Home Field Advantage: Measuring the Impact of Video Assistant Referee and Fans Attendance on Player and Referee Performance

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On March 13, 2020, the German Bundesliga announced that all football matches in Germany were suspended indefinitely due to the COVID-19 pandemic.[1] After consulting with the German government, the Bundesliga restarted on May 16, 2020 under the condition that all games be played behind closed doors- without fans in attendance.[2]

While this has made it hard for teams economically and for fans to support their teams in person, this pandemic has provided match data which allows us to test the impact of fans on match results, since all other variables are held constant except for fan attendance.

According to Albert & Koning's *Statistical Thinking in Sports*, the home team in club soccer wins approximately 46% of its games.[3] An analysis done by Aurel Nazmiu 21st club, revealed that in the Bundesliga, the top German Professional Soccer League, the average home win percentage from 1992-2019 was approximately 46.2%. Nazmiu describes the drivers of home field advantage as "familiar conditions, less travel and, of course, a dominant local crowd behind the home side".[4] Albert's *Handbook of Statistical Methods and Analysis in Sports* has a chapter on referee bias in soccer. According to a study referenced on page 407 by Boyko et al. (2007), "Crowd density had significant effects on goal difference and home team penalties". [5]

Within home field advantage, this paper will focus on further analyzing the impact of fan attendance on match results and player performance. According to a paper written by J. James Reade, "It has been widely noted that home advantage has not only disappeared but even reversed in these ghost games, with a statistically implausible sequence of results compared with normal times.Between the return from the league's [Bundesliga] shutdown and 14th June 2020, home teams in the Bundesliga, had won just 20% of the matches played (11 of 55, compared with 43% in the same season before March. Away teams, however, had won 51% (28 of 55) of the post-shutdown matches, compared with 35% in the season beforehand." [6]

The Introduction of the Video Assistant Referee

While the research that has already been done by Reade and Nazmiu is compelling, it fails to account for the impact of a possible confounding variable: Video Assistant Referee(VAR). According to the Bundesliga's official website, VAR "was introduced in the Bundesliga for the 2017/18 season [to make football a fairer sport]." [7]

VAR's uses were determined by the International Football Association Board, and put into the rules of football in Germany. According to the IFAB website [8], "The referee may receive assistance from the VAR only in relation to four categories of match-changing decisions/incidents. In all these situations, the VAR is only used after the referee has made a (first/original) decision (including allowing play to continue), or if a serious incident is missed/not seen by the match officials. The referee`s original decision will not be changed unless there was a 'clear and obvious error' (this includes any decision made by the referee based on information from another match official e.g. offside). The categories of decision/incident which may be reviewed in the event of a potential 'clear and obvious error' or 'serious missed incident' are:

a. Goal/no goal

b. Penalty kick/no penalty kick

c. Direct red cards (not second yellow card/caution)

d. Mistaken identity (red or yellow card)

If the referee penalises an offence and then gives the wrong player from the offending (penalised) team a yellow or red card, the identity of the offender can be reviewed; the actual offence itself cannot be reviewed unless it relates to a goal, penalty incident or direct red card."

For this paper I will analyze the impact of fans on match performance, given that VAR is being used. It is important to take into consideration the impact that VAR has on team performance before analyzing the impact of fans on team performance. It is possible that the changes to in game win percentage and other metrics may be due to VAR and not to the absence of fans.

Data Collection and Methodology

I will be conducting hypothesis testing to analyze the impact of VAR on performance first, then measuring the impact of removing fans. I am focusing on the Bundesliga due to the large sample of games available where VAR is present with fans in attendance, and where VAR is present and fans are not in attendance.

The data comes from the FBreference website. I collected every match played from the start of the 2016 season though March 10, 2021 (2021 season is through match week 25 approximately 70% of all games played during the 20-21 campaign). This data can be found in the “TestCase.csv" file. For each match, we have the season the match was played in, the date the match was played, the name of the home team and the away team, the number of fans in attendance, the venue, the final score, and a URL for that game’s the match report. Within each match report, are useful metrics for our analysis. The metrics we will focus on for this analysis that come from the match report are, pass completion, pass attempts, fouls conceded, tackles, interceptions, yellow cards and red cards for both the home and away teams.

