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Home Bias and Referee Bias in European Football

The Role of Stoppage Time Allocation

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Abstract

Football referees possess substantial discretion in allocating stoppage time, a decision that is comparatively opaque yet potentially consequential for match outcomes. This paper examines whether stoppage time allocation contributes to home advantage in contemporary European professional football. Using a dataset of 18,085 matches across the 2014/15–2023/24 seasons, we analyse first- and second-half stoppage time separately. Our results indicate that first-half stoppage time is largely explained by interruptions and shows no systematic dependence on match context. In contrast, second-half stoppage time is strongly context-dependent: close matches receive more stoppage time on average, no matter whether the home team is leading or trailing.

JEL Codes: C20, D91, L83, Z20, Z21

Keywords: Bias, Football, Home Advantage, Referee, Stoppage Time

Heimvorteil und Schiedsrichterbias im europäischen Fußball

Die Rolle der Nachspielzeit

Zusammenfassung

Schiedsrichter haben bei der Festlegung der Nachspielzeit einen großen Ermessensspielraum, wobei ihre Entscheidung vergleichsweise intransparent ist, aber den Spielausgang maßgeblich beeinflussen kann. Diese Studie untersucht, ob die Vergabe von Nachspielzeit im heutigen europäischen Profifußball zum Heimvorteil beiträgt. Auf Basis eines Datensatzes mit 18.085 Partien aus den Saisons 2014/15 bis 2023/24 wird die Nachspielzeit getrennt nach erster und zweiter Halbzeit analysiert. Die Ergebnisse zeigen, dass die Nachspielzeit in der ersten Halbzeit überwiegend durch Unterbrechungen erklärt wird und nicht systematisch vom Spielkontext abhängt. In der zweiten Halbzeit ist die Nachspielzeit dagegen kontextabhängig: Enge Spiele erhalten im Durchschnitt mehr Nachspielzeit, wenn eines der beiden Teams zurückliegt.

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Home Bias and Referee Bias in European Football

The Role of Stoppage Time Allocation

1. Introduction

Unlike most major team sports where game clocks stop during natural interruptions, football employs a unique timing system. While matches are nominally fixed at 90 minutes, referees possess authority to extend play through stoppage time to compensate for delays and interruptions, with substantial autonomy in determining additional time.

Home bias is one of the best-documented behavioural effects in sport among referees (e.g., Courneya & Carron 1992, Pollard & Pollard 2005, Dilger & Vischer 2024). The formal rules of the game provide only general guidance regarding compensation, leaving referees considerable discretion. Unlike visible decisions such as penalties or disciplinary cards, temporal allocation receives minimal scrutiny from media, fans, and governing bodies, despite its potential to systematically favour certain teams. This relative invisibility, combined with subjective compensation determinations, creates conditions where referee bias can operate with limited accountability—particularly problematic given referees documented tendency to favour home teams.

In high-stakes environments driven by broadcast rights, sponsorship deals, and prize money, stoppage time allocation represents one of football's most discretionary yet consequential regulatory decisions. Every additional minute represents potential goal-scoring opportunities that could alter competitive outcomes.

Existing empirical research on stoppage time bias has produced consistent findings across individual league studies (Garicano et al. 2005, Dohmen 2008, Scoppa 2008) and cross-league analyses during the COVID-19 pandemic (Scoppa 2021, Sors et al. 2020). However, the landscape of professional football has undergone substantial transformation since most of this evidence was collected. Video Assistant Referee (VAR) implementation has increased baseline stoppage time (Lago-Peñas et al. 2019), revised IFAB guidelines led to added time nearly doubling at the 2022 FIFA World Cup from 7.3 to 11.6 minutes per match (Wei et al. 2024), and the permanent introduction of five substitutions has further altered match dynamics. These institutional changes, combined with the return of full-capacity crowds after the pandemic, warrant a reassessment of whether established bias patterns persist under contemporary conditions. Moreover, existing studies typically examine aggregate stoppage time without distinguishing

between first-half and second-half allocation—a distinction that may reveal important differences in referee susceptibility to social pressure across match phases.

This study addresses the research gap by examining stoppage time's contribution to home bias across multiple leagues and seasons. The central research question is:

To what extent does referee stoppage time allocation contribute to home advantage in professional football?

Our analysis draws from 18,085 matches across Europe's top five leagues from 2014/15 to 2023/24 seasons, collected using automated Python scripts. The dataset encompasses the English Premier League, Spanish La Liga, German Bundesliga, Italian Serie A, and French Ligue 1. Detailed first and second-half stoppage time data enables nuanced examination of referee behaviour through regression analysis across different match phases.

2. Theoretical Background

The theoretical understanding of the home advantage has undergone significant evolution over recent decades. Traditional explanations emphasised environmental factors such as travel fatigue and unfamiliar playing conditions (Schwartz & Barsky 1977), elements arguably inherent to competitive sport (Boyko et al. 2007). Furthermore, the influence of these factors has been found to vary depending on the degree of professionalisation within a league (Böttger & Vischer 2025). However, contemporary research has fundamentally shifted focus toward referee decision-making as the primary transmission mechanism through which crowd influence manifests (Boyko et al. 2007, Sutter & Kocher 2004). This shift gained empirical support during the COVID-19 pandemic when mandatory spectator exclusion created natural experimental conditions. The resulting reduction in home advantage across major leagues, accompanied by demonstrably more balanced referee decisions, provided quasi-experimental evidence for crowd influence as a causal mechanism rather than mere correlation (Dilger & Vischer 2022, Scoppa 2021).

