Causal effects of an absent crowd on performances and refereeing decisions during Covid-19

Alex Bryson, Peter Dolton, J. James Reade, Dominik Schreyer, Carl Singleton*

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Abstract

The Covid-19 pandemic has induced worldwide natural experiments on the effects of crowds. We exploit one of these experiments that took place over several countries in almost identical settings: professional football matches played behind closed doors within the 2019/20 league seasons. We find large and statistically significant effects on the number of yellow cards issued by referees. Without a crowd, fewer cards were awarded to the away teams, reducing home advantage. These results have implications for the influence of social pressure and crowds on the neutrality of decisions.

Keywords: Attendance; Coronavirus; Covid-19; Home advantage; Natural Experiments; Referee Bias; Social Pressure

JEL Codes: C90, D91, L83, Z20

* a.bryson@ucl.ac.uk, UCL's Social Research Institute, UCL, 20 Bedford Way, London, WC1H 0AL. P.Dolton@sussex.ac.uk, Department of Economics, University of Sussex, Brighton, BN1 9SL. j.j.reade@reading.ac.uk & c.a.singleton@reading.ac.uk (corresponding author), Department of Economics, University of Reading, Whiteknights Campus, RG6 6UA, UK. dominik.schreyer@whu.edu, Center for Sports and Management (CSM), WHU – Otto Beisheim School of Management, Erkrather Str. 224a, 40233 Düsseldorf, Germany.

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1. Introduction

In a variety of settings, economic and social actors are reliant on adjudicators to apply rules in an impartial manner, with neither fear nor favour. The impacts on these judgments of different forms of pressure are usually difficult to disentangle, but the Covid-19 pandemic has created the opportunity to observe judgments when social pressure has been removed.

Sports can do a lot for economics, providing rich environments to learn about economic behaviour and uncover causal relationships (Palacios-Huerta, 2016; Bar-Eli et al., 2020). There is already a well-developed literature investigating the effects of social pressure in sports on the decision making of participants and on contest outcomes (e.g., Dohmen and Sauermann, 2016; Garicano et al., 2005; Sutter and Kocher, 2004). Past studies have shown that playing behind closed doors, in one-off matches, especially reduces aspects of football home advantage (Pettersson-Lidbom and Priks, 2010; Reade et al., 2020). They suggested that the lack of social pressure from the crowd affects the referee, with fewer punishments for foul play for the team playing away from home. But it is unclear from one-off matches whether the driver of reduced home advantage was the lack of social pressure or unfamiliarity with playing and officiating without a crowd.

In this study, we exploit the natural experiment arising from the Covid-19 induced near-complete absence of fans from sporting arenas.[2] Using data from 6,481 football matches played before and after the mid-season shutdown in 17 countries, including 1,498 played without spectators, we find that the absence of crowds reduced home advantage persistently, with the gap between home and away team punishments significantly narrowing.

Besides contributing to the wider economics literature from field experiments on the impacts of social pressure (see the summary by Bursztyn and Jensen, 2017), answers to these questions are of direct interest to the multi-billion-dollar sports industry, because they inform understanding of the role that officials play. More broadly, those running sports have a responsibility to the fans and others who pay substantial sums, either on season tickets or TV subscriptions, to see high quality contests that are competitive but neutrally refereed. Betting and financial markets are also interested in any margins associated with sporting outcomes and the nature of referee decisions. Recent articles on football played without crowds in the

[2] Covid-19 led to most professional football being completely suspended and then resumed without crowds. In the English Premier League, for example, the last match was played on 9th March, then the sport was locked down, and the 2019/20 season did not resume until 17th June. This 13-week hiatus was mirrored in many other countries across Europe and further afield.

Economist and Financial Times are testament to the widespread interest in these matters beyond the sports pages.[3] This study also contributes rare evidence from a natural experiment on whether individuals make different and potentially biased decisions in situations where there is some form of salient group membership (see the summary by Charness and Sutter, 2012).

2. Data

Our main dataset contains 6,481 matches played in twenty-three professional leagues and seventeen countries in the 2019/20 season (Table 1). We focus on this set of leagues and matches to abstract from potential between-season confounding trends in match outcomes, such as the introduction of video assistant referees, earpieces and microphones for referees, and league instructions on how to interpret the rules. In other words, we will mostly use only within season variation as we need to be sure that other factors remain constant. The matches in the dataset involved 369 football teams and were officiated by 472 referees, with one team playing in their home stadium and another team visiting. The studied leagues all had at least ten matches played without spectators in the 2019/20 season.[4] 1,498 (23%) of the matches were played behind closed doors. Almost all matches played from mid-May 2020 had zero crowd attendance, with exceptions in Australia, Denmark, Hungary, Poland, Serbia and Slovenia, where some matches were played with small restricted crowds. Over all leagues, the average crowd attendance was approximately 13,500 before the shutdown and just 200 after (but zero in eleven of the seventeen countries).

The first two rows of Table 1 indicate that the share of matches ending in a home win fell from 43.8% before the shutdown to 41.2% after. Figure 1 shows that the mean differences between teams in the numbers of goals scored and yellow cards received within matches decreased and increased, respectively, in most countries after the shutdown, suggesting that home advantage was reduced.[5] Although other changes to the leagues could have affected outcomes, such as the length of the mid-season break in training and allowing more in-match

[3] See 'Graphic detail: Covid-19 and football', in *The Economist*, 25th July 2020 and 'Net benefit: Home advantage in play but football refs are fairer', in the *Financial Times*, 18th July 2020.
[4] We dropped matches played in Turkey and Nicaragua due to attendance data being missing for many games. We also discarded leagues which run on a calendar year basis, such as South Korea, which had few matches in their seasons before Covid-19. See Online Appendix Figure B1 for the distribution of matches with fans and behind closed doors throughout the 2019/20 season.
[5] Referees issue yellow cards as punishments to players deemed to have engaged in foul play, time-wasting or dissent. If a player is issued with two yellow cards, then they are sent off and cannot return to the field of play. Particularly serious offenses result in direct red cards.

substitutions, these differed across countries; the only common change was the effective removal of stadium crowds.

