	0.282	7.378	−17	17
Δ Points Last Four Matches	1,224	−0.105	4.085	−12	12	1,224	−0.128	3.607	−11	11
Δ Days Pause	1,143	−0.037	1.043	−7	7	1,224	0.007	1.560	−7	7
Geographical Factors										
Distance	1,224	299.808	146.681	14.507	640.690	1,224	304.540	143.485	5.840	628.920
$\|\Delta\ \text{Altitude} \times 10^{-2}\|$	1,224	1.466	1.462	0.000	4.870	1,224	1.693	1.361	0.010	5.340
Specific Matches FE										
Derby	1,224	0.044	0.205	0	1	1,224	0.026	0.160	0	1
Within-Week Match	1,224	0.077	0.266	0	1	1,224	0.087	0.283	0	1
Match ≥ 6pm	1,224	0.382	0.486	0	1	1,224	0.342	0.474	0	1
New Coach Home Team	1,224	0.090	0.286	0	1	1,224	0.094	0.292	0	1
Stadium FE										
Capacity	1,224	46,953.8	17,940	15,000	81,365	1,224	25,845.0	14,081.0	10,700	60,559
Share Standing Places	1,224	0.253	0.158	0.000	0.836	1,224	0.470	0.191	0.164	0.836
Track	1,224	0.069	0.254	0	1	1,224	0.111	0.314	0	1
Within-Match Data										
Δ Yellow Cards	1,224	−0.252	1.600	−6	6	1,224	−0.263	1.786	−6	6
Δ Fouls	1,224	−0.484	5.011	−24	19	1,224	−0.573	5.297	−18	16
Δ Corners	1,224	0.689	4.347	−14	19	1,224	0.734	4.022	−12	14
Δ Shots	1,224	2.123	8.035	−29	25	1,224	1.821	7.039	−21	24
Betting Odds										
Home	1,224	2.963	2.352	1.050	22.230	1,224	2.469	0.773	1.280	7.510
Draw	1,224	4.411	1.560	3.000	15.370	1,224	3.608	0.392	2.850	5.940
Away	1,224	4.574	4.358	1.120	41.000	1,224	3.475	1.326	1.400	11.680

Table A2: Investigation of Division Heterogeneity in Expectations (p_{iH})

	p_{Hm}													
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
COVID-19	−0.020**	−0.014*	−0.021**	−0.013*	−0.022**	−0.013*	−0.020**	−0.014*	−0.020**	−0.014*	−0.031***	0.017	0.185	−0.306***
	(0.009)	(0.007)	(0.009)	(0.007)	(0.009)	(0.007)	(0.009)	(0.007)	(0.009)	(0.007)	(0.011)	(0.012)	(0.122)	(0.064)
×(Δ Player Value)			−0.004***	0.056***										
			(0.0005)	(0.008)										
×(Δ Table Ranking)					0.003***	−0.002***								
					(0.001)	(0.001)								
×(Δ Points Last 4 Matches)							−0.003**	0.004***						
							(0.001)	(0.001)						
×(Δ Days Pause)									−0.00003	0.004*				
									(0.005)	(0.002)				
×(Share Standing Places)											0.040	−0.068***		
											(0.027)	(0.021)		
×ln(Pre-COVID Attendance)													−0.019*	0.030***
													(0.012)	(0.007)
Covariates	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	1,224	1,224	1,224	1,224	1,224	1,224	1,224	1,224	1,224	1,224	1,224	1,224	1,224	1,224
Adjusted R^2	0.839	0.640	0.848	0.653	0.842	0.645	0.840	0.642	0.839	0.640	0.840	0.642	0.840	0.645

Note: *p<0.1; **p<0.05; ***p<0.01. OLS Regressions with heteroskedasticity-robust standard errors. For covariates, s. Table 4.