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Betting Market Efficiency in the Presence of Unfamiliar Shocks: The Case of Ghost Games during the COVID-19 Pandemic

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Abstract

Betting markets have been frequently used as a natural laboratory to test the efficient market hypothesis and to obtain insights especially for financial markets. We add to this literature in analyzing the velocity and accuracy in which market expectations adapt to an exogenous shock: the introduction of soccer ghost games during the COVID-19 pandemic. We find that betting odds do not properly reflect the effect of ghost games regarding changes in home advantage. Furthermore, we present evidence for a slow to non-existing adaption process with respect to new match results, indicating a lack of semi-strong efficiency. Based on these findings, we also identify very simple but highly profitable betting strategies which underline our rejection of the efficient market hypothesis.

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

JEL Codes: G14, Z20, Z21, Z23

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1 Introduction

Betting markets have been analyzed rather frequently - often with the purpose to obtain a better understanding of prediction markets and expectation formation and also to test the efficient market hypothesis. 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 infomation processing and tests of the various forms of the so-called efficient market hypothesis, which states that asset prices reflect all relevant information and that is, by and large, impossible to outperform the market in a systematic fashion. Put differently, assets always trade at their fair value on competitive markets according to the efficient market hypothesis. 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, curremt and future events is reflected in an asset's current price, while the strong form of the efficient market hypothesis states that all public and private information is completely refelcted in current asset prices.(Fama 1970, Malkiel 1973).

The analysis of betting markets and their efficiency has continuously found a number of biases. Typical findings are a favorite-longshot bias and a sentiment bias (see (Thaler & Ziemba 1988), Sauer (1998) or 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 adaption processes 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 gost game series provide a unique opportunity or a natural experiment. As a number of papes have recently found a loss of home advantage during ghist games (see Bryson et al. (2020), Dilger & Vischer (2020) and Fischer & Haucap (2020)), Fischer & Haucap (2020) also find that the loss of home advantage is confined to first division games, but was not observed in the second professional soccer league in Germany. In addition ,Fischer & Haucap (2020) find that even in the first German soccer division the home advantage returned over time, as players got more used to empty stadiums. As the German professional soccer leagues have been the first to introduce ghost games after the shutdow in March 2020, betting market inefficiencies resulting from ghost games are expected to be more severe in Germany than in other countries which may have already benefited from the experience from matches in Germany.

Our analysis finds that betting markets severely underestimated the loss in home advantage in German first division soccer while markets overestimated it for the second division. In addition, we can only identify a very weak adaption of expectations over time in the second division and none in the first division although match outcomes deviated strongly from bettors' beliefs during the ghost games. The lack of updating expectations may be seen as a violation of semi-strong market efficiency. Hence, unfamiliar 'first time ever' shocks can cause relevant inefficiencies which can apparently also persist for some time.

Consequently, we identify a number of profitable betting strategies. Interestingly, bettors apparently did not react, even though there has been significant media coverage on apparent changes in home advantage for first division clubs.

The remainder of this paper is no organized as follows: In section 2, we provide an overview of related literature, before we present our empirical approach and results in scetions 3 and 4. Section 5 discusses the robstness of our findings 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 contribute to the analysis of market efficiency on the one hand and also discuss the relevance of the home advantage in sports for betting markets. Works on the latter mainly discuss reasons and drivers for the home advantage. This literature primarily discusses travel fatigue and altitude (Oberhofer et al. 2010, van Damme & Baert 2019), psychological and mental circumstances (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, Sutter & Kocher 2004, Unkelbach & Memmert 2010), and location familiarity (Clarke & Norman 1995, Pollard 2002) as potential drivers of 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 Bryson et al. (2020), Dilger & Vischer (2020), Endrich & Gesche (2020) and Pettersson-Lidbom & Priks (2010) who also focus on the impact of empty seats on referee decisions. Using the same data as the present paper, Fischer & Haucap (2020) observe a significant decline in the home advantage in the first German soccer division but not in the second and third German divisions. While these works on the home advantage focus on changing match outcomes and respective impact channels, we are not aware of any research on the effect of ghost matches on betting market efficiency.

Similar to the changing behavior on the pitch, also gambling behavior off the pitch is affected by the COVID-19 pandemic,as reported by Auer et al. (2020) and Hakansson (2020) who identify reduced sports gambling during the lockdown. The former also find that most sports bettors do not substitute sports betting with other forms of gambling such as online casinos throughout the lockdown.

In general, there exists a broad literature on sports betting markets (for literature reviews see Sauer (1998) or Williams (1999)) and soccer betting in particular. However, most studies take a static look at 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 across several seasons which can be identified by analysing past data. Especially the favorite-longshot bias, namely that bets on clear favorites are more profitable than bets on underdogs, has attracted much attention (Cain et al. 2003),(Angelini & De Angelis 2019, Cain et al. 2000, Deschamps & Gergand 2007, Oikonomidis et al. 2015), 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. 2019, Elaad et al. 2020, Forrest & Simmons 2008, Franck et al. 2011, Goddard & Asimakopoulos 2004, Kuypers 2000, Oikonomidis et al. 2015)[1]. 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, Williams 1999), bettors' willingness to especially make profit from correctly predicting unexpected match outcomes (Sauer 1998), and odd salience.