Among various referee decisions susceptible to bias—including disciplinary sanctions and penalty awards—stoppage time allocation presents distinctive characteristics that make it particularly vulnerable to unconscious influence. Unlike sports with mechanically stopped clocks, football referees maintain exclusive temporal authority through discretionary stoppage time additions, creating conditions conducive to unconscious bias (Sutter & Kocher 2004). The regulatory framework governing stoppage time reveals structural ambiguities that facilitate bias.

While the "Laws of the Game" (IFAB 2024) mandate compensation for time lost due to substitutions, injuries, disciplinary actions, and celebrations, the precise calculation methodology remains deliberately unspecified. This regulatory vacuum is compounded by the asymmetric nature of stoppage time authority: announced durations serve as minimum requirements that referees may extend but cannot reduce (IFAB 2024). Such discretionary authority, combined with real-time social pressure, creates conditions conducive for unconscious bias to influence decision-making.

Stoppage time decisions are psychologically distinct, which amplifies susceptibility to bias. While penalty awards and disciplinary actions involve criterion-based judgments with explicit regulatory guidance, stoppage time calculation relies heavily on subjective assessment of legitimate time losses. This subjectivity, operating under intense temporal pressure and crowd scrutiny, distinguishes stoppage time from other referee decisions and explains its vulnerability to social influence. This vulnerability persists even under controlled conditions. Butler et al. (2025) examine stoppage time allocation at international championships, where matches are played at neutral venues. Despite identical rules governing both halves, referees systematically allocate more time in the second half than the first. That such inconsistencies emerge in the absence of home advantage suggests a structural susceptibility of stoppage time decisions that home-crowd pressure in domestic leagues may amplify.

Empirical research in domestic league settings confirms this expectation. The systematic investigation of stoppage time bias originated with Garicano et al. (2005), whose analysis of Spanish La Liga established the foundational empirical framework. Their study demonstrated that referees systematically shortened matches when home teams held narrow leads and extended them when home teams trailed, even after controlling for legitimate time-loss factors including substitutions and disciplinary actions. Studies across diverse competitive contexts have confirmed these patterns while revealing interesting cross-cultural variations. Dohmen (2008) documented similar home-favourable asymmetries across twelve Bundesliga seasons, though with notably less pronounced effects than those observed in Spain, suggesting potential cultural or institutional moderators of bias magnitude. Sutter and Kocher (2004) provided additional German evidence, while Scoppa (2008) confirmed systematic home bias in Italian Serie A, establishing the phenomenon's presence across major European leagues.

Later research has provided increasingly precise quantification of bias effects. Riedl et al. (2015) demonstrated through eleven Bundesliga seasons that referees awarded approximately 18 additional seconds of stoppage time in close matches when home teams trailed by one goal

compared to equivalent situations where they led. While individually modest, such temporal asymmetries accumulate across seasons and can prove decisive in closely contested matches where additional scoring opportunities become critical. Similar patterns emerged in different competitive contexts, with Yewell et al. (2014) documenting approximately 26 seconds of additional time for trailing home teams in Major League Soccer. Studies uniformly document bias exclusively in close games where additional time could realistically influence outcomes, with no evidence of favouritism in matches with two-goal margins or larger (Garicano et al. 2005, Scoppa 2008). This contextual sensitivity supports theories emphasising unconscious rather than deliberate bias, as officials appear most susceptible to crowd influence precisely when such influence would be most consequential for match outcomes.

The scope of stoppage time bias extends beyond simple home-away distinctions to encompass more complex forms of favouritism. Buraimo et al. (2010) documented systematic patterns indicating that referees extended close games when high-profile teams trailed and shortened them when such teams led, revealing 'big-club favouritism' in temporal allocation decisions. Further evidence of this layered decision-making comes from Lago-Peñas and Gómez-López (2016), who also demonstrated that referees granted more time in close matches and when higher-ranked teams were behind and less when they were ahead. These findings suggest that referee time management responds simultaneously to multiple social pressures, including team status, media attention, and commercial importance alongside traditional crowd influence. However, not all systematic patterns reflect favouritism. Morabito and Scoppa (2024) find that referees extend stoppage time both when the home team trails and when the away team trails—a pattern inconsistent with pure crowd-pressure explanations. The authors interpret this as inequity aversion: referees appear motivated to provide trailing teams an opportunity to equalise, regardless of home status.

The relationship between institutional structures and bias susceptibility received compelling examination through natural experimental conditions. Rickman and Witt (2008) exploited the introduction of professional referee contracts in the English Premier League during the 2001/02 season, featuring annual salaries supplementing traditional match fees. This reform coincided with substantial reduction in previously documented stoppage time favouritism. Prior to professionalisation, referees systematically awarded less stoppage time when home teams held one-goal leads; post-reform, this pattern largely disappeared. These findings suggest that incentive structures fundamentally influence referee behaviour. Under fee-based compensation systems, referees may exhibit greater susceptibility to crowd influence, whereas professional

contracts with career-oriented performance monitoring appear to encourage more impartial decision-making through enhanced accountability mechanisms.