Table 2 shows the simple mean differences in nine match outcomes, comparing those played with and without a crowd in 2019/20.[6] Matches played behind closed doors were three percentage points less likely to end in a home win (p-value< 0.1). In these matches, significantly fewer yellow cards were awarded to the away teams for foul play by the referees compared with when crowds were present, leading the gap between the home and away team yellow cards, normally negative, to increase by around a third of a card (p-value< 0.01). There was a small decrease in the numbers of red cards issued to away teams behind closed doors compared with when a crowd was present in the 2019/20 season (p-value< 0.05).

3. Estimation and Results

The raw differences described above do not control for the scheduling of leagues before and after shutdown. It is also unclear whether these differences can be accounted for by the general variation in crowd size (e.g., Buraimo et al., 2010), or from some disproportionate effect of there being no crowd at all. For six different outcome variables (home win vs not, goal difference, total cards, home and away yellow cards, and the difference between them), we estimate the following using ordinary least squares (OLS):

$$y_{ijkm} = \beta_1 BCD_{ijkm} + \beta_2 ATT_{ijkm} + h_i + a_j + r_k + \varepsilon_{ijkm}\ , \qquad (1)$$

where y denotes the match outcomes; *BCD* is a dummy indicator that takes the value of one if a match is played behind closed doors, and zero otherwise; *ATT* measures crowd attendance in tens of thousands; h_i and a_j are fixed effects, capturing the home and away teams; and r_k is a referee fixed effect - these address the general tendency of some teams or referees, for example, to earn and award more yellow cards. Subscripts are for: home team i, away team j, referee k, and match m. The country and league fixed heterogeneities are absorbed by the sets of fixed effects.

The results from estimating Equation (1) are presented in Table 3. They suggest that we can explain between 25-34% of the variance depending on the outcome examined. Accounting for team and referee heterogeneity and clustering the standard errors, neither playing behind

[6] See Online Appendix Figure A2 for the full distributions for home and away goals, and home and away yellow cards.

closed doors nor the regular variation in the size of the crowd significantly affected the likelihood of a home win, the goal difference or the total goals scored in matches played in the 2019/20 season (β_1, Table 3, columns I-III). Significantly fewer yellow cards were awarded to the away team without any crowd at all (p-value< 0.01; column V), contributing to the gap in yellows between the home and away teams narrowing by around a third compared with there being a crowd (p-value< 0.01; column VI). The normal variation in crowd attendance did not significantly affect this gap. These results suggest that the total absence of the generally home-team-supporting crowd reduced the social pressure on referees to punish the away team more harshly, leading to fairer decisions. It is less likely that the mechanism behind this is a change in the performances of players, since the final scorelines of matches were not significantly different without fans.[7] We also tested the sensitivity of these results to adding regressors in Equation (1) for the cumulative number of matches played by the teams and officiated by the referees behind closed doors. These were insignificant for all outcomes, suggesting that there was no re-familiarisation to the home stadium surroundings with fans absent. This supports the conclusion that the lack of social pressure from the home crowd was the cause of different punishment patterns, compared with when crowds were present.

The results are approximately identical when we estimate the Poisson model equivalents of Equation (1) (Online Appendix Table A1). The significant reduction in the punishment gap between home and away teams when the crowd was absent is robust to weighting each home team or each country equally in Equation (1) (Online Appendix Table A2 & A3). We also relax the within season focus and add matches to the dataset from the past five seasons in each league. This allows us to check the robustness of the model specification. In Online Appendix Table A4, find that the main result of relatively fewer yellow cards for away teams in matches behind closed doors is robust to country-month fixed effects; i.e., this is not driven by changes in play and decision-making as football seasons reach their conclusions, when the consequences of individual performances and decisions are clearer (e.g., winning championships or relegation).[8] In Online Appendix Table A5, we control for the fixed

[7] This is consistent with the studies of pre-Covid-19 football by Pettersson-Lidbom and Priks, 2010, and Reade et al., 2020. For smaller sets of leagues, with their better data availability, these studies also found no effects of the absent crowd on other within match outcomes, such as the numbers of shots on goal and the balance of ball possession.

[8] There are some qualitative differences in the results shown in Online Appendix Tables A4 & A5 compared with Table 3. For example, there is a significant effect of closed doors football on the likelihood of a home win in A4. However, we would caution against reading too much into this, as comparing football outcomes across seasons could be less robust than within seasons, as the makeup of leagues changes and rules are altered, and referees have been instructed to interpret them differently in different seasons.

characteristics of matchups between home and away teams across seasons. The main results are robust to the possibility that some matchups, e.g., local derbies such as A.C. Milan vs Inter Milan, have different characteristics and may have taken place more or less often behind closed doors. In Online Appendix Table A6, we only consider matches taking place on a weekend, as research has suggested systematically different match outcomes on weekdays (e.g., Goller and Krumer, 2020) and a greater share of matches took place on weekdays after Covid-19. The results are qualitatively unchanged, with slightly larger estimated effects of empty stadiums on weekends. Finally, in Online Appendix Table A7, we re-estimate Equation (1) for only the countries where small crowds returned after the shutdown, adding the term $\beta_3 ATT * COVID_{ijkm}$, where $COVID$ is an indicator variable for the post shutdown period. We find that β_3 is generally insignificant, such that there was no difference in how the normal variation in crowds affected outcomes after the shutdown. In this limited set of countries, with normally smaller crowds, the disproportionate effect of playing behind closed doors on away yellow cards is insignificant. It is possible that the absence of social pressure may have been felt less by the referees in these countries, since they normally work in front of relatively small and sparse crowds anyway.