Secondly, the sentiment bias addresses the issue that odds do not always efficiently account for heterogeneity in teams' fan support. As the sentiment mainly affects betting demand for specific match outcomes, betting providers react by using inefficient odds to ensure a more balanced betting volume across the three different options. Another reason may be the objective to attract betting volumes from highly supported teams by raising their odds[2]. Evidence for the sentiment bias is e.g. provided by Feddersen et al. (2017), Forrest & Simmons (2008) and Na & Kunkel (2019) on basis of social media presence, average attendance, and survey data[3].

Lastly, some studies also offer evidence for a persistent mispricing of the home advantage in betting odds. Elaad (2020) finds an overpredicted home advantage in some English soccer divisions. Vlastakis et al. (2009) provides supporting evidence with European match data. 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. Outside of soccer, there is also further evidence that the home advantage is not appropriately reflected in betting odds (Coleman 2017, Golec & Tamarkin 1991, Schnytzer & Weinberg 2008, Vergin & Sosik 1999) which partly already vanished (Gandar et al. 2001).

In contrast to those static, backward looking perspectives on market efficiency, we can study the adaption

[1] Whereas those findings mainly focus on the longshot bias in match outcomes (home win, draw, away win), Reade, Singleton & Williams (2020) detect the same bias for scorelines.

[2] Still, Flepp et al. (2016) provide evidence against this hypothesis. They argue that high transparency in betting markets exacerbates odd distortion by providers.

[3] Soccer-related sentiment bias is also evident in financial markets as e.g. shown by Palomino et al. (2009).

process of match-related expectations due to new experiences - implying an evaluation of the market's semi-strong efficiency from a dynamic 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 changes. Angelini et al. (2019), 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 conjcture that the drastic decrease in home advantage in the first German division may even lead to an overreaction in the odds, as the size of the effect size may have been rather unexpected. We will see below that, although the share of home wins on average decreased by about 15 percentage points (Fischer & Haucap 2020), no beeting market reaction can be observed. Since literature on unforeseen or unknown shocks in betting markets is rare[4], our study should contribute to the understanding of betting markets' reactions to such unfamiliar events.

3 Empirical Strategy

For our empirical analysis, we make use of a betting provider's closing odds for matches of the two German top soccer divisions - Bundesliga and 2. Bundesliga[5,6]. We use date from three seasons (2017/18-2019/20) for the two divisions, resultung in a total number of 1836 matches. 83 (81) of these matches have been played without any audience in Bundesliga (2. Bundesliga) and, thus, form our ghost game treatment group. For further variables, we use the data from Fischer & Haucap (2020) and refer to the Appendix of that paper for further detailed explanations of data sources. Descriptive statistics of the data are attached in Table A1 of the Appendix.

We rely on a similar regression design as previous literature (Deutscher et al. 2018, Forrest & Simmons 2008, Franck et al. 2011). It is also assumed that efficient betting odds include all relevant information. As we use closing odds, the betting provider had the opportunity to adapt odds throughout the days and hours before the match. Those adaptions should reflect demand for all three betting options - home win, draw, away win - and hence should account for public and private market information of the betting provider and the bettors. We suggest that the odds o_{ij} for each match outcome $i \in \{H, D, A\}$ of a game j represent

[4]Note that there is some knowledge on the relevance of short-term match circumstances such as weather e.g. in American football (Borghesi 2007, 2008). Further, there is also evidence of 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) which provides some further information on time-sensitive inefficiencies in betting markets. Still, some of those studies also only focus on past information and weak-form efficiency. In contrast, we analyze a short-time shock which occurs for the first time ever. This makes it possible to examine unbiased adaption behavior.

[5]We make use of the betting odds provided by *football-data.co.uk*.

[6]Unfortunately, there is a single match (Bayern Munich against Hannover 96 in the season 2018/2019) for which we do not have closing odds of the betting provider. For this match, we use odds which were collected one day before the match from a competitor. The correlation between the two betting providers' odds is above 96.5% for all three match outcomes.

implicit probabilities p_{ij} following the formula:

$$p_{ij} = \frac{\frac{1}{o_{ij}}}{\sum\limits_{\{H,D,A\}} \frac{1}{o_{ij}}}$$

Efficient odds, and implicit probabilities respectively, include all relevant information, so that they should optimally explain 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_{ij}. Hence, we run the following probit regression for the two divisions:

$$Y_{ij} = \beta_0 + \beta_1 p_{ij} + \beta_2 Corona_j + \beta_3 Corona_j \times (\#Matchday)_j + \gamma' X_{ij} + \epsilon_{ij}$$

where Y_{ij} is the outcome of match j from the perspective of team i which is 1 for a win and 0 otherwise. $Corona_j$ is a dummy variable which indicates matches played as ghost games. We also interact this variable with a running time index $\#Matchday_j$ which should identify a potential adaption process over time, as it indicates the number of ghost game matchdays that have been played until match j. X_{ij} is a matrix of 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 β_1 is not significantly different from 1 as this would be in line with a directly proportional relationship between odds and match outcome[7]. Further all other covariates have to be insignificant as this implies that the odds already include all relevant information, for example on changes induced by ghost games. If we find that β_2 or β_3 are significantly different from 0, we interpret this as an indicator for mispricing and an inefficient expectation adaption process with regard to ghost games.