While statistically robust across multiple studies, the aggregate competitive impact of stoppage time bias appears bounded relative to other home advantage mechanisms. Garicano et al. (2005) estimated that stoppage time asymmetries influenced approximately 2.5 % of La Liga match outcomes—measurable but modest effects on competition results. Riedl et al. (2015) found no aggregate impact on goals or points despite documenting significant bias, suggesting that additional time does not consistently translate into scoring opportunities. However, the competitive significance of stoppage time bias appears amplified in high-stakes scenarios where social pressure intensifies. Studies consistently document stronger bias effects in matches with narrow score differences, indicating that referee susceptibility to crowd influence increases precisely when such influence would be most consequential (Garicano et al. 2005, Scoppa 2008). In championship races, relegation battles, and European qualification scenarios, even modest systematic advantages sustained across multiple fixtures could translate into points differences that prove crucial for season-long competitive objectives.

3. Hypotheses

Drawing from the theoretical literature and robust empirical evidence documenting systematic patterns of referee bias in stoppage time allocation across multiple European leagues, we develop testable hypotheses that will guide our empirical analysis of the home advantage in professional football. These hypotheses are grounded in established findings from prior research while taking advantage of the unique features of our dataset to extend existing knowledge about referee behaviour.

Our primary hypothesis addresses the fundamental mechanism of home bias that has been consistently documented across different leagues and time periods. Based on seminal research by Garicano et al. (2005) in Spanish football, Sutter and Kocher (2004) in the German Bundesliga, and Scoppa (2008) in Italian Serie A, we expect that referees systematically favour home teams through their discretionary stoppage time allocation decisions. Environmental familiarity and crowd support, as identified by Schwartz and Barsky (1977), create conditions where referee bias can manifest through extended playing time when home teams trail.

H1: Referees award more stoppage time when home teams are trailing compared to when they are leading.

The magnitude of this bias should be most pronounced in competitive scenarios where referee decisions can have the greatest impact on match outcomes. Research consistently demonstrates that referee favouritism is strongest when score differences are minimal at the end of regulation time, as these represent situations where additional stoppage time provides meaningful opportunities for result-changing events. Drawing from evidence that referee bias diminishes when additional time is unlikely to affect results (Lago-Peñas & Gómez-López 2016) we expect that bias patterns will vary according to competitive circumstances.

H2: Home bias in stoppage time allocation is stronger in close matches than in matches with larger score differences.

The temporal structure of football matches creates different pressure situations that should influence the magnitude of referee bias across different phases of competition. The second half represents the final opportunity for teams to influence match outcomes through additional playing time, potentially intensifying the pressure on referees to respond to crowd expectations. As competitive stakes escalate toward the conclusion of matches, we expect referee susceptibility to social influence to increase correspondingly.

H3: Home bias in stoppage time allocation is more pronounced in the second half compared to the first half.

These hypotheses provide a comprehensive framework for our empirical analysis and will enable us to contribute new insights to the literature on referee bias while taking advantage of the scope and detail of our dataset covering Europe's top five leagues.

4. Data

This study utilises a comprehensive dataset covering ten consecutive seasons from 2014/15 to 2023/24 for the five major European football leagues: the English Premier League, German Bundesliga, Spanish La Liga, Italian Serie A, and French Ligue 1. To address the research question, we employ a multi-source data collection approach, merging stoppage time data with match-specific performance and environmental variables.

The stoppage time allocated for both the first and second halves were extracted from the match report pages of the sports platform ESPN using a custom Python web-scraping script. Stoppage time is measured as the elapsed added time between minute 45 or 90 and the recorded end-of-half whistle time in ESPN's live match commentary (minute-level time stamps). While this

captures the realised added time rather than the announced minimum, the measure may still contain reporting imprecision due to rounding and ticker conventions. To complement these timing data, we integrated match-level information from football-data.co.uk, which provides detailed records of match outcomes, half-time scores, and disciplinary sanctions (yellow and red cards). Furthermore, we included closing betting odds (specifically from Bet365) as a proxy for the ex-ante expected probability of success and relative team strength. This allows us to control for the inherent quality difference between teams, ensuring that the observed stoppage time effects are not merely a reflection of a team's dominance. For the Italian league in the 2019/20 to 2023/24 seasons, Bet365 betting odds were replaced with Betway odds due to data inconsistencies. Consistency checks show that the two bookmakers' odds differ only marginally and are highly correlated. As betting odds are included solely as control variables, this adjustment does not affect the main results.

The dataset covers the years of the COVID-19 pandemic, which we treat as a natural experiment. This period provides a unique variation in social pressure, ranging from full-capacity stadiums to matches played without spectators ("ghost games") or with significantly restricted attendance. Methodologically, we addressed missing spectator data for ghost games by systematically setting the attendance to zero rather than excluding these observations. This ensures a robust sample size while allowing us to isolate the impact of the crowd's physical presence on referee behaviour across a continuous spectrum of social pressure.

After cleaning the data and merging the various sources, the final dataset comprises 18,085 match-level observations. This high number of observations provides sufficient statistical power to account for league-specific fixed effects and structural changes in the game, such as the implementation of the VAR and the permanent increase in the maximum number of permitted substitutions from three to five per team, both of which significantly altered the baseline for stoppage time allocation.

5. Empirical Results

Table 1 provides an overview of the variables used in our analysis, comprising a total of 18,085 match-level observations across the ten-season observation period. The average stoppage time awarded in the second half is 4.93 minutes, which is approximately double the average of 2.48 minutes awarded in the first half. This discrepancy is consistent with the higher frequency of match-altering events, such as substitutions and goals, that typically occur during the final stages of a game.

Variable	N	Mean	Std. Dev.	Min	Max
Attendance	18,085	26,444.47	19,711.14	0	98,902
VAR Implementation	18,085	0.5799281	0.4935838	0	1
Five-Substitution Rule	18,071	0.3800564	0.4854138	0	1
Stoppage Time (1st Half)	18,085	2.476859	1.649629	0	46
Stoppage Time (2nd Half)	18,085	4.926016	1.882071	0	18
Home Win	18,071	0.443639	0.496827	0	1
Home Points	18,071	0.6953129	0.4602875	0	1
Home Goals	18,085	1.54266	1.310726	0	10
Away Goals	18,085	1.221012	1.169112	0	9
Score Difference (1st Half)	18,085	0.1364114	1.108234	-6	5
Total Goals (1st Half)	18,085	1.132043	1.048764	0	7
Total Substitutions (1st Half)	18,085	0.2300802	0.4833913	0	9
Score Difference (2nd Half)	18,066	0.3051035	1.756602	-9	9
Total Goals (2nd Half)	18,085	1.352004	1.135849	0	8
Total Substitutions (2nd Half)	18,085	6.314404	2.168529	0	12
Final Goal Difference	18,071	0.3218416	1.831686	-9	9
Betting Odds (Home Win)	18,082	2.510922	2.126328	1.02	26
Betting Odds (Draw)	18,079	3.94635	1.498095	1.1	21
Betting Odds (Away Win)	18,079	4.584678	3.852728	1.07	41
Fouls (Home)	18,084	12.52206	4.072425	0	33
Fouls (Away)	18,084	12.8252	4.178697	0	32
Yellow Cards (Home)	18,083	1.932699	1.360338	0	9
Yellow Cards (Away)	18,084	2.169321	1.393921	0	9
Red Cards (Home)	18,084	0.0915174	0.3056672	0	3
Red Cards (Away)	18,084	0.1117562	0.3346512	0	3
Corners (Home)	18,084	5.460075	2.947064	0	20
Corners (Away)	18,084	4.429993	2.600375	0	19

Table 1: Descriptive Statistics for All Used Variables

The spectator attendance exhibits significant variation, ranging from 100 to nearly 99,000 in regular matches, while the inclusion of "ghost games" expands this range down to zero. On average, home teams score 1.54 goals compared to 1.22 for away teams, resulting in a mean final goal difference of 0.32. Disciplinary data reveals that away teams, on average, receive more yellow cards (2.17) and red cards (0.11) than home teams (1.93 and 0.09, respectively), providing initial descriptive support for the presence of home-favouring asymmetries in officiating.

Stoppage Time (1st Half) and Stoppage Time (2nd Half) measure the amount of added time at the end of the first and second half, respectively. These variables are based on the stoppage time recorded in the ESPN live match report. Home Win is a binary indicator that equals one if the home team wins the match and zero otherwise. Home Points is a binary variable that equals one if the home team obtains at least one point, i.e. in the case of a home win or a draw, and zero otherwise. Score Difference (1st Half) captures the goal difference from the home team's perspective at the end of minute 44. This timing reflects the fact that stoppage time for the first half is typically announced during the 45th minute. Consequently, goals scored during stoppage time in the first half are not included in this variable. Total Goals (1st Half) measures the total

number of goals scored by both teams up to and including minute 44. As with the score difference, goals scored during first-half stoppage time are not reflected in this variable. Total Substitutions (1st Half) counts the total number of substitutions made by both teams up to and including minute 44 and excludes any substitutions occurring during first-half stoppage time. Analogously, Total Goals (2nd Half), and Total Substitutions (2nd Half) are defined based on match events up to and including minute 89. Score Difference (2nd Half) measured at the end of the 89th minute, reflecting the cumulative match score rather than only events from the second half. Events occurring during second-half stoppage time are therefore not captured by these variables. All variables described below refer to match events over the entire duration of the game, including both halves.

Building on these descriptive insights, we first examine the determinants of match outcomes to establish the baseline presence of home advantage within our sample. Table 2 presents the regression results for three dependent variables: a binary indicator for a home win, the number of points obtained by the home team, and the number of goals scored by the home team. Across all specifications, spectator attendance exhibits a positive and highly significant effect on home success. This indicates that social pressure exerts a measurable influence on competitive outcomes even after controlling for team strength and match-specific events. The control variables behave as theoretically expected: the betting odds for a home win show a negative coefficient, indicating that higher odds (implying a lower ex-ante probability of winning) are associated with fewer home wins. Furthermore, disciplinary sanctions significantly impact the result. Receiving a red card substantially decreases a home team's likelihood of winning, whereas a red card for the away team significantly increases it. Crucially, the models also reveal a distinct relationship between stoppage time and match outcomes. The observed negative association suggests that extended stoppage time is more common in matches where the home team is trailing or drawing, while shorter added time is typically observed when the home team leads comfortably. We interpret this pattern as descriptive evidence motivating our subsequent analysis of scoreline-dependent stoppage time allocation. To test our hypotheses, we employ two different regression models in Table 2. For our dependent variables Home Win and Home Points, we apply binary logistic regression. The regression equation for a binary regression model is as follows:

$$P(Y = 1) = \frac{1}{1 + e^{-(\beta_0 + \beta_1 x_1 + \beta_2 x_2 + \cdots + \beta_k x_k)}}.$$

Y is the binary dependent variable (Home Win or Home Points), β_0 is the intercept, e is the base of the natural logarithm, $\beta_1, \beta_2, \dots, \beta_k$ are the coefficients estimated by the logit model and $x_1, x_2, \dots, x_k$ are the independent variables.

In the case of the linear regression with Home Goals as the dependent variable, the regression equation is as follows:

$$Y_i = \beta_0 + \beta_1 X_{1i} + \beta_2 X_{2i} + \cdots + \beta_k X_{ki} + \varepsilon_i$$

Y_i is the dependent variable (Score Difference), X_{ki} is the explanatory variable k for observation i, β represents the regression coefficients, and ε denotes the error term.

Table 2 examines the presence of home advantage in the five major European leagues using standard outcome-based measures, namely home wins, home points, and goals scored by the home team. For each outcome, we estimate baseline specifications as well as models including robust effects. The regressions control for commonly used determinants of home advantage, a set of match-level control variables, and explicitly account for the potential influence of stoppage time on match outcomes.

The results in Table 2 indicate the presence of a systematic home bias in the top five European leagues. Attendance is positively and highly significantly associated with home wins, home points, and goals scored by the home team across all specifications, suggesting that crowd presence contributes to favourable outcomes for the home team. Betting odds perform as expected, confirming that market-based expectations are appropriately controlled for.

Referee-related variables exhibit economically meaningful effects. Disciplinary actions against the home team are generally associated with worse home outcomes, while red cards shown to the away team substantially increase the likelihood of favourable home results. Stoppage time displays asymmetric effects across halves: first-half stoppage time is positively related to home performance, whereas additional stoppage time in the second half is consistently and significantly negatively associated with home outcomes. Overall, these patterns suggest that referee decisions, including cards and stoppage time, play an important role in shaping home bias.

	(1) Home Win	(2) Home Win	(3) Home Points	(4) Home Points	(5) Home Goals	(6) Home Goals
Attendance	0.00000761***	0.00000687***	0.00000791***	0.00000651***	0.00000434***	0.00000400***
	(0.000000928)	(0.00000132)	(0.00000105)	(0.00000134)	(0.000000503)	(0.000000820)
VAR Implementation	0.0172	0.250	-0.00757	0.134	0.0301	0.0335
	(0.0455)	(0.168)	(0.0489)	(0.171)	(0.0246)	(0.0712)
Five-Substitution Rule	0.124**	0.207	0.0957	0.188	0.151***	0.118
	(0.0461)	(0.113)	(0.0492)	(0.129)	(0.0250)	(0.0885)
Betting Odds (Home Win)	-0.0798***	-0.0539**	-0.0686***	-0.0423**	-0.0222***	-0.0187
	(0.0106)	(0.0208)	(0.0115)	(0.0159)	(0.00457)	(0.0134)
Betting Odds (Draw)	-0.384***	-0.469***	-0.424***	-0.497***	-0.102***	-0.121***
	(0.0203)	(0.0484)	(0.0221)	(0.0353)	(0.00933)	(0.0312)
Betting Odds (Away Win)	0.294***	0.324***	0.344***	0.379***	0.127***	0.133***
	(0.00882)	(0.0201)	(0.0119)	(0.0182)	(0.00394)	(0.0126)
Fouls (Home)	0.0142**	0.0146**	0.0150**	0.0161**	-0.000884	-0.00186
	(0.00449)	(0.00508)	(0.00480)	(0.00505)	(0.00243)	(0.00266)
Fouls (Away)	-0.0120**	-0.0107	0.000134	0.00157	-0.0173***	-0.0184***
	(0.00436)	(0.00580)	(0.00471)	(0.00573)	(0.00237)	(0.00285)
Yellow Cards (Home)	-0.0799***	-0.0776***	-0.0383**	-0.0339	-0.0520***	-0.0529***
	(0.0136)	(0.0139)	(0.0143)	(0.0181)	(0.00734)	(0.00813)
Yellow Cards (Away)	-0.0193	-0.0197	0.0105	0.0126	0.0236***	0.0211***
	(0.0131)	(0.0117)	(0.0142)	(0.0121)	(0.00713)	(0.00597)
Red Cards (Home)	-0.920***	-0.909***	-0.778***	-0.769***	-0.266***	-0.256***
	(0.0628)	(0.0781)	(0.0546)	(0.0624)	(0.0296)	(0.0253)
Red Cards (Away)	0.700***	0.710***	0.806***	0.820***	0.321***	0.322***
	(0.0499)	(0.0558)	(0.0630)	(0.0573)	(0.0269)	(0.0250)
Stoppage Time (1st Half)	0.0345**	0.0228*	-0.00409	-0.0149	0.0711***	0.0699***
	(0.0105)	(0.0107)	(0.0111)	(0.0132)	(0.00569)	(0.0108)
Stoppage Time (2nd Half)	-0.102***	-0.111***	-0.0439***	-0.0490***	-0.108***	-0.106***
	(0.00987)	(0.0137)	(0.0103)	(0.0111)	(0.00520)	(0.0132)
Constant	0.493***	0.487***	1.148***	1.251***	1.864***	2.029***
	(0.124)	(0.147)	(0.135)	(0.147)	(0.0611)	(0.106)
N	18,053	18,053	18,053	18,053	18,053	18,053
League Season FE	No	Yes	No	Yes	No	Yes
R^2	0.127	0.131	0.133	0.139	0.173	0.179

*Note: Standard errors in parentheses; * p < 0.1, ** p < 0.05, *** p < 0.01; (1) main model home wins, (2) main model home wins with league and season fixed effects, (3) model home points, (4) model home points with league and season fixed effects, (5) model home goals, (6) model home goals with league and season fixed effects.*

Table 2: Regression Models for Home Wins, Home Points and Home Goals

Table 3 reports linear regression estimates for stoppage time in the first half. The specifications follow the variable definitions described above and include both half-specific controls as well as match-level variables referring to the entire game, which serve as general indicators of match intensity and eventfulness. To capture the competitive context of the match, we include interaction terms based on match closeness and scoreline direction from the home team's perspective. A close game is defined as a match with an absolute goal difference of at most one goal. Based on the score difference, we distinguish whether the home team is leading, trailing, or the match is tied. The interaction terms allow the effect of match closeness on stoppage time to vary by scoreline direction. The reference category in the interaction specification is a draw, such that the estimated coefficients capture deviations from this baseline. This setup enables us to assess whether referees allocate first-half stoppage time asymmetrically in close matches depending on whether the home team is leading or trailing.

	(1) Stoppage Time (1st Half)	(2) Stoppage Time (1st Half)	(3) Stoppage Time (1st Half)	(4) Stoppage Time (1st Half)
Attendance	0.00000861***	-0.000000126	0.00000849***	-0.000000252
	(0.000000629)	(0.000000799)	(0.000000630)	(0.000000792)
VAR Implementation	0.436***	-0.0986	0.437***	-0.102
	(0.0306)	(0.123)	(0.0306)	(0.126)
Five-Substitution Rule	0.459***	0.928**	0.458***	0.921**
	(0.0311)	(0.321)	(0.0311)	(0.325)
Score Difference (1st Half)	-0.0378***	-0.0391**		
	(0.0110)	(0.0120)		
Total Goals (1st Half)	0.107***	0.123***	0.0972***	0.111***
	(0.0108)	(0.0263)	(0.0111)	(0.0272)
Total Substitutions (1st Half)	1.012***	1.014***	1.012***	1.013***
	(0.0231)	(0.0381)	(0.0231)	(0.0381)
Betting Odds (Home Win)	-0.0404***	-0.00946	-0.0397***	-0.00936
	(0.00576)	(0.00852)	(0.00578)	(0.00843)
Betting Odds (Draw)	0.0367**	-0.0157	0.0425***	-0.00945
	(0.0121)	(0.0176)	(0.0122)	(0.0186)
Betting Odds (Away Win)	-0.0417***	0.00194	-0.0470***	-0.00376
	(0.00532)	(0.00810)	(0.00545)	(0.00854)
Corners (Home)	0.0131**	0.00535	0.0156***	0.00819*
	(0.00415)	(0.00341)	(0.00414)	(0.00339)
Corners (Away)	0.0101*	0.00651	0.00863	0.00516
	(0.00461)	(0.00423)	(0.00460)	(0.00393)
Fouls (Home)	-0.0203***	0.00594	-0.0208***	0.00560
	(0.00307)	(0.00331)	(0.00307)	(0.00328)
Fouls (Away)	-0.0154***	0.00725*	-0.0145***	0.00822*
	(0.00299)	(0.00326)	(0.00299)	(0.00326)
Yellow Cards (Home)	0.0630***	0.0705***	0.0675***	0.0757***
	(0.00919)	(0.00871)	(0.00923)	(0.00877)
Yellow Cards (Away)	0.0462***	0.0606***	0.0473***	0.0629***
	(0.00890)	(0.0105)	(0.00895)	(0.0103)
Red Cards (Home)	0.252***	0.274***	0.260***	0.282***
	(0.0373)	(0.0485)	(0.0375)	(0.0477)
Red Cards (Away)	0.132***	0.156***	0.125***	0.149***
	(0.0340)	(0.0309)	(0.0342)	(0.0301)
Close Game			-0.0490	-0.0889
			(0.0421)	(0.0455)
Home Lead			-0.00150	-0.0276
			(0.0543)	(0.0525)
Close Game x Home Lead			-0.0396	-0.0114
			(0.0543)	(0.0556)
Home Trail			-0.00960	-0.0179
			(0.0349)	(0.0317)
Constant	1.712***	1.018***	1.741***	1.074***
	(0.0820)	(0.0999)	(0.0939)	(0.116)
N	18,053	18,053	18,053	18,053
League Season FE	No	Yes	No	Yes
R^2	0.174	0.312	0.174	0.312

*Note: Standard errors in parentheses; * p < 0.1, ** p < 0.05, *** p < 0.01; (1) includes score difference, (2) includes score difference and league season fixed effects, (3) includes match situation dummies (close game, home lead, home trail), (4) includes match situation dummies and league season fixed effects.*

Table 3: Regression Models for Stoppage Time (1st Half)

The results show that first-half stoppage time is positively and significantly related to attendance in specifications without league and season fixed effects, indicating that larger crowds are associated with longer added time. However, this effect disappears once league and season fixed effects are included, suggesting that the attendance effect is largely driven by cross-league or time-specific variation. Goal difference at halftime is negatively and significantly associated

with first-half stoppage time, implying that less balanced matches receive slightly less added time, consistent with lower competitive tension in less close games. The interaction effects between match closeness and scoreline direction are small and statistically insignificant across specifications. This indicates that referees do not systematically condition first-half stoppage time on whether a close match favours or disadvantages the home team. Overall, these findings suggest that first-half stoppage time is primarily driven by mechanical interruptions rather than strategic considerations related to match closeness or home bias.

In Table 4, we re-estimate the regression models for second-half stoppage time to examine whether referee behaviour differs between the first and second halves of the match. The results indicate that second-half stoppage time responds more strongly to match conditions than in the first half. Attendance is positively and significantly associated with added time in specifications without league and season fixed effects, but the effect again disappears once fixed effects are included. Goal difference has a negative and highly significant effect, implying that less balanced matches receive less added time. In contrast to the first half, match closeness plays a central role in the second half. Close games are associated with a substantial and highly significant increase in stoppage time of approximately 1.2 minutes. The coefficients further suggest asymmetries across scoreline states: when the home team is leading, added time is slightly increased relative to close draws, when the home team is trailing the stoppage time increases even more. Although the interaction effects are small, they point toward context-dependent time allocation late in the match. Comparing both halves, the results show that stoppage time in the first half is largely driven by mechanical interruptions, whereas second-half stoppage time is more sensitive to match closeness and competitive context, consistent with more strategic referee behaviour as the match approaches its end.

Table 5 analyses referee disciplinary decisions by examining yellow and red cards awarded to home and away teams to examine whether referee disciplinary decisions exhibit potential bias. The results show a strong and highly significant relationship between fouls committed and cards received, confirming the mechanical link between infractions and disciplinary sanctions. Attendance is positively and significantly associated with yellow cards for both home and away teams, suggesting that matches with larger crowds are generally more intensely officiated. However, attendance does not exhibit a robust effect on red cards. The VAR implementation is associated with an increase in yellow cards for both teams, while its effect on red cards is weak and inconsistent across specifications. This pattern is consistent with context-dependent officiating that varies with match dominance. Overall, while fouls remain the primary determinant

of disciplinary actions, the asymmetric effects with respect to score difference and team status provide suggestive evidence that referee decisions are not purely mechanical and may reflect contextual or behavioural considerations.

	(1) Stoppage Time (2nd Half)	(2) Stoppage Time (2nd Half)	(3) Stoppage Time (2nd Half)	(4) Stoppage Time (2nd Half)
Attendance	0.00000910***	-0.000000285	0.00000919***	-6.39e-08
	(0.000000717)	(0.00000109)	(0.000000688)	(0.000000992)
VAR Implementation	0.495***	-0.327*	0.481***	-0.323*
	(0.0349)	(0.137)	(0.0335)	(0.137)
Five-Substitution Rule	0.856***	0.693*	0.789***	0.673*
	(0.0413)	(0.340)	(0.0397)	(0.319)
Score Difference (2st Half)	-0.111***	-0.105***		
	(0.00836)	(0.00908)		
Total Goals (2st Half)	-0.127***	-0.104***	-0.0196	0.00206
	(0.0114)	(0.0227)	(0.0114)	(0.0230)
Total Substitutions (2st Half)	-0.0429***	-0.0221*	-0.0144	0.00703
	(0.00760)	(0.00996)	(0.00739)	(0.00879)
Betting Odds (Home Win)	-0.0636***	-0.0511***	-0.0467***	-0.0346***
	(0.00657)	(0.00587)	(0.00632)	(0.00561)
Betting Odds (Draw)	-0.0772***	-0.0650***	-0.0435**	-0.0365**
	(0.0139)	(0.0125)	(0.0134)	(0.0112)
Betting Odds (Away Win)	-0.0247***	-0.00599	-0.0292***	-0.00880
	(0.00625)	(0.00637)	(0.00596)	(0.00557)
Corners (Home)	0.0426***	0.0329***	0.0369***	0.0265***
	(0.00471)	(0.00537)	(0.00453)	(0.00494)
Corners (Away)	0.0436***	0.0359***	0.0373***	0.0295***
	(0.00523)	(0.00455)	(0.00503)	(0.00415)
Fouls (Home)	-0.0117***	0.0153***	-0.0127***	0.0142***
	(0.00350)	(0.00348)	(0.00336)	(0.00314)
Fouls (Away)	-0.00841*	0.0164***	-0.0120***	0.0128***
	(0.00341)	(0.00294)	(0.00327)	(0.00263)
Yellow Cards (Home)	0.163***	0.152***	0.136***	0.123***
	(0.0105)	(0.0116)	(0.0101)	(0.0110)
Yellow Cards (Away)	0.173***	0.167***	0.137***	0.130***
	(0.0101)	(0.0142)	(0.00978)	(0.0135)
Red Cards (Home)	0.196***	0.207***	0.212***	0.221***
	(0.0427)	(0.0574)	(0.0410)	(0.0548)
Red Cards (Away)	0.269***	0.281***	0.279***	0.294***
	(0.0389)	(0.0453)	(0.0373)	(0.0440)
Close Game			1.256***	1.237***
			(0.0463)	(0.0556)
Home Lead			0.265***	0.247***
			(0.0594)	(0.0475)
Close Game x Home Lead			-0.0563	-0.0433
			(0.0594)	(0.0501)
Home Trail			0.455***	0.437***
			(0.0382)	(0.0402)
Constant	4.242***	3.573***	2.938***	2.303***
	(0.101)	(0.124)	(0.110)	(0.141)
N	18,049	18,049	18,053	18,053
League Season FE	No	Yes	No	Yes
R^2	0.175	0.324	0.241	0.389

*Note: Standard errors in parentheses; * p < 0.1, ** p < 0.05, *** p < 0.01; (1) includes score difference, (2) includes score difference and league season fixed effects, (3) includes match situation dummies (close game, home lead, home trail), (4) includes match situation dummies and league season fixed effects.*

Table 4: Regression Models for Stoppage Time (2nd Half)

	(1) Yellow Cards (Home)	(2) Yellow Cards (Home)	(3) Yellow Cards (Away)	(4) Yellow Cards (Away)	(5) Red Cards (Home)	(6) Red Cards (Away)
Fouls (Home)	0.123***	0.115***			0.00381***	
	(0.00233)	(0.00342)			(0.000567)	
Attendance	0.00000186***	0.00000254***	0.00000391***	0.00000367***	8.48e-09	-0.000000199
	(0.000000519)	(0.000000708)	(0.000000535)	(0.000000832)	(0.000000126)	(0.000000184)
VAR Implementation	0.136***	0.106	0.180***	0.166	-0.00580	-0.0164*
	(0.0253)	(0.0706)	(0.0262)	(0.0912)	(0.00613)	(0.00706)
Five-Substitution Rule	0.0492	-0.102	0.0302	-0.422***	0.0102	-0.0410*
	(0.0257)	(0.0985)	(0.0266)	(0.0879)	(0.00624)	(0.0159)
Final Goal Difference	-0.0716***	-0.0684***	0.00241	0.00424	-0.0251***	0.0213***
	(0.00565)	(0.00527)	(0.00585)	(0.00504)	(0.00137)	(0.00178)
Betting Odds (Home Win)	-0.0159***	-0.0298***	-0.000161	-0.0110	-0.00230*	-0.000646
	(0.00474)	(0.00522)	(0.00493)	(0.00787)	(0.00115)	(0.00111)
Betting Odds (Draw)	-0.0108	0.0197	-0.0997***	-0.0816***	-0.00941***	-0.000798
	(0.00979)	(0.0129)	(0.0102)	(0.0168)	(0.00238)	(0.00207)
Betting Odds (Away Win)	-0.0252***	-0.0434***	0.0216***	0.0103	0.00415***	-0.00438***
	(0.00431)	(0.00535)	(0.00446)	(0.00688)	(0.00105)	(0.00120)
Fouls (Away)			0.123***	0.118***		0.00399***
			(0.00236)	(0.00296)		(0.000508)
Constant	0.469***	0.721***	0.661***	0.907***	0.0758***	0.128***
	(0.0492)	(0.0542)	(0.0522)	(0.0652)	(0.0119)	(0.0108)
N	18,053	18,053	18,054	18,054	18,054	18,054
League Season FE	No	Yes	No	Yes	No	No
R^2	0.166	0.203	0.149	0.191	0.0228	0.0284

*Note: Standard errors in parentheses; * p < 0.1, ** p < 0.05, *** p < 0.01; (1) model Yellow Cards Home Team (2) model Yellow Cards Home Team with League and Season Fixed Effects; (3) model Yellow Cards Away Team (2) model Yellow Cards Away Team with League and Season Fixed Effects; (5) model Red Cards Home Team; (6) model Red Cards Away Team.*

Table 5: Regression Models for Cards

6. Discussion

In this section, we discuss the implications of our hypotheses regarding referee bias in stoppage time allocation before addressing the limitations of our study and outlining directions for future research.

H1: Referees award more stoppage time when home teams are trailing compared to when they are leading.

While the analysis of the first half (Table 3) suggests that stoppage time is determined primarily by mechanical factors such as substitutions and goals rather than the scoreline, the results for the second half (Table 4) reveal a different pattern. Here, the coefficients indicate that referee behaviour is indeed sensitive to the scoreline. Specifically, both Home Lead and Home Trail are associated with significantly more stoppage time compared to when the match is tied. Crucially, however, the coefficient for Home Trail is substantially larger than for Home Lead, indicating that referees award additional seconds of stoppage time when the home team is behind compared to when they are ahead. This pattern is consistent across all specifications and supports Morabito and Scoppa (2024), who suggest an inequity aversion in stoppage time

allocation. We therefore find support for the hypothesis, confirming that discretionary decisions favour the home team, albeit exclusively in the final stage of the match.

H2: Home bias in stoppage time allocation is stronger in close matches than in matches with larger score differences.

This hypothesis is primarily supported by the results in Table 4, which isolate the effect of match closeness in the second half. Matches defined as "close" (goal difference ≤ 1) receive more stoppage time than matches with decisive margins. This finding aligns with established literature, such as Garicano et al. (2005) and Scoppa (2008), who argue that referee susceptibility to social pressure is highest when their decisions can directly influence the match outcome. In contrast, Table 3 shows that in the first half, match closeness does not exert a comparable influence on time allocation. Overall, the results provide robust evidence that the magnitude of home bias is contingent on competitive suspense, with referees exercising their discretion most actively when the stakes are highest.

H3: Home bias in stoppage time allocation is more pronounced in the second half compared to the first half.

To evaluate this hypothesis, we examine the drivers of stoppage time across both halves. The contrast between Table 3 and Table 4 is striking and strongly supports the hypothesis. In the first half, stoppage time is consistently explained by observable interruptions—substitutions, goals, and disciplinary actions—with no significant impact from interaction terms related to match closeness or home advantage. Conversely, the second half exhibits clear patterns of strategic time allocation driven by the competitive context. This is consistent with Sutter and Kocher (2004), who argue that referees show bias in the second half because extra time decisions at that stage can directly influence the match outcome, whereas first-half decisions have limited strategic significance. As the final whistle nears, the potential for crowd noise and player protests to influence the referee increases, resulting in the significant discretionary variations we observe in the second half that are absent in the first.

Taken together, the results provide compelling evidence that discretionary stoppage time allocation serves as a mechanism for home bias, but one that is highly context dependent. The analysis of spectator attendance adds a further layer of complexity: while raw attendance figures show positive effects in simple models, this significance disappears when controlