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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 currently taking place over several countries in almost identical settings: professional football matches played behind closed doors. 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 refereeing decisions.

**Keywords:** Attendance, Coronavirus, Covid-19, Home Advantage, Natural Experiments, Referee Bias, Social Pressure
**JEL Codes:** B41, B55, C01, C12, C25, C52, K42

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# 1. Introduction

It is uncommon to encounter truly experimental data outside of the laboratory, especially for high-stakes outcomes. But the Covid-19 pandemic has created exceptional circumstances, which allow us to contribute to the small literature investigating the effects of a home crowd on the outcomes of sporting fixtures and referee impartiality (e.g., Dohmen and Sauermann, 2016; Garicano et al., 2005; Sutter and Kocher, 2004).[2] We exploit the natural experiment arising from the Covid-19 induced shutdown of football seasons and the later resumption mostly behind closed doors. 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.

Past studies have shown that playing behind closed doors, in one-off matches, reduces aspects of football home advantage (Pettersson-Lidbom and Priks, 2010; Reade et al., 2020). They also 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.

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 and refereed neutrally. The betting and financial markets are also interested in any margins associated with sporting outcomes and the nature of referees' decisions. Recent articles on football played without crowds in the 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

[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.

[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.

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). These matches 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] In total, 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 11 of the 17 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 substitutions, these differed across countries; the only common change was the effective removal of stadium crowds.

Table 2 shows the simple mean differences in seven 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

[4] We dropped matches played in Turkey and Nicaragua due to attendance data being missing for many games. See 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.

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

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$< 0.01$).

## 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 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 ($\beta_1$, 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. 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 support the conclusions from Pettersson-Lidbom and Priks, 2010 and Reade et al., 2020, who only looked at one-off matches behind closed doors.[7]

The results are approximately identical when we estimate the Poisson model equivalents of Equation (1) (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) (Appendix Table A2 & A3). We also 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 Appendix Table A4, we find that the main result is robust to country-month fixed effects; i.e., the main results are 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). In Appendix Table A5, we control for the fixed 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. Finally, in Appendix Table A6, 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 $\beta_3$ 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.

[7] Fischer and Haucap (2020) found some evidence that the behind closed doors effect did decrease over time in German football only after COVID-19.

# 4. 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 crowd may influence outcomes in a way which unfairly benefits some competitors. This suggests that the location of events could 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.

Our paper also contributes to what is known about the way in which referees 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 when it is anticipated that the crowd could be partisan, for example, in the Olympics (Balmer et al., 2003) or even in reality TV contests (Collins et al., 2019). More generally, any judged contest with adversaries and a crowd present needs to examine the fairness of the 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 Appendix Table A7 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 Appendix Figure A1).

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*** |

*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 Appendix Table A8 for these statistics and others by country.

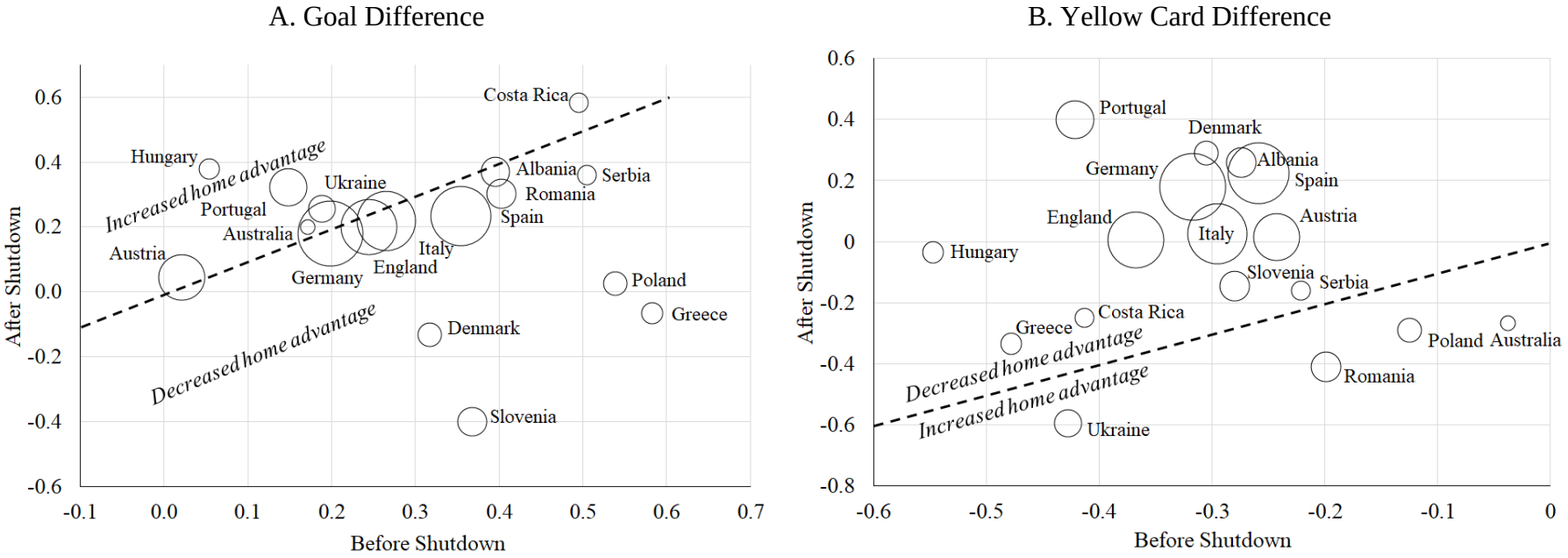
TABLE 3: Estimated effects of playing football behind closed doors on match outcomes

| | 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.

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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 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 A7: 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 Appendix Figure A1).

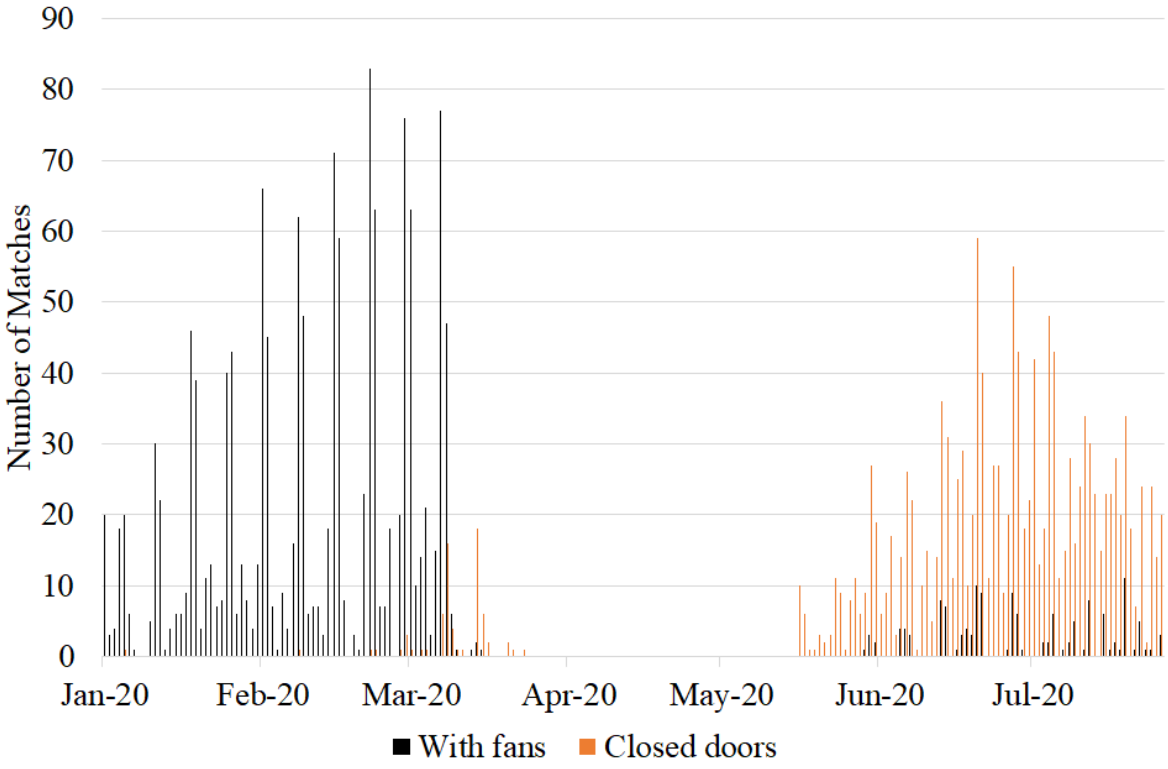
TABLE A8: Differences in sample means, matches played behind closed doors vs with fans, 2019/20 season: by country

| | 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.

# B. Additional Figures

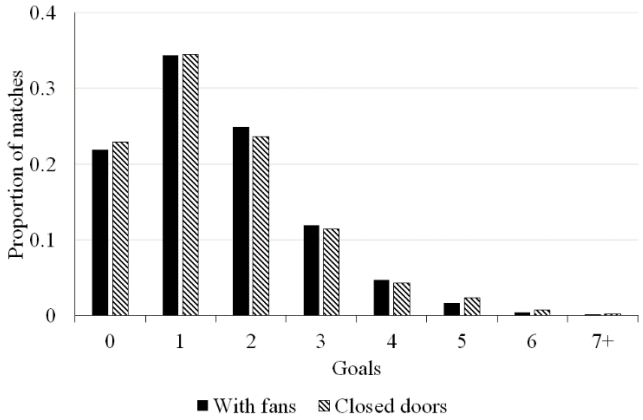
FIGURE B1: Number of matches in the analysis by day, with fans and behind closed doors, 1st January to 3rd August 2020, 2019/20 season



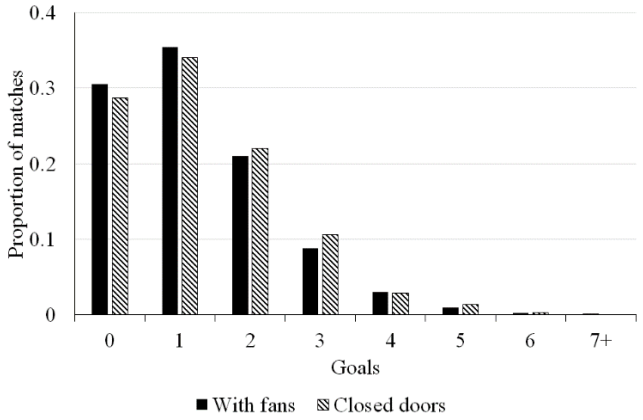

*Notes*: author calculations using data from worldfootballdata.net, accessed 3/8/2020. See Table 1 and Figure 1 in the main text for further dataset description.

FIGURE A2: Distributions of home and away goals and yellow cards, 2019/20 season, with fans vs behind closed doors

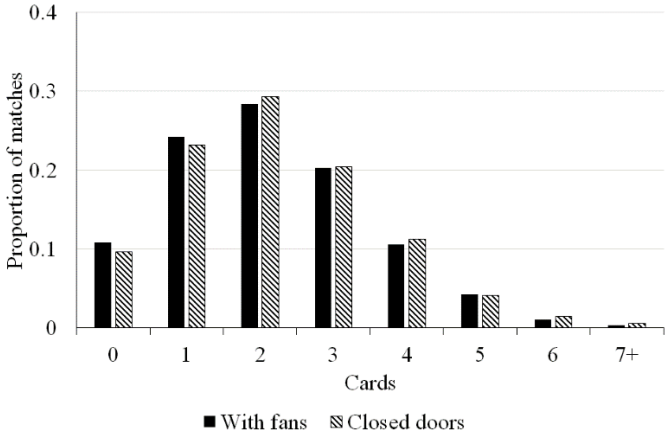
A. Home Goals



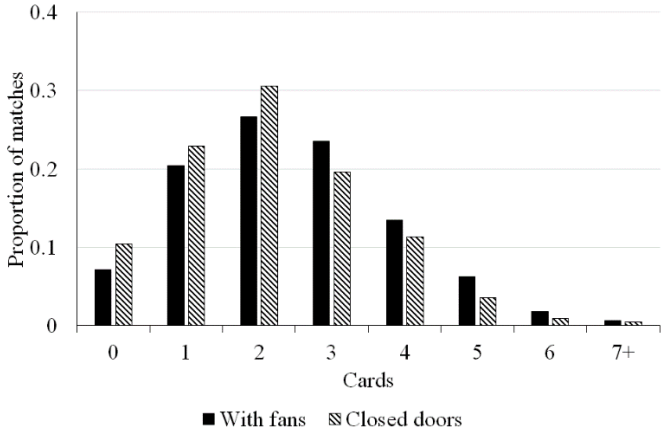

B. Away Goals




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.