4 Results

In recent papers, Fischer & Haucap (2020), Bryson et al. (2020) and Dilger & Vischer (2020)find that the home advantage fell drastically for Bundesliga games during the ghost game period of the season 2019/2020. In contrast, nothing changed in the second division, as Fischer & Haucap (2020) point out. In fact, if at all the home advantage even slightly increased (about one percentage point more home wins), but the finding is not statistically significant and may be pure chance. A first t-test shows that betting odds seem to incorporate a small decline in the home advantage of about two percentage points for ghost games - though neither statistically significantly in the first ($p = 0.319$) nor in the second division ($p = 0.254$). Also note

[7]Technically, also β_0 should not be significantly different from 0 at the same time.

that overall the home advnatage decreased by more than 15 percentage points (Fischer & Haucap 2020) whereas it remained unchanged in 2. Bundesliga.

To exclude that these findings merely reflect the inclusion of other determinants of match outcomes, we have controlled for multivariate determinants of match outcomes and run the regressions explained above. Results are presented in Table 1.

Table 1: Accuracy of Implicit Probabilities

	Win	
	(BL)	(2BL)
p_{ij}	1.075***	0.548***
	(0.091)	(0.108)
Home	-0.004	0.068***
	(0.021)	(0.021)
Home×Corona	-0.298^{***}	0.059
	(0.061)	(0.131)
Home×Corona×(#Matchday)	0.056**	-0.006
	(0.023)	(0.022)
(Δ Average Attendance)$\times 10^{-5}$	-0.010	0.051
	(0.043)	(0.071)
Observations	1836	1836
McFadden R^2	0.123	0.028

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_{ij} is highly significant for predicting match outcomes. Although this paper focuses on inefficiencies from shocks, also note that 2. Bundesliga odds imply a negative longshot bias, as the coefficient of p_{ij} is significantly smaller than 1. This is consistent with previous results by Forrest & Simmons (2008) on Spanish and Scottish professional soccer, but it contrasts previous findings on the German second division (for different seasons though) 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 first division (Bundesliga) which contrasts Angelini & De Angelis (2019) who have found such a pattern for matches played between 2006 and 2017. The finding is consistent tough with Oikonomidis et al. (2015). A potential reason for the inefficiency only being present in the second division could be the relatively thin betting market for second division games, as accuracy tends to increase with the market size (Brown & Yang 2019).

The betting market for 2. Bundesliga matches further seems to misprice the general level of the home advantage. The implicit probabilities for a home win are 6.8 percentage points lower than they should be across all three observed seasons. Both a negative longshot bias and an underestimated home advantage cannot be found in the odds for the first division. When combining both biases in 2. Bundesliga, one can derive that the highest returns can be achieved when betting on home outsiders. In fact, betting on 2. Bundesliga home teams where the probability of a home win is smaller than that of an away win, would have resulted in an average return over all three seasons of 12.45%.

However, Bundesliga bettors misprice the effect of ghost games. In general, the regression reveals that the odds imply a probability of a home team win that is 24.2 percentage points higher than it actually was for the case of the first ghost game matchday. Furthermore, the effect vansihed with time over the ghost game period and even disappeared right after the fifth matchday. Thereafter, home team wins were even underestimated. Since it took five matchdays until the inefficiency disappeared and given that the "opposite" inefficiency returned afterwards, we conclude that expectations only changed rather slowly. Interestingly enough, comparable patterns cannot be observed for in the second division. Hence, this regression provides double-edged evidence. Over the early matchdays, the inefficiency was persistent even though it decreased and it returned during the later matches.

As we cannot infer whether the fluctuation in the efficiency gap originated from an improving accuracy of the market or from match outcomes better fitting the odds by coincidence, we cannot finally conclude whether market expectations adapted to ghost games. Especially Figure 1 supports the hypothesis that fluctuations in the efficiency do not originate from an improved odd accuracy but from a trend in the match outcome towards a recovering home advantage. The dotted line in Figure 1 demarks the beginning of the ghost game period. No changes and adaptations in the odds are evident. For the second division, Figure 1 also raises the question whether efficient odds maybe only fitted the ghost game outcomes so well because of the non-changing home advantage instead of the suitable adaptation of bettors in their expectations. Thus, we will shed light on the determinants of the odds in a next step and examine whether the presence of ghost games affected betting prices.

Note that we also controlled for differences in the average attendance per season, as it is one typical proxy used to measure a potential sentiment bias. As we do not find any significant effects, a sentiment bias does not seem to be present in the data. Hence, there are no obvious market-beating strategies that would bet on teams with more or less fan support.

Examining the dispersion of betting odds in the market, we also have to account for all relevant drivers of match outcome to avoid an omitted variable bias when measuring the impact of ghost games on odds and the implicit probabilities. Hence, we include several covariates in the respective regressions such as ability

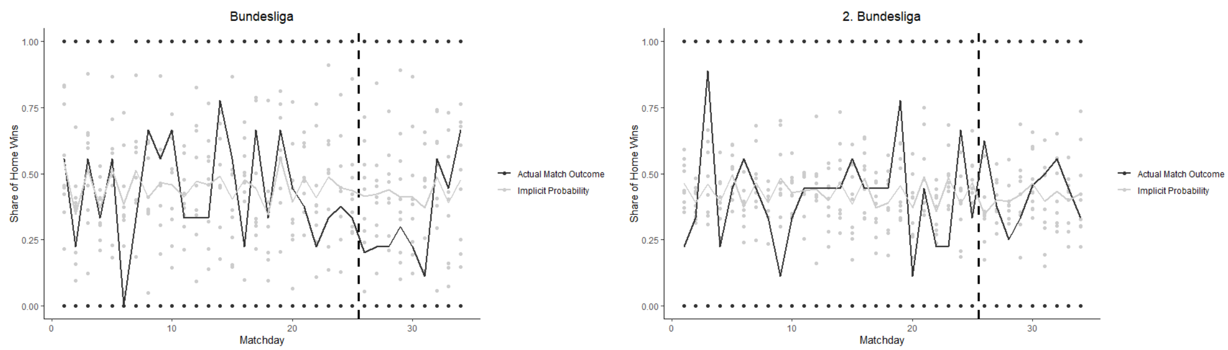

Figure 1: Match Outcome and Implicit Probabilities in 2019/2020

measures which, for example, capture a team's market value or table ranking differences between home and away teams. Results are listed in Table 2.

We find that the implicit probabilities p_{Hj} of home win odds do not account for the decrease of the home advantage in the first division. The implicit probability of an away team win also remains unchanged. The lack of change in implicit probabilities dramatically ignores the actual change in probabilities of a home team win of 15.3 percentage points, as documented in Fischer & Haucap (2020). Although we cannot directly conclude that weak-form inefficiency is violated due to the underestimation of ghost game effects on home advantage, as there is no past information, it should have been evident and plausible that ghost games are less advantageous for home teams when the stadium is empty and there is no crowd support. Hence, lack of statistical significance of the $Corona_j$ dummy also questions the market's weak-form efficiency.

Further, there are two interesting observations: First, we cannot observe an adaption in the expected decline of the home advantage after the first ghost game match results. That is, although the home advantage drastically decreased during the first ghost game matchdays in the first division and afterwards also showed a positive trend, the market did not significantly adapt its expectations, as the interactions of the $Corona_j$ dummy with the actual matchday index are not statistically significant[8]. Since ghost games have been rather rare before the COVID-19 pandemic(Reade, Schreyer & Singleton 2020), an adaption 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 adaption process over time. Second, we observe a contrary pattern in the market reaction to ghost games in the second division: The expected decrease in the home advantage is higher and significant with about 4.5 percentage points less home wins and a comparable increase in the expectation of away wins[9]. In addition, a weak adaption process over time can be observed as e.g. the probability of an away win decreases until the fifth ghost game matchday and shows

[8]When also considering the insignificant variables, the ghost game effect on e.g. the home win probability in the Bundesliga decreases to about -3.4 percentage points after the sixth ghost game matchday and recovers afterwards.

[9]Interestingly, this ante expectation is near to the average effect on the home advantage found in a study across 17 countries by Bryson et al. (2020), minus three percentage points.

Table 2: Determinants of Implicit Probabilities

	p_{Hj}		p_{Dj}		p_{Aj}	
	(BL)	(2BL)	(BL)	(2BL)	(BL)	(2BL)
Corona	0.002	-0.045^{**}	0.009	0.008	0.005	0.043^{**}
	(0.025)	(0.018)	(0.012)	(0.007)	(0.028)	(0.019)
Corona×(#Matchday)	−0.012	0.016^{**}	−0.003	0.001	0.014	-0.017^{*}
	(0.017)	(0.008)	(0.006)	(0.003)	(0.018)	(0.009)
Corona×(#Matchday)^2	0.001	−0.002	0.00001	-0.0005^{*}	−0.001	0.002^{*}
	(0.002)	(0.001)	(0.001)	(0.0003)	(0.002)	(0.001)
Ability Covariates						
Δ Player Value	0.015^{***}	0.094^{***}			-0.015^{***}	-0.087^{***}
	(0.001)	(0.007)			(0.001)	(0.008)
Δ Table Ranking	-0.007^{***}	-0.005^{***}			0.006^{***}	0.004^{***}
	(0.001)	(0.001)			(0.001)	(0.001)
Δ Points Last Three Matches	0.003^{***}	0.003^{***}			-0.002^{***}	-0.003^{***}
	(0.001)	(0.001)			(0.001)	(0.001)
Δ Days Pause	0.001	0.0004			−0.002	−0.0005
	(0.002)	(0.001)			(0.002)	(0.001)
|Δ Player Value|			-0.006^{***}	-0.021^{***}		
			(0.0003)	(0.003)		
|Δ Table Ranking|			-0.002^{***}	-0.001^{***}		
			(0.0004)	(0.0002)		
|Δ Points Last Three Matches|			−0.0003	−0.0003		
			(0.001)	(0.0004)		
|Δ Days Pause|			0.001	0.0003		
			(0.001)	(0.001)		
Geographical Factors						
ln(Travel Distance)	0.008	0.009^{*}	0.003^{*}	-0.006^{***}	-0.019^{***}	−0.004
	(0.005)	(0.005)	(0.002)	(0.002)	(0.005)	(0.005)
|Δ Stadium Altitude×10^{-2}|	0.0005	−0.0003	-0.004^{**}	0.00003	0.011^{***}	−0.0003
	(0.003)	(0.002)	(0.001)	(0.001)	(0.004)	(0.002)
Specific Matches FE						
Derby	0.007	−0.003	0.014^{**}	−0.008	-0.033^{**}	0.008
	(0.016)	(0.017)	(0.006)	(0.006)	(0.015)	(0.017)
Within-Week Match	-0.016^{*}	−0.012	−0.002	0.004	0.009	0.007
	(0.009)	(0.008)	(0.003)	(0.003)	(0.011)	(0.008)
Match ≥ 6pm	0.004	0.009^{*}	0.004^{**}	−0.001	−0.001	−0.009
	(0.005)	(0.005)	(0.002)	(0.001)	(0.005)	(0.005)
New Coach Home Team	−0.008	0.006	0.008^{*}	0.004	−0.001	−0.009
	(0.011)	(0.009)	(0.004)	(0.003)	(0.010)	(0.007)
Stadium FE						
ln(Stadium Capacity)	−0.003	0.004	−0.009	−0.004	0.025^{***}	−0.001
	(0.017)	(0.018)	(0.008)	(0.006)	(0.007)	(0.007)
Share Standing Places	−0.065	0.034	0.039^{***}	0.008	0.044^{***}	-0.051^{***}
	(0.042)	(0.037)	(0.013)	(0.011)	(0.015)	(0.009)
Stadium with Track	-0.052^{***}	−0.004	0.021^{***}	0.007	0.024^{***}	−0.006
	(0.012)	(0.013)	(0.005)	(0.005)	(0.008)	(0.007)
Observations	918	918	918	918	918	918
R^2	0.846	0.627	0.644	0.307	0.830	0.627
Adjusted R^2	0.843	0.620	0.638	0.295	0.827	0.621