Inspired by Christopher B. Martin, PhD’s Premier League history web scraper [9] for FBreference, I built a web scraper that pulls the above mentioned match statistics for all 1,440 matches from the 2016-17 season through March 10th 2021. The web scraper can be found in the file titled “Final Project Scraper.ipynb". Due to the limitation on my computer’s memory, I have split the data from the TestCase.csv file into smaller CSV files- one for each season. The combined match data has been aggregated into one CSV file titled “Final Data.csv”.

The 6 performance metrics I will evaluate are:

-Home team win percentage= games won by the home team/Total games played

-Goal Differential= goals scored by the home team - goal scored by the away team

-Home team pass completion percentage= home pass completion/ home pass attempts

-Home team blocks and interceptions = home blocks + home interceptions

-Home team fouls and cards= fouls conceded + 2*Yellow Cards + 4*Red Cards

-Away team fouls and cards= fouls conceded + 2*Yellow Cards + 4*Red Cards

VAR Hypotheses

Matches from the 2016-17 season were classified as “No VAR” matches, while all other matches were classified as “VAR” matches. In total there were 306 matches classified as “no VAR” and 1,134 matches classified as VAR.

For Home team win percentage, a two-sample proportion t test is used to evaluate whether the mean win percentage with VAR present is significantly different from the mean when VAR is not present at a significance of alpha =0.05.

For all other metrics a two-sided sample t-test is used to evaluate whether the mean metric is significantly different when VAR is present vs when it is not, at a significance of alpha =0.05. Our Null Hypothesis for each t-test is that VAR has no significant difference on the mean metric in question, all other variables held constant.

FAN Hypotheses

For fans, matches were classified as “Fans” or “No Fans” depending on whether the attendance recorded was zero. In total, there are 867 matches where Fans are present and VAR is also present. There are 267 matches where no fans are present and VAR is present. There are 306 matches where no VAR is present, and fans are present. There are zero matches where both VAR and Fans are present

Our null hypotheses, significance criteria, and t-tests are identical to their corresponding metric in the VAR analysis. The only difference is that if we fail to reject a null hypothesis in VAR, instead of using the whole population of matches, only the matches where VAR is present will be used for fan significance testing.

Results

The detailed results for each test can be found in the tables in the appendix. Additionally, the code for the t-tests can be found in the file called “Analysis of Bundesliga Matches.ipynb” which I encourage all readers to look at.

In matches where fans were in attendance, all other variables held constant:

-VAR had no significant difference at the .05 level of significance on:

Home team win percentage (P-Value = 0.1653)

Goal differential (P-Value = 0.1094)

-VAR had a significant difference at the .05 level of significance on:

Home team pass accuracy (P-Value = 0.000)

Home team total blocks and interceptions (P-Value =0.000)

Total fouls, yellow cards, and red cards called against the home team (P-Value = 0.0163)

Total fouls, yellow cards, and red cards called against the away team (P-Value = 0.0052)

In matches where fan attendance was zero, all other variables held constant:

-Fans had no significant difference at the .05 level of significance on:

-Goal Differential (P-Value = 0.5606)

-Total fouls, yellow cards, and red cards called against the away team (P-Value= 0.6191)

-Home team pass accuracy (P-Value = 0.0677)

-Fans had a significant difference at the .05 level of significance on:

-Home team win percentage (P-Value = 0.004109)

-Home team total blocks and interceptions (P-Value = 0.0006)

-Total fouls, yellow cards, and red cards called against the home team (P-Value= 0.0005)

Conclusions/ Recommendations

We rejected the null hypothesis that VAR has no impact on home team pass accuracy, home team blocks and interceptions, and total fouls, yellow cards, and red cards for home and away teams. We fail to reject the null hypothesis that VAR has no effect on win percentage and goal differential.

We reject the null hypothesis that fan attendance does not affect home team win percentage, total blocks and interceptions and total fouls, yellow cards, and red cards against the home team. We fail to reject the null hypothesis that fans have no effect on goal differential, fouls yellows and red cards for the away teams, and home team pass accuracy.

More analysis is needed to further understand the impact of home field advantage on team performance. Our scope was limited to just the Bundesliga games, and not all leagues have the same win percentage. It is also possible that not all leagues were equally impacted by not having fans in attendance.