4 Comparison with other studies

The results here support the conclusions from Pettersson-Lidbom and Priks (2010) and Reade et al. (2020), who only looked at small numbers of one-off and sporadic matches played behind closed doors in specific leagues. There are also three studies of the so-called 'Ghost Games' taking place in Germany without crowds since Covid-19 (Endrich and Gesche, 2020; Fischer and Haucap, 2020; Dilger and Vischer, 2020). All those football matches are including in our sample, and to compare we re-estimate Equation (1) for Germany only (Online Appendix Table A10). The estimated positive effect of playing behind closed doors on the gap in yellow cards between the home and away teams was larger in Germany than among all countries, at almost half a card (p-value< 0.05; column VI). This is almost identical to the most comparable estimate in Endrich and Gesche (2020), despite the differences in our methodology and the addition of the third tier of professional German football here. Our estimate is also less precise despite using more German matches, perhaps due to addressing more clusters in the data.[9]

[9] Note that in Germany there were nine rounds of matches played behind closed doors in 2019/20, meaning that the estimates are based on only four or five matches played in each of the stadiums without fans. This small

Endrich and Gesche (2020) do not control for the regular variation in stadium attendances within the football season. Instead, our estimates give the disproportionate effect of playing behind closed doors above any general effect of reducing the crowd's size from thousands to zero. Further, whereas we control for home and away team specific fixed effects, thus addressing stadium heterogeneity, Endrich and Gesche (2020) only address general team-specific heterogeneity. Our results can be interpreted as the impact on match outcomes within a stadium from playing with no crowd. Endrich and Gesche (2020) add in-match controls to their regression model, such as the numbers of fouls awarded against the teams. With no crowd, they estimate that one additional foul is awarded against the home team relative to the away team, and that each additional foul generally translates into around 0.1 yellow cards. In other words, Endrich and Gesche (2020) suggest that German referees not only punish the home team relatively more severely but also more often without a crowd. We did not include such in-match controls in our regression as the data were not available for all the 17 countries and 23 leagues in our study. But we are reassured that Endrich and Gesche (2020) found the yellow cards effects of ghost games were barely changed when all other in-match controls besides fouls were omitted. This is consistent with our further finding here that overall match scorelines appear to be unaffected by playing without a crowd.[10]

Interestingly, Endrich and Gesche (2020) found that the effects of closed doors football on match outcomes were larger in German stadiums according to the normal pre-Covid-19 number of away supporters. They suggested that this is consistent with social pressure from the home-team-supporting crowd being the mechanism driving the effects. Since German crowds are generally larger, this may contribute to why we find smaller general effects of crowds across the 23 countries studied here.

To the best of our knowledge, there are at least four other studies which have considered the closed doors or lockdown effects in football since Covid-19 on leagues in multiple countries. Ferraresi and Gucciardi (2020), McCarrick et al. (2020) and Scoppa (2020) only focus on a few of the top European leagues, but their results are generally consistent with our own. Cueva's (2020) study of 41 leagues and 30 countries is perhaps most similar to this study. Unlike our empirical strategy, and thus notwithstanding significant changes in rules and referee

number of matches in any given stadium and league is why we prefer to pool estimates across the various football leagues.

[10] However, emphasising the potential difficulties in focusing on just one country, Online Appendix Table A10 shows a marginally statistically significant of playing behind closed doors on the goal difference in German matches, which we did not find when pooling countries.

instructions across seasons, he uses variation within and between seasons, extending the pre-lockdown 'control' period as far back as 2012. He finds significant effects of lockdown, not only on yellow cards but also red cards and match results. Although Cueva lacks attendance data, he defines leagues where limited crowds were allowed in stadiums after Covid-19 as being in "partial lockdown". He finds that the closed doors effects are weaker or reversed in these matches, which is consistent with our results in Online Appendix Table A7, where we focus on leagues which had both closed doors football and a known positive number of spectators after Covid-19.

5. Conclusion and discussion

In this study, we have used the natural experiment of football matches played behind closed doors to retrieve estimates of the extent to which a crowd impacts on final outcomes and referee decisions. We find that the absence of a partisan home crowd has no effect on the final match scoreline, but it does result in a reduction of one-third of a yellow card for away teams relative to home teams. We suggest that these results are causally due to a complete lack of crowd pressure and the influence that this normally has on a referee to make decisions which favour the home team.

Our findings are important for economics, not just for sports fans. Relatively little experimental evidence exists about how a partisan audience or crowd may influence outcomes in a way that unfairly benefits some competitors. This suggests that the location of events can be important. It justifies why neutral venues are often sought for the finals of key competitions, with equal allocations of seats for the supporters of the participating individuals or teams (e.g., sports cup finals or political debates).

Our paper also contributes to what is known about the way in which referees and judges make decisions. We have found causal evidence suggesting that they can be unfairly biased in favour of one side or another by the presence of external crowds. This has implications for the judging and citing of any competitive event or outcome, when it is anticipated that the audience could be partisan, for example, in the Olympics (Balmer et al., 2003), in reality TV contests (Collins et al., 2019), or even in a jury trial. More generally, any contest with adversaries and a crowd present needs to examine the fairness of any justice which may be administered.

A further implication of our findings is that they call into question the neutrality of referees or arbitrators in the presence of a crowd. This means that we should be cognisant of the possible influence that crowds can have on arbitrated, judged or refereed decisions.

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Tables

TABLE 1: Sample descriptive statistics for professional football in the 2019/20 season

	Before shutdown	After shutdown
Home win %	43.8	41.2
Mean attendance (1,000s)	13.5	0.2
Number of…		
Teams	370	370
Referees	452	403
Leagues	23	23
Countries	17	17
Matches behind closed doors	73	1,425
All matches	4,915	1,566

Notes: author calculations using data from worldfootballdata.net, accessed 3/8/2020. See Figure 1 for a list of the domestic leagues represented by each country and Online Appendix Table A8 for descriptives and sample sizes by country. Mean attendance calculations include matches played behind closed doors, i.e., zero values. 'Shutdown' refers to the period from approximately mid-March to mid-May where no professional football was played in these countries (see Online Appendix Figure B1).

TABLE 2 Differences in sample means, matches played behind closed doors vs with fans, 2019/20 season

	Mean difference (Behind closed doors - with crowd)
Home win share	-0.03*
Goal diff. (Home - Away)	-0.07
Total goals	0.08*
Home yellows	0.07*
Away yellows	-0.29***
Yellows diff. (Home - Away)	0.36***
Total yellows (Home + Away)	-0.22***
Home reds	0.01
Away reds	-0.02**

Notes: ***, **, * indicate significance from zero, i.e., no difference (behind closed doors minus with fans), at 1%, 5% and 10% levels, respectively, two-sided unpaired *t*-tests. Yellows includes second yellow cards. See Table 1 and Figure 1 for dataset description. See Online Appendix Table A9 for these statistics and others by country.

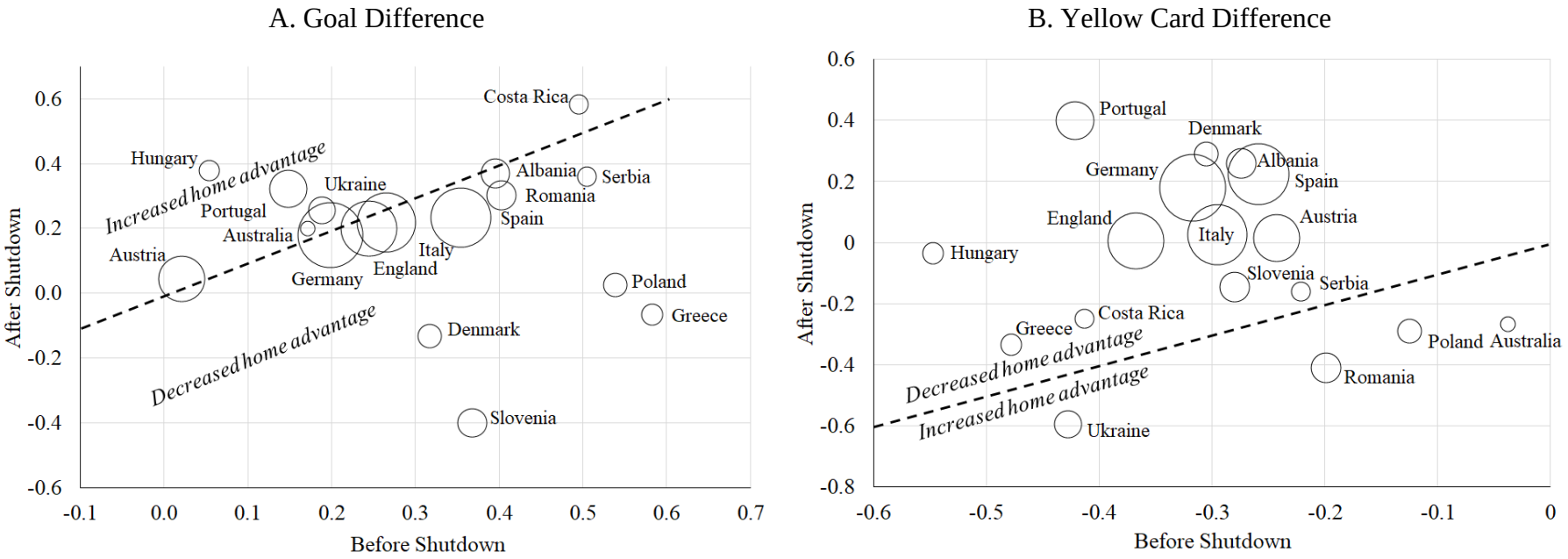
TABLE 3: Estimated effects of playing football behind closed doors on match outcomes

	Home win share	Goal diff. (Home-Away)	Total goals	Home yellows	Away yellows	Yellows diff. (Home-Away)
	(I)	(II)	(III)	(IV)	(V)	(VI)
Closed doors ($\hat{\beta}_1$)	-0.026	-0.064	0.036	0.099*	-0.221***	0.320***
	(0.02)	(0.07)	(0.07)	(0.05)	(0.06)	(0.07)
Attendance (10,000s) ($\hat{\beta}_2$)	-0.006	0.002	-0.004	0.037	0.079***	-0.042
	(0.01)	(0.04)	(0.04)	(0.03)	(0.03)	(0.03)
Home team fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Away team fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Referee fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
R^2	0.281	0.336	0.240	0.316	0.302	0.240
N	6,316	6,316	6,316	6,316	6,316	6,316

Notes: ***, ** indicate significance from one at 1%, 5% and 10% levels, respectively, two-sided tests. Standard errors robust to three-way clustering (home team, away team, referee) are displayed in parentheses. OLS estimates of Equation 1. Yellows includes second yellow cards. See Table 1 and Figure 1 for dataset description.

Figures

FIGURE 1: Average match differences between home and away team outcomes within professional football leagues, 2019/20 season, before and after shutdown.



Notes: author calculations using data from worldfootballdata.net, accessed 3/8/2020. Averages of Home minus Away outcomes over all matches in sample periods. Dashed line is $y = x$. Bubbles are proportional in area to the number of matches in the dataset in each country after 1st April 2020, see also Table 1. Leagues represented: Australia, A-League; Albania, Superliga; Austria, Bundesliga and Bundesliga 2; Costa Rica, Primera Divisíon; Denmark, Super-liga; England, Premier League and Championship; Germany, Bundesliga, 2. Bundesliga and 3. Liga; Greece, Super League; Hungary, OTP Bank Liga; Italy, Serie A and Serie B; Poland, Ekstraklasa; Portugal, Primeira Liga; Romania, Liga 1; Serbia, SuperLiga; Slovenia, PrvaLiga; Spain, La Liga and Segunda Divisíon; Ukraine, Premier League.

Experimental effects of crowd absence on performances and refereeing decisions during Covid-19

Alex Bryson, Peter Dolton, J. James Reade, Dominik Schreyer, Carl Singleton*

Online Appendix

A. Additional Tables

TABLE A1: Estimated effects of playing football behind closed doors on match outcomes (Poisson regression)

	Total goals	Home yellows	Away yellows
	(III)	(IV)	(V)
Closed doors ($\hat{\beta}_1$)	0.011	0.045*	-0.087***
	(0.03)	(0.02)	(0.03)
Attendance (10,000s) ($\hat{\beta}_2$)	-0.003	0.018	0.045***
	(0.01)	(0.01)	(0.01)
Home team fixed effects	Yes	Yes	Yes
Away team fixed effects	Yes	Yes	Yes
Referee fixed effects	Yes	Yes	Yes
Pseudo R^2	0.063	0.085	0.076
N	6,316	6,316	6,316

Notes: ***, ** indicate significance from one at 1%, 5% and 10% levels, respectively, two-sided tests. Standard errors robust to three-way clustering (home team, away team, referee) are displayed in parentheses. Poisson regression estimates of Equation 1. Yellows includes second yellow cards. See Table 1 and Figure 1 for dataset description.

* a.bryson@ucl.ac.uk, UCL's Social Research Institute, UCL, 20 Bedford Way, London, WC1H 0AL. P.Dolton@sussex.ac.uk, Department of Economics, University of Sussex, Brighton, BN1 9SL. j.j.reade@reading.ac.uk & c.a.singleton@reading.ac.uk (corresponding author), Department of Economics, University of Reading, Whiteknights Campus, RG6 6UA, UK. dominik.schreyer@whu.edu, Center for Sports and Management (CSM), WHU – Otto Beisheim School of Management, Erkrather Str. 224a, 40233 Düsseldorf, Germany.

TABLE A2: Estimated effects of playing football behind closed doors on match outcomes: equal home team weighting

	Home win share	Goal diff. (Home-Away)	Total goals	Home yellows	Away yellows	Yellows diff. (Home-Away)
	(I)	(II)	(III)	(IV)	(V)	(VI)
Closed doors ($\hat{\beta}_1$)	-0.032	-0.075	0.039	0.091*	-0.215**	0.306***
	(0.02)	(0.08)	(0.07)	(0.05)	(0.06)	(0.07)
Attendance (10,000s) ($\hat{\beta}_2$)	-0.008	-0.000	-0.003	0.032	0.082***	-0.049
	(0.01)	(0.04)	(0.04)	(0.03)	(0.03)	(0.03)
Home team fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Away team fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Referee fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
R^2	0.293	0.349	0.251	0.324	0.308	0.250
N	6,316	6,316	6,316	6,316	6,316	6,316

Notes: ***, ** indicate significance from one at 1%, 5% and 10% levels, respectively, two-sided tests. Standard errors robust to three-way clustering (home team, away team, referee) are displayed in parentheses. OLS estimates of Equation 1, with observations weighted according to $\sqrt{(\alpha_i N_I / \sum_i \alpha_i)}$, where $\alpha_i = 1/N_i$ is the inverse of the total number of matches in the sample played by the home team in their own stadium and N_I is the number of distinct home teams; we weight teams equally in the regression. Yellows includes second yellow cards. See Table 1 and Figure 1 for dataset description, and Table 3 for comparable estimates without weighting.

TABLE A3: Estimated effects of playing football behind closed doors on match outcomes: equal country weighting

	Home win share	Goal diff. (Home-Away)	Total goals	Home yellows	Away yellows	Yellows diff. (Home-Away)
	(I)	(II)	(III)	(IV)	(V)	(VI)
Closed doors ($\hat{\beta}_1$)	-0.054**	-0.148	0.134	0.085	-0.158**	0.242***
	(0.03)	(0.09)	(0.10)	(0.06)	(0.07)	(0.08)
Attendance (10,000s) ($\hat{\beta}_2$)	-0.019*	-0.043	0.012	0.061*	0.150***	-0.089**
	(0.01)	(0.04)	(0.04)	(0.03)	(0.04)	(0.05)
Home team fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Away team fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Referee fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
R^2	0.329	0.377	0.254	0.334	0.320	0.272
N	6,316	6,316	6,316	6,316	6,316	6,316

Notes: ***, ** indicate significance from one at 1%, 5% and 10% levels, respectively, two-sided tests. Standard errors robust to three-way clustering (home team, away team, referee) are displayed in parentheses. OLS estimates of Equation 1, with observations weighted according to $\sqrt{(\alpha_c N_c / \sum_c \alpha_c)}$, where $\alpha_c = 1/N_c$ is the inverse of the total number of matches in the sample played in country c and N_c is the number of distinct countries; we weight countries equally in the regression. Yellows includes second yellow cards. See Table 1 and Figure 1 for dataset description, and Table 3 for comparable estimates without weighting.

TABLE A4: Estimated effects of playing football behind closed doors on match outcomes, 2015/16 to 2019/20 seasons: controlling for seasonality

	Home win share	Goal diff. (Home-Away)	Total goals	Home yellows	Away yellows	Yellows diff. (Home-Away)
	(I)	(II)	(III)	(IV)	(V)	(VI)
Closed doors ($\hat{\beta}_1$)	-0.087***	-0.167*	-0.147	0.221***	-0.110	0.330***
	(0.02)	(0.09)	(0.10)	(0.07)	(0.07)	(0.08)
Attendance (10,000s) ($\hat{\beta}_2$)	-0.007	0.035	-0.022	0.091***	0.087***	0.004
	(0.01)	(0.03)	(0.04)	(0.02)	(0.03)	(0.02)
Home team-season fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Away team-season fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Referee fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Country-month effects	Yes	Yes	Yes	Yes	Yes	Yes
R^2	0.257	0.326	0.215	0.311	0.299	0.230
N	25,369	25,369	25,369	25,369	25,369	25,369

Notes: ***, ** indicate significance from one at 1%, 5% and 10% levels, respectively, two-sided tests. Standard errors robust to three-way clustering (home team, away team, referee) are displayed in parentheses. OLS estimates of Equation 1, with the addition of country-month fixed effects, and home team-season and away team-season fixed effects. Due to collinearity with the 2020 closed doors period for some countries, months May-July are combined as one period for the 'country-month' fixed effects. Yellows includes second yellow cards. See Table 1 and Figure 1 for dataset description.

TABLE A5: Estimated effects of playing football behind closed doors on match outcomes, 2015/16 to 2019/20 seasons: controlling for matchups

	Home win share	Goal diff. (Home-Away)	Total goals	Home yellows	Away yellows	Yellows diff. (Home-Away)
	(I)	(II)	(III)	(IV)	(V)	(VI)
Closed doors ($\hat{\beta}_1$)	-0.069***	-0.126**	-0.066	0.239***	-0.094	0.333***
	(0.03)	(0.09)	(0.09)	(0.07)	(0.07)	(0.09)
Attendance (10,000s) ($\hat{\beta}_2$)	0.013*	0.088***	0.008	0.046**	0.065***	-0.018
	(0.01)	(0.03)	(0.03)	(0.02)	(0.02)	(0.02)
Matchup fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Referee fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Country-month effects	Yes	Yes	Yes	Yes	Yes	Yes
R^2	0.433	0.476	0.398	0.465	0.463	0.412
N	25,399	25,399	25,399	25,399	25,399	25,399

Notes: ***, ** indicate significance from one at 1%, 5% and 10% levels, respectively, two-sided tests. Standard errors robust to two-way clustering (matchup, referee) are displayed in parentheses. OLS estimates of Equation 1, with the addition of country-month fixed effects and replacing home and away team fixed effects with matchup fixed effects, i.e., the unique combination of a home and away team, e.g., FC Barcelona hosting Real Madrid C.F. Due to collinearity with the 2020 closed doors period for some countries, months May-July are combined as one period for the 'country-month' fixed effects. Yellows includes second yellow cards. See Table 1 and Figure 1 for dataset description.

TABLE A6: Estimated effects of playing football behind closed doors on match outcomes: weekend matches only (Saturday and Sunday)

	Home win share	Goal diff. (Home-Away)	Total goals	Home yellows	Away yellows	Yellows diff. (Home-Away)
	(I)	(II)	(III)	(IV)	(V)	(VI)
Closed doors ($\hat{\beta}_1$)	-0.029	0.047	0.022	0.167**	-0.250**	0.417***
	(0.03)	(0.10)	(0.12)	(0.08)	(0.09)	(0.11)
Attendance (10,000s) ($\hat{\beta}_2$)	-0.004	-0.058	-0.55	0.067*	0.076**	-0.009
	(0.01)	(0.04)	(0.04)	(0.04)	(0.03)	(0.05)
Home team fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Away team fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Referee fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
R^2	0.362	0.409	0.312	0.393	0.373	0.320
N	4,273	4,273	4,273	4,273	4,273	4,273

Notes: ***, ** indicate significance from one at 1%, 5% and 10% levels, respectively, two-sided tests. Standard errors robust to three-way clustering (home team, away team, referee) are displayed in parentheses. See Table 1 and Figure 1 for dataset description, and Table 3 for comparable estimates for matches on any day of the week.

TABLE A7: Estimated effects of playing football behind closed doors or with restricted crowd numbers on match outcomes (Australia, Denmark, Hungary, Poland Serbia and Slovenia)

	Home win share	Goal diff. (Home-Away)	Total goals	Home yellows	Away yellows	Yellows diff. (Home-Away)
	(I)	(II)	(III)	(IV)	(V)	(VI)
Closed doors ($\hat{\beta}_1$)	-0.177***	-0.501*	0.129	-0.215	-0.112	-0.103
	(0.06)	(0.26)	(0.21)	(0.16)	(0.14)	(0.23)
Attendance (10,000s) ($\hat{\beta}_2$)	-0.012	-0.087	0.003	-0.036	0.523**	-0.559***
	(0.05)	(0.14)	(0.19)	(0.13)	(0.20)	(0.19)
Attendance × COVID (10,000s) ($\hat{\beta}_3$)	0.021	0.312	-0.570*	0.429	0.349	0.081
	(0.18)	(0.48)	(0.34)	(0.43)	(0.45)	(0.53)
Home team fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Away team fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Referee fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
R^2	0.340	0.362	0.248	0.342	0.319	0.318
N	1,147	1,147	1,147	1,147	1,147	1,147

Notes: ***, ** indicate significance from one at 1%, 5% and 10% levels, respectively, two-sided tests. Standard errors robust to three-way clustering (home team, away team, referee) are displayed in parentheses. OLS estimates of Equation 1, with an additional term $\beta_3 ATT * COVID_{ijkm}$. Yellows includes second yellow cards. See Table 1 and Figure 1 for dataset description, and Table 3 for comparable estimates for all countries.

TABLE A8: Sample descriptive statistics for professional football leagues in the 2019/20 season: by country

	Home win %		Mean attendance (1,000s)		Number of…			Number of matches		
	Before shutdown	After shutdown	Before shutdown	After shutdown	Teams	Referees	Leagues	Total	Behind closed doors	After shutdown
Albania	46.8	46.3	1.5	0.0	10	19	1	178	54	54
Australia	47.2	40.0	8.9	0.9	11	13	1	120	11	15
Austria	35.2	37.5	3.6	0.0	28	31	2	420	136	136
Costa Rica	48.6	50.0	2.5	0.0	12	20	1	242	30	24
Denmark	49.1	31.6	6.2	2.2	14	15	1	205	14	38
England	43.4	42.0	26.8	0.0	44	40	2	932	200	200
Germany	40.8	39.2	22.3	0.0	56	67	3	992	274	273
Greece	48.3	30.0	6.4	0.0	14	45	1	212	36	30
Hungary	41.2	48.3	3.2	2.9	12	15	1	177	10	29
Italy	42.9	43.1	15.3	0.0	40	46	2	760	247	225
Poland	50.0	34.2	9.1	2.6	16	15	1	246	15	38
Portugal	39.8	44.4	11.2	0.0	18	21	1	306	90	90
Romania	45.8	46.4	3.5	0.0	14	24	1	252	60	56
Serbia	51.4	52.0	2.0	1.2	16	27	1	233	17	25
Slovenia	44.8	30.9	1.4	0.1	10	19	1	180	18	55
Spain	43.1	42.4	18.2	0.0	42	42	2	841	232	231
Ukraine	44.9	44.7	4.0	0.0	12	23	1	185	54	47
All leagues	43.8	41.2	13.5	0.2	370	472	23	6,481	1,498	1,566

Notes: author calculations using data from worldfootballdata.net, accessed 3/8/2020. See Figure 1 for a list of the domestic leagues represented by each country. Mean attendance calculations include matches played behind closed doors, i.e., zero values. 'Shutdown' refers to the period from approximately mid-March to mid-May where no professional football was played in these countries (see Online Appendix Figure B1).

TABLE A9: Differences in sample means, matches played behind closed doors vs with fans, 2019/20 season: by country

	Home win share	Goal diff. (Home-Away)	Total goals	Home yellows	Away yellows	Yellows diff. (Home-Away)	Home reds	Away reds
Albania	-0.00	-0.02	0.83***	0.03	-0.51**	0.53	-0.02	-0.00
Australia	-0.10	-0.19	0.55***	-0.08	0.05	-0.13	-0.06	-0.08
Austria	0.02	0.02	-0.12	0.17	-0.08	0.26	0.03	0.01
Costa Rica	-0.02	0.22	0.30	0.21	-0.06	0.26	-0.05	-0.05
Denmark	-0.26*	-0.63	-0.70	0.39	-0.28	0.67	-0.06	-0.10
England	-0.01	-0.04	0.00	-0.13	-0.50***	0.37***	-0.02	0.00
Germany	-0.01	-0.02	-0.08	0.25***	-0.24**	0.49***	-0.02	-0.03
Greece	-0.12	-0.36	-0.09	-0.14	-0.19	0.04	0.07	-0.18**
Hungary	-0.24	-0.64	-0.27	-0.29	-0.89**	0.60	0.10	-0.14
Italy	-0.00	-0.03	0.20	-0.14	-0.46***	0.32**	0.00	-0.07**
Poland	-0.29**	-0.77*	0.53	-0.32	-0.12	-0.19	0.00	0.02
Portugal	0.05	0.17	0.26	0.28	-0.54***	0.82***	0.11**	-0.01
Romania	-0.01	-0.06	-0.01	-0.17	0.10	-0.27	-0.01	-0.01
Serbia	-0.05	0.49	0.59	-0.46	-0.44	-0.02	-0.10	0.08
Slovenia	-0.14	-0.77	0.10	-0.07	-0.90**	0.82	0.07	-0.10
Spain	-0.01	-0.13	-0.13	0.02	-0.47***	0.49***	0.03	-0.03
Ukraine	0.02	0.18	0.76***	-0.47**	-0.25	0.23	-0.17**	-0.07
All leagues	-0.03*	-0.07	0.08*	0.07*	-0.29***	0.36***	0.01	-0.02**

Notes: ***, **, * indicate significance from zero, i.e., no difference (behind closed doors minus with fans), at 1%, 5% and 10% levels, respectively, two-sided unpaired *t*-tests. Yellows includes second yellow cards. Reds includes straight red cards and second yellow cards. See Table 1 and Figure 1 for dataset description.

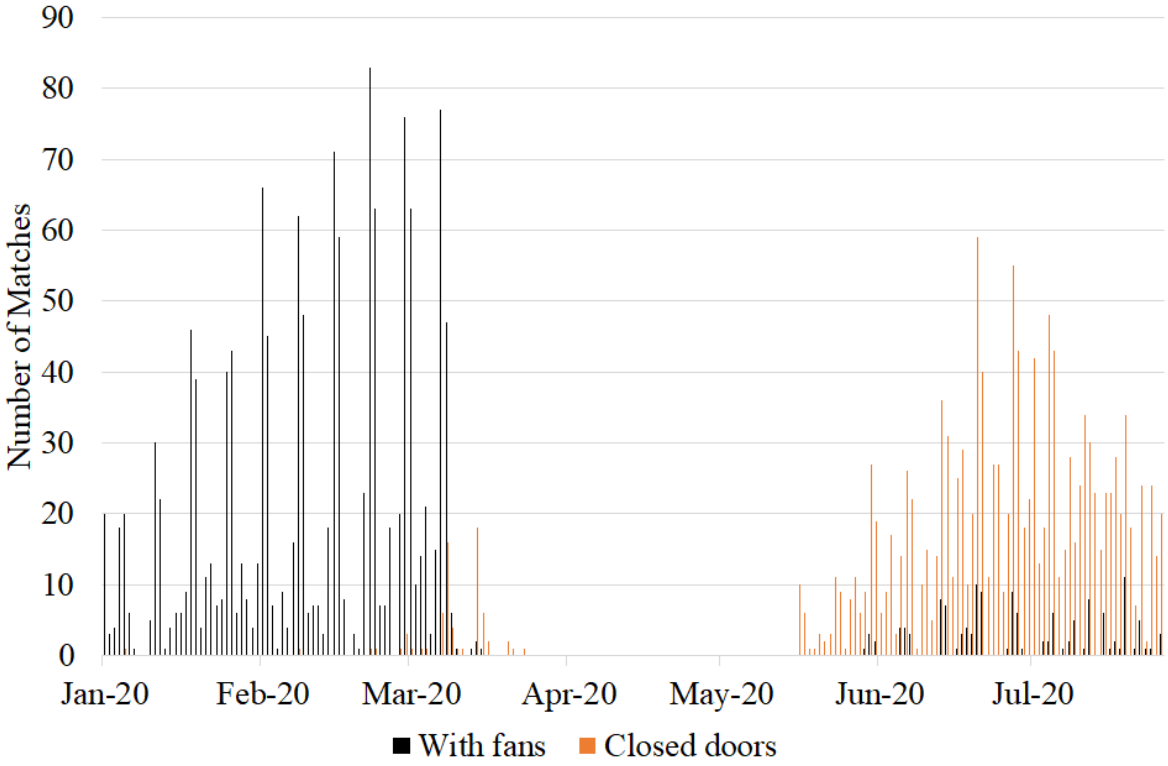
TABLE A10: Estimated effects of playing football behind closed doors on match outcomes: Germany only

	Home win share	Goal diff. (Home-Away)	Total goals	Home yellows	Away yellows	Yellows diff. (Home-Away)
	(I)	(II)	(III)	(IV)	(V)	(VI)
Closed doors ($\hat{\beta}_1$)	-0.046	0.346*	-0.084	0.189	-0.283*	0.472**
	(0.06)	(0.19)	(0.17)	(0.17)	(0.14)	(0.22)
Attendance (10,000s) ($\hat{\beta}_2$)	0.025	0.169**	-0.008	-0.035	-0.021	-0.015
	(0.02)	(0.07)	(0.08)	(0.07)	(0.04)	(0.07)
Home team fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Away team fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Referee fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
R^2	0.237	0.303	0.210	0.275	0.257	0.233
N	992	992	992	992	992	992

Notes: ***, ** indicate significance from one at 1%, 5% and 10% levels, respectively, two-sided tests. Standard errors robust to three-way clustering (home team, away team, referee) are displayed in parentheses. OLS estimates of Equation 1, using only observations for the three professional leagues in Germany. Yellows includes second yellow cards. See Table 1 and Figure 1 for dataset description.

B. Additional Figures

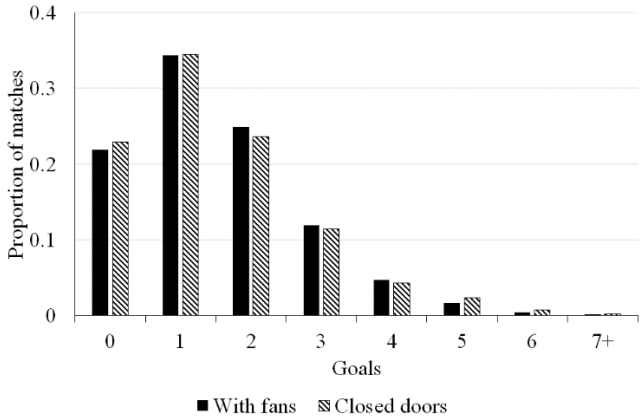
FIGURE B1: Number of matches in the analysis by day, with fans and behind closed doors, 1st January to 3rd August 2020, 2019/20 season



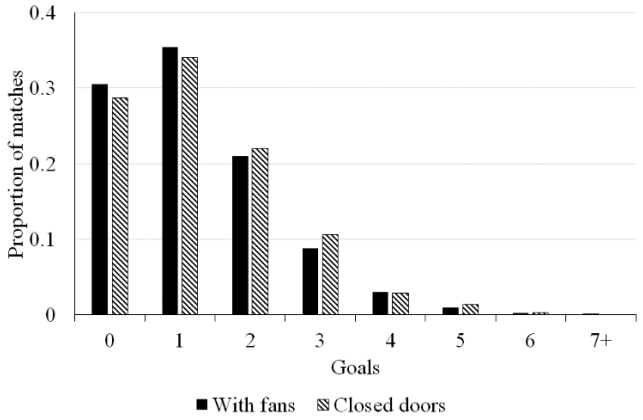
Notes: author calculations using data from worldfootballdata.net, accessed 3/8/2020. See Table 1 and Figure 1 in the main text for further dataset description.

FIGURE B2: Distributions of home and away goals and yellow cards, 2019/20 season, with fans vs behind closed doors

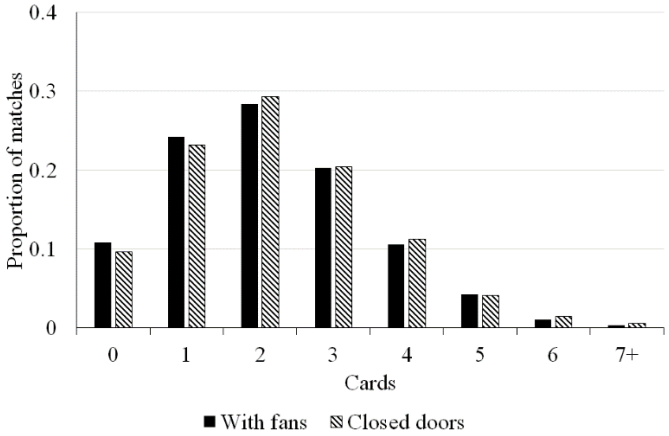
A. Home Goals



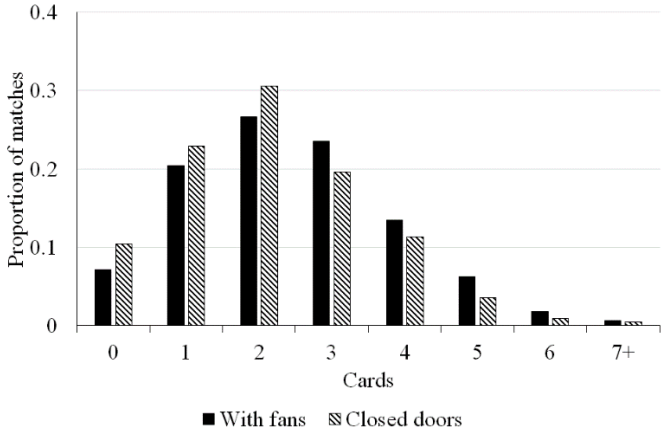
B. Away Goals



C. Home Yellow Cards



B. Away Yellow Cards



Notes: author calculations using data from worldfootballdata.net, accessed 3/8/2020. See Table 1 and Figure 1 in the main text for further dataset description.