Note: *p<0.1; **p<0.05; ***p<0.01. OLS Regressions with heteroskedasticity-robust standard errors. Clusters on home team and season level for p_{Hj} and p_{Dj} while on away team and season level for p_{Aj} respectively.

a non-monotonic development. Still, the average effect on away wins of approximately minus one percentage point during ghost games (Fischer & Haucap 2020) is never reached and the away win probability increases again after the fifth matchday. When recapitulating that the development of the home advantage strongly differed between Bundesliga and 2. Bundesliga (s. Figure 1) in that the 2. Bundesliga estimates have been much more accurate than those of the first division, the missing reaction of the market to observed, salient results in the first division throughout the ghost game period is rather surprising and suggests semi-strong inefficiency. Moreover, the higher expected ghost game effect in the 2. Bundesliga indicates that the betting market did not correctly assess the role of stadium occupancy for the reduction in the home advantage as a crucial driver of this effect (Fischer & Haucap 2020).

After finding different violations of weak and semi-strong market efficiency, let us identify some simple[10] but highly 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 first division, 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 3.

Table 3: Return of Simple Betting Strategies

	Bundesliga		**2. Bundesliga**	
	Before	Ghost Games	Before	Ghost Games
Home Win	−1.51%	−30.95%	−3.66%	11.74%
Draw	2.90%	5.04%	7.32%	17.72%
Away Win	−5.73%	16.20%	−4.38%	−17.80%

Indeed, we find it to be highly profitable to follow a simple 'always away win' strategy in the Bundesliga for ghost games. On the contrary, as there was no decline in the home advantage in the second division an 'always home win' strategy would not have been profitable for second league matches. Whereas those 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 three seasons in the dataset and in both divisions which supports former findings on weak-form inefficiency, e.g., by Deschamps & Gergand (2007). We take those results as further evidence for market inefficiency - during but also partly before ghost games. If a bettor simply had bet symmetrically on all outcomes for all ghost games in both divisions, no loss would have been realized (revenue of 0.28%).

Although the (negative) longshot bias is not the primary subject of our analysis, we also notice that e.g.

[10] As literature even finds professional tipsters to barely outperform prediction models based on only publicly available information (Forrest & Simmons 2000), we rely on realistic strategies which could have been implemented by any type of bettor.

only betting on match outcomes with an implicit probability of maximum 20 percent in the 2. Bundesliga would have resulted in 165 bets in 918 matches and a positive return of 7.24%[11].

5 Robustness Checks

After having presented results on the violations of the efficient market hypothesis, we also provide robustness checks. Firstly, we run identical regressions as in Table 2 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 on betting providers. Table A2 of the appendix mostly[12] reveals the insensitivity of the results to the choice of the betting provider - exemplarily shown for the home team odds. The ghost game effect on the share of home wins significantly ranges between 3.4 and 5.1 percentage points in the 2. Bundesliga and thus overestimates the actual effect. For the primary division, all coefficients are insignificant. But importantly, no clear adaption 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 second division.

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

Additionally, we also test for robustness by including lagged match outcomes instead of the interaction with the matchday running index to the regressions. 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 (s. Table A3 in the appendix), from which a violation of semi-strong market efficiency and non-optimal updating of expectations can be derived. Only betting odds seem to react to the number of draw matches from the last two matchdays. There is only one exception for the second lag of the difference between realized and expected home wins, which however negatively affects future implicit probabilities. This is not in line with efficient expectation updating as this would require a positive coefficient but better fits to the phenomenon of a "gambler's fallacy". When more home wins are realized than expected, this could cause that bettors to

[11] Note that, at first glance, it may be surprising that the high mispricing of the home advantage in 2. Bundesliga matches cannot be profitably exploited. But this is due to the fact that home teams often are favorites which reduces the attractivty of the bet due to the negative longshot bias.

[12] There is one exception. Betting provider IV seems to generally had overstated the home win probability in both divisions in contrast to its competitors. Still, this difference shrank over time as the provider e.g. significantly reduced the implicit home win probability in the Bundesliga in the run of the matchdays.

believe that it is time for less home wins again - resulting in this negative coefficient then.

Finally, we also ran the same regressions as in Table A3 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. Unsurprisingly, this approach did not change our results either.

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. As the betting provider's overround ($\sum_i \frac{1}{o_{ij}} - 1$) is quite low in this competitive market (2.97%) in contrast to former research on betting markets (Deschamps & Gergand 2007)[13], we suggest that the betting provider should have been aware of the observed developments - just to ensure not to run into deficit due to possible and profitable betting strategies. Supporting this, it would be very surprising if not a single provider out of the six presented 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 more important in the premier division instead of the second division. 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. 2019, Choi & Hui 2014, Croxson & Reade 2014, Gil & Levitt 2007) finds an adaption process to in-game exogenous shocks such as goals over time which we hardly observe[14].

In addition, another question is why people assumed the second division to suffer from a higher reduction in the home advantage. We suggest that, at the beginning, bettors could have focused on a more even

[13]Deschamps & Gergand (2007) also state that higher disagreement between betting providers' odds leads to higher margins which is in line with product differentation theory. As our robustness checks provide insight to the dense relation between competitors' odds, decreasing differentiation as well as increasing competition and market transparency via e.g. the internet lowered overrounds over the years.

[14]Gil & Levitt (2007) document inefficiencies in the betting market in the sense of arbitrage opportunities for a short period of time after a goal has been scored.

competitive balance in the second division, so that the home advantage is of a more essential role as e.g. proposed by Forrest et al. (2005). The expectation that competition is more balanced in the second division can be revealed by having a look at the standard deviation of e.g. the home odds, 2.33 (Bundesliga) and 0.76 (2. Bundesliga), or the higher power of of the table ranking for the odds in the Bundesliga (s. Table 3). Still, competitive balance is only one of many drivers of the home advantage.

Interestingly, a general pattern, that bettors excessively rely on long-term experiences and do not adapt expectations on basis of recent match results, is not persistent in every dimension of our data. Whereas the documented short-term inefficiency results from to less consideration of recent match outcomes in the Bundesliga and 2. Bundesliga, our data also provides evidence of a short-term overestimation of results when it comes to the current shape of the teams - measured in the difference of points gathered throughout the last three matches between home and away team. This variable is highly significantly priced in the betting odds (s. Table 2) but does not affect the actual match outcome (s. e.g. Table 2 in Fischer & Haucap (2020)). Control regressions with further performance covariates support this inefficiency (s. Table A4)[15]. In this case, it seems that bettors especially rely on shortly experienced matches in both divisions - indicating a small sample size neglect or even herding tendencies with regard to just recently overperforming teams which thus seem highly profitable to bet on. Hence, we suggest that betting markets not generally underweigh short-term experiences but seemingly in a completely new and unknown scenario such as ghost games as e.g. present in Table A3. Bettors tend to rely on their long-term experience under unknown circumstances.

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 inefficiency 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 adapt 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 adaption 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.

[15] When controlling for additional covariates in Table A4, we also detect a negative longshot-bias for the Bundesliga - a change in comparison to Table 1.

Also importantly, we want to emphasize that there has been media coverage on the drastic decrease in the home advantage in the premier division during the 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 - an important finding from a welfare perspective. Nevertheless, there is also positive news for efficient market pursuers. The fact that all betting providers analyzed show similar odds - even after the shock - which do not allow for much arbitrage in such extraordinary times underlines the basic smoothness of the market.

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 which could have also contributed to the found effects. Though, there is no clear intuition why more substitutions should have reduced the home advantage. Especially in this context of uncertainty, we further want to emphasize the relevance of private information with regard to e.g. how optimal teams could prepare for the ghost games during the pandemic-induced break which we did not control for. Finally, we are aware that our research only partly is 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 proofessional soccer divisions. The very different match outcomes between the two leagues over the course of the ghost game season did not result in a proper adaption 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 believ that these findings are relevant for all types of prediction markets, especially financial markets, where a slow adaption 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 first German division did not affect bettors' behavior which suggests that inefficiencies may persist even in the presence of reasonably transparent markets. As Germany has been the first country to launch ghost games during the COVID-19 pandemic, we recommend to conduct further research on other countries' leagues to examine whether betting odds are more efficient there - e.g. due to learning from first experiences from Germany.