There are metrics which were not looked at like saves, penalties, and stoppage time which may all have been affected by either VAR or not having fans in attendance. Further study on the impact of VAR is also necessary. As officials get more experience using VAR, it is possible that we see their impact on win percentage change.

For other leagues like the Premier league, it will be harder to measure the impact of fans, as VAR was brought in during the 20/21 season when the pandemic took place. Other factors can affect home field advantage, like the distance travelled by the away team can be explored further. This paper should not be seen as definitive, but should serve as inspiration for future analysis on the impact of fans on the beautiful game.

References

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Appendix

1. Two sample proportion t-test for Win Percentage given VAR with Fans.

VarPresent	NoVAR	VAR
HomeResult		
L	0.267974	0.307958
T	0.241830	0.247982
W	0.490196	0.444060

In [23]:
```
total_proportion_Won = (Fans.HomeResult == "W").mean()
num_NoVAR=Fans[Fans.BiAttendance=="NoVAR"].shape[0]
num_VAR=Fans[Fans.BiAttendance=="VAR"].shape[0]
```

In [24]:
```
prop = Fans.groupby("VarPresent")["HomeResult"].agg([lambda z: np.mean(z=="W"), "size"])
prop.columns = ["prop_won", 'counts']
prop.head()
```

Out[24]:

	prop_won	counts
VarPresent		
NoVAR	0.490196	306
VAR	0.444060	867

In [25]:
```
variance= total_proportion_Won*(1-total_proportion_Won)
standard_error= np.sqrt(variance*(1/prop.counts.VAR + 1/prop.counts.NoVAR))
print(standard_error)
```

```
0.033118294393471207
```

In [26]:
```
best_estimate= (prop.prop_won.VAR-prop.prop_won.NoVAR)
print(best_estimate)

h_est=0

test_stat= (best_estimate-h_est)/standard_error

print(test_stat)
```

```
-0.046136101499423265
-1.39306997369159
```

In [27]:
```
# Calculate the  p-value
pvalue = 2*dist.norm.cdf(-np.abs(test_stat)) # Multiplied by two indicates a two tailed testing.
print("Computed P-value is", pvalue)
##Not Significant difference
```

```
Computed P-value is 0.1635986319051237
```

2. Two sample t-test on Goal Differential given VAR with Fans

```
(   Variable       N      Mean        SD        SE  95% Conf.  Interval
 0       VAR   867.0  3.047290  1.679609  0.057043   2.935332  3.159247
 1     NoVAR   306.0  2.866013  1.762549  0.100758   2.667744  3.064282
 2  combined  1173.0  3.000000  1.702738  0.049716   2.902457  3.097543,
           Independent t-test    results
 0  Difference (VAR - NoVAR) =      0.1813
 1        Degrees of freedom =   1171.0000
 2                         t =      1.6022
 3     Two side test p value =      0.1094
 4    Difference < 0 p value =      0.9453
 5    Difference > 0 p value =      0.0547
 6                 Cohen's d =      0.1065
 7                 Hedge's g =      0.1065
 8             Glass's delta =      0.1079
 9                         r =      0.0468)
```

3. Two sample t-test on Home Pass Accuracy given VAR with Fans

```
(   Variable       N      Mean        SD        SE  95% Conf.  Interval
 0       VAR   867.0  0.772074  0.068681  0.002333   0.767496  0.776652
 1     NoVAR   306.0  0.750712  0.087308  0.004991   0.740891  0.760534
 2  combined  1173.0  0.766501  0.074547  0.002177   0.762231  0.770772,
           Independent t-test    results
 0  Difference (VAR - NoVAR) =      0.0214
 1        Degrees of freedom =   1171.0000
 2                         t =      4.3422
 3     Two side test p value =      0.0000
 4    Difference < 0 p value =      1.0000
 5    Difference > 0 p value =      0.0000
 6                 Cohen's d =      0.2887
 7                 Hedge's g =      0.2885
 8             Glass's delta =      0.3110
 9                         r =      0.1259)
```

4. Two sample t-test on Home team Tackles and Interceptions given VAR with Fans

	Variable	N	Mean	SD	SE	95% Conf.	Interval
0	VAR	867.0	25.816609	7.088996	0.240755	25.344078	26.289140
1	NoVAR	306.0	38.699346	8.975438	0.513092	37.689699	39.708994
2	combined	1173.0	29.177323	9.493446	0.277188	28.633482	29.721164,