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A Appendix

Table A1: Descriptive Statistics on Data Used

	Bundesliga							2. Bundesliga						
	N	Mean	St. Dev.	Min	Pctl(25)	Pctl(75)	Max	N	Mean	St. Dev.	Min	Pctl(25)	Pctl(75)	Max
Corona	918	0.090	0.287	0	0	0	1	918	0.088	0.284	0	0	0	1
Δ Attendance	918	0	24,369	−66,736	−16,890	16,890	66,736	918	0	16,232	−46,388	−9,224	9,224	46,388
Match Outcome														
Home Win	918	0.436	0.496	0	0	1	1	918	0.417	0.493	0	0	1	1
Draw	918	0.244	0.430	0	0	0	1	918	0.300	0.458	0	0	1	1
Away Win	918	0.320	0.467	0	0	1	1	918	0.283	0.451	0	0	1	1
Ability Covariates														
Δ Player Value	918	0	8.154	−24.720	−3.428	3.428	24.720	918	0	0.664	−2.650	−0.185	0.185	2.650
Δ Table Ranking	918	0.196	7.155	−17	−5	6	17	918	0.273	7.370	−17	−5	5	17
Δ Points Last Three Matches	918	−0.196	3.463	−9	−3	2	9	918	−0.282	3.062	−9	−3	2	8
Δ Days Pause	918	−0.038	1.007	−7	−1	1	7	918	0.004	1.471	−7	−1	1	7
Geographical Factors														
Distance	918	298.24	146.07	14.507	184.09	417.00	640.69	918	309.89	143.47	5.840	196.54	411.44	628.92
$\lvert\Delta$ Altitude$\times 10^{-2}\rvert$	918	1.474	1.469	0	0.380	2.410	4.870	918	1.703	1.362	0.010	0.655	2.598	5.340
Specific Matches FE														
Derby	918	0.046	0.209	0	0	0	1	918	0.026	0.160	0	0	0	1
Within-Week Match	918	0.071	0.257	0	0	0	1	918	0.075	0.264	0	0	0	1
Match $\geq$ 6pm	918	0.377	0.485	0	0	1	1	918	0.338	0.473	0	0	1	1
New Coach Home Team	918	0.082	0.274	0	0	0	1	918	0.102	0.303	0	0	0	1
Stadium FE														
Capacity	918	47,396	17,751	15,000	30,210	60,559	81,365	918	25,904	13,703	10,700	15,330	31,502	60,559
Share Standing Places	918	0.248	0.150	0	0.175	0.348	0.836	918	0.461	0.190	0.164	0.302	0.625	0.836
Track	918	0.074	0.262	0	0	0	1	918	0.093	0.290	0	0	0	1
Closing Odds														
Home	918	2.891	2.326	1.05	1.69	3.085	22.23	918	2.452	0.763	1.28	1.97	2.74	7.51
Draw	918	4.423	1.622	3.08	3.56	4.578	15.37	918	3.645	0.412	2.85	3.39	3.77	5.94
Away	918	4.697	4.589	1.12	2.39	5.207	41	918	3.556	1.351	1.4	2.703	4.015	11.68
Early Odds														
Betting Provider I: Home	918	2.762	2.067	1.03	1.66	2.9	19	918	2.355	0.737	1.28	1.9	2.55	8
Betting Provider I: Draw	918	4.255	1.506	3	3.5	4.3	21	918	3.519	0.356	3	3.3	3.6	5.75
Betting Provider I: Away	918	4.482	3.940	1	2.4	5	34	918	3.465	1.266	1.36	2.7	3.8	11
Betting Provider II: Home	918	2.821	2.100	1.05	1.683	3	18.45	918	2.437	0.751	1.31	1.973	2.69	8.6
Betting Provider II: Draw	918	4.366	1.499	3.11	3.57	4.54	15	918	3.587	0.369	3.01	3.34	3.71	5.9
Betting Provider II: Away	918	4.693	4.368	1.15	2.42	5.24	37	918	3.586	1.322	1.42	2.782	4.06	10.55
Betting Provider III: Home	918	2.756	2.035	1.03	1.65	2.9	17.5	918	2.37	0.721	1.3	1.95	2.6	8.25
Betting Provider III: Draw	918	4.241	1.417	3	3.5	4.4	18	918	3.491	0.347	2.95	3.3	3.6	5.5
Betting Provider III: Away	918	4.431	3.907	1	2.4	5	41	918	3.443	1.193	1.36	2.7	3.9	9.5
Betting Provider IV: Home	918	2.707	1.819	1.05	1.7	2.85	16	918	2.343	0.647	1.3	1.95	2.6	7.8
Betting Provider IV: Draw	918	4.098	1.209	3.1	3.4	4.237	15	918	3.467	0.330	3	3.3	3.55	5.5
Betting Provider IV: Away	918	4.270	3.635	1	2.4	4.8	37	918	3.301	1.090	1.4	2.6	3.7	9
Betting Provider V: Home	918	2.772	2.156	1.02	1.67	2.88	21	918	2.348	0.711	1.27	1.91	2.6	8.5
Betting Provider V: Draw	918	4.194	1.433	3	3.4	4.33	19	918	3.478	0.349	2.9	3.25	3.6	5.5
Betting Provider V: Away	918	4.524	4.424	1	2.4	5	51	918	3.369	1.209	1.38	2.62	3.787	10
Betting Provider VI: Home	918	2.771	2.119	1.03	1.67	2.9	22	918	2.384	0.697	1.29	1.95	2.6	7.5
Betting Provider VI: Draw	918	4.362	1.596	3	3.5	4.5	23	918	3.587	0.368	3	3.4	3.7	6
Betting Provider VI: Away	918	4.543	4.453	1	2.4	4.8	46	918	3.392	1.154	1.4	2.7	3.8	9.5

Table A2: Determinants of Implicit Probabilities

	Provider I: p_{Hj}		Provider II: p_{Hj}		Provider III: p_{Hj}		Provider IV: p_{Hj}		Provider V: p_{Hj}		Provider VI: p_{Hj}	
	(BL)	(2BL)	(BL)	(2BL)	(BL)	(2BL)	(BL)	(2BL)	(BL)	(2BL)	(BL)	(2BL)
Corona	−0.001	−0.046**	−0.003	−0.051**	−0.002	−0.045**	0.022	−0.034*	0.002	−0.049***	0.0005	−0.045**
	(0.022)	(0.021)	(0.022)	(0.020)	(0.020)	(0.020)	(0.022)	(0.018)	(0.021)	(0.018)	(0.023)	(0.018)
Corona×(#Matchday)	−0.014	0.016	−0.014	0.017	−0.014	0.014	−0.023*	0.011	−0.015	0.017*	−0.014	0.015
	(0.015)	(0.011)	(0.014)	(0.011)	(0.014)	(0.011)	(0.014)	(0.009)	(0.014)	(0.010)	(0.015)	(0.009)
Corona×(#Matchday)^2	0.002	−0.001	0.002	−0.002	0.002	−0.001	0.003	−0.001	0.002	−0.002	0.002	−0.001
	(0.002)	(0.001)	(0.002)	(0.001)	(0.002)	(0.001)	(0.002)	(0.001)	(0.002)	(0.001)	(0.002)	(0.001)
Covariates	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	918	918	918	918	918	918	918	918	918	918	918	918
R^2	0.874	0.673	0.874	0.674	0.878	0.685	0.877	0.697	0.878	0.684	0.876	0.678
Adjusted R^2	0.872	0.667	0.872	0.668	0.876	0.679	0.875	0.691	0.876	0.678	0.874	0.673

Note: *p<0.1; **p<0.05; ***p<0.01. OLS Regressions with heteroskedasticity-robust standard errors clustered on the home team and season level. For covariates, s. Table 2.

Table A3: Relevance of the Lagged Difference Between Real and Expected Match Outcomes

	p_{Hj}		p_{Dj}		p_{Aj}	
	(BL)	(2BL)	(BL)	(2BL)	(BL)	(2BL)
Corona	-0.005	-0.011	-0.014^{**}	-0.008^{**}	0.031^{***}	0.015
	(0.027)	(0.011)	(0.006)	(0.003)	(0.009)	(0.013)
Corona$\times\Delta$Home Win$_{t-1}$	-0.045	-0.024				
	(0.091)	(0.040)				
Corona$\times\Delta$Home Win$_{t-2}$	0.138	-0.078^{**}				
	(0.152)	(0.033)				
Corona$\times\Delta$Draw$_{t-1}$			0.060^{**}	0.038^{**}		
			(0.029)	(0.017)		
Corona$\times\Delta$Draw$_{t-2}$			0.052	0.012		
			(0.034)	(0.017)		
Corona$\times\Delta$Away Win$_{t-1}$					0.050	0.007
					(0.082)	(0.029)
Corona$\times\Delta$Away Win$_{t-2}$					0.058	-0.059
					(0.085)	(0.058)
Covariates	Yes	Yes	Yes	Yes	Yes	Yes
Observations	918	918	918	918	918	918
R^2	0.846	0.627	0.645	0.297	0.830	0.626
Adjusted R^2	0.843	0.620	0.638	0.284	0.827	0.619

Note: *p<0.1; **p<0.05; ***p<0.01. OLS Regressions with heteroskedasticity-robust standard errors. Clusters on home team and season level for p_{Hj} and p_{Dj} while on away team and season level for p_{Aj} respectively. For covariates, s. Table 2 except for the removed interations with the running matchday index. Δ gives the difference between the realized frequency and the implicit probability from the odds for each match outcome (home win, draw, away win) on the matchday level. t is the time index representing the matchday. That is, if the average implied probability for a home win is 45% at a specific matchday but e.g. only 33% matches end with a home win, Δ Home Win will be -0.12=12%.

Table A4: Role of Short-Term Expectations

	Win	
	(BL)	(2BL)
p_{ij}	0.821***	0.634***
	(0.137)	(0.134)
Home	0.029	0.053**
	(0.025)	(0.024)
Home×Corona	−0.302***	0.066
	(0.059)	(0.131)
Home×Corona×(#Matchday)	0.057**	−0.007
	(0.023)	(0.022)
(Δ Average Attendance)$\times 10^{-5}$	−0.039	0.062
	(0.046)	(0.102)
Δ Player Value	0.005**	−0.013
	(0.002)	(0.025)
Δ Table Ranking	−0.005**	−0.001
	(0.002)	(0.002)
Δ Points Last Three Matches	−0.006*	−0.010***
	(0.003)	(0.003)
Δ Days Pause	−0.003	−0.003
	(0.008)	(0.007)
Observations	1836	1836
McFadden R^2	0.126	0.031

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.

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