	Independent t-test	results
0	Difference (VAR - NoVAR) =	-12.8827
1	Degrees of freedom =	1171.0000
2	t =	-25.4077
3	Two side test p value =	0.0000
4	Difference < 0 p value =	0.0000
5	Difference > 0 p value =	1.0000
6	Cohen's d =	-1.6894
7	Hedge's g =	-1.6884
8	Glass's delta =	-1.8173
9	r =	0.5961)

5. Two sample t-test on Home team fouls, yellow cards and red cards given VAR with Fans

	Variable	N	Mean	SD	SE	95% Conf.	Interval
0	VAR	867.0	16.698962	5.786864	0.196532	16.313227	17.084697
1	NoVAR	306.0	17.633987	6.012830	0.343731	16.957603	18.310370
2	combined	1173.0	16.942882	5.858483	0.171055	16.607273	17.278490,

	Independent t-test	results
0	Difference (VAR - NoVAR) =	-0.9350
1	Degrees of freedom =	1171.0000
2	t =	-2.4052
3	Two side test p value =	0.0163
4	Difference < 0 p value =	0.0082
5	Difference > 0 p value =	0.9918
6	Cohen's d =	-0.1599
7	Hedge's g =	-0.1598
8	Glass's delta =	-0.1616
9	r =	0.0701)

6. Two sample t-test on Away team fouls, yellow cards and red cards given VAR with Fans

```
(   Variable       N       Mean        SD        SE  95% Conf.   Interval
 0       VAR   867.0  18.295271  5.836139  0.198206  17.906251  18.684291
 1     NoVAR   306.0  19.375817  5.715031  0.326707  18.732933  20.018701
 2  combined  1173.0  18.577153  5.821745  0.169982  18.243649  18.910657,
           Independent t-test    results
 0  Difference (VAR - NoVAR) =     -1.0805
 1        Degrees of freedom =   1171.0000
 2                         t =     -2.7995
 3     Two side test p value =      0.0052
 4    Difference < 0 p value =      0.0026
 5    Difference > 0 p value =      0.9974
 6                Cohen's d =     -0.1861
 7                Hedge's g =     -0.1860
 8            Glass's delta =     -0.1851
 9                         r =      0.0815)
```

7. Two sample proportion t-test for Win Percentage given Fan Attendance

BiAttendance	Fans	NoFans
HomeResult		
L	0.297528	0.374532
T	0.246377	0.265918
W	0.456095	0.359551

```
total_proportion_won = (df.HomeResult == "W").mean()

num_NoFans=df[df.BiAttendance=="NoFans"].shape[0]
num_Fans=df[df.BiAttendance=="Fans"].shape[0]
```

```
assert num_NoFans*total_proportion_won>10, "Assumption not met"
assert num_Fans*total_proportion_won>10, "Assumption not met"
assert num_NoFans*(1-total_proportion_won)>10, "Assumption not met"
assert num_Fans*(1-total_proportion_won)>10, "Assumption not met"
```

```
prop = df.groupby("BiAttendance")["HomeResult"].agg([lambda z: np.mean(z=="W"), "size"])
prop.columns = ["prop_won", 'counts']
prop.head()
```

	prop_won	counts
BiAttendance		
Fans	0.456095	1173
NoFans	0.359551	267

```
variance= total_proportion_won*(1-total_proportion_won)
standard_error= np.sqrt(variance*(1/prop.counts.Fans + 1/prop.counts.NoFans))
print(standard_error)
```

```
0.03364364623082332
```

```
best_estimate= (prop.prop_won.Fans-prop.prop_won.NoFans)
print(best_estimate)

h_est=0

test_stat= (best_estimate-h_est)/standard_error

print(test_stat)
```

```
0.09654491987317643
2.8696330715998557
```

```
# Calculate the  p-value
pvalue = 2*dist.norm.cdf(-np.abs(test_stat)) # Multiplied by two indicates a two tailed testing.
print("Computed P-value is", pvalue)

##Significant difference
```

```
Computed P-value is 0.0041094837257014535
```

8. Two sample t-test on Goal Differential given Fan Attendance

```
(   Variable       N      Mean        SD        SE  95% Conf.  Interval
 0      Fans  1173.0  3.000000  1.702738  0.049716   2.902457  3.097543
 1    NoFans   267.0  3.067416  1.730733  0.105919   2.858869  3.275962
 2  combined  1440.0  3.012500  1.707559  0.044998   2.924231  3.100769,
              Independent t-test    results
 0  Difference (Fans - NoFans) =     -0.0674
 1          Degrees of freedom =   1438.0000
 2                           t =     -0.5821
 3       Two side test p value =      0.5606
 4      Difference < 0 p value =      0.2803
 5      Difference > 0 p value =      0.7197
 6                  Cohen's d =     -0.0395
 7                  Hedge's g =     -0.0395
 8              Glass's delta =     -0.0396
 9                           r =      0.0153)
```

9. Two sample t-test on Home team pass accuracy given Fan Attendance

```
(   Variable       N      Mean        SD        SE  95% Conf.  Interval
 0      Fans   867.0  0.772074  0.068681  0.002333   0.767496  0.776652
 1    NoFans   267.0  0.780696  0.062949  0.003852   0.773111  0.788281
 2  combined  1134.0  0.774104  0.067447  0.002003   0.770174  0.778034,
              Independent t-test    results
 0  Difference (Fans - NoFans) =     -0.0086
 1          Degrees of freedom =   1132.0000
 2                           t =     -1.8284
 3       Two side test p value =      0.0677
 4      Difference < 0 p value =      0.0339
 5      Difference > 0 p value =      0.9661
 6                  Cohen's d =     -0.1280
 7                  Hedge's g =     -0.1279
 8              Glass's delta =     -0.1255
 9                           r =      0.0543)
```

10. Two sample t-test on Home team Tackles and Interceptions given Fan Attendance

```
(   Variable       N       Mean        SD        SE  95% Conf.   Interval
 0      Fans   867.0  25.816609  7.088996  0.240755  25.344078  26.289140
 1    NoFans   267.0  27.569288  8.000345  0.489613  26.605278  28.533299
 2  combined  1134.0  26.229277  7.347892  0.218201  25.801154  26.657400,
              Independent t-test    results
 0  Difference (Fans - NoFans) =     -1.7527
 1          Degrees of freedom =   1132.0000
 2                           t =     -3.4241
 3       Two side test p value =      0.0006
 4      Difference < 0 p value =      0.0003
 5      Difference > 0 p value =      0.9997
 6                  Cohen's d =     -0.2397
 7                  Hedge's g =     -0.2395
 8              Glass's delta =     -0.2472
 9                           r =      0.1012)
```

11. Two sample t-test on Home team fouls, yellow cards and red cards given Fan Attendance

```
(   Variable       N       Mean        SD        SE  95% Conf.   Interval
 0      Fans   867.0  16.698962  5.786864  0.196532  16.313227  17.084697
 1    NoFans   267.0  18.101124  5.652290  0.345915  17.420045  18.782202
 2  combined  1134.0  17.029101  5.783688  0.171751  16.692115  17.366086,
              Independent t-test    results
 0  Difference (Fans - NoFans) =     -1.4022
 1          Degrees of freedom =   1132.0000
 2                           t =     -3.4807
 3       Two side test p value =      0.0005
 4      Difference < 0 p value =      0.0003
 5      Difference > 0 p value =      0.9997
 6                  Cohen's d =     -0.2436
 7                  Hedge's g =     -0.2435
 8              Glass's delta =     -0.2423
 9                           r =      0.1029)
```

12. Two sample t-test on Away team fouls, yellow cards and red cards given Fan Attendance

```
(   Variable       N       Mean        SD        SE  95% Conf.   Interval
 0      Fans   867.0  18.295271  5.836139  0.198206  17.906251  18.684291
 1    NoFans   267.0  18.093633  5.650424  0.345800  17.412779  18.774487
 2  combined  1134.0  18.247795  5.791110  0.171971  17.910378  18.585213,
              Independent t-test    results
 0  Difference (Fans - NoFans) =      0.2016
 1          Degrees of freedom =   1132.0000
 2                           t =      0.4973
 3       Two side test p value =      0.6191
 4      Difference < 0 p value =      0.6905
 5      Difference > 0 p value =      0.3095
 6                  Cohen's d =      0.0348
 7                  Hedge's g =      0.0348
 8              Glass's delta =      0.0345
 9                           r =      0.0148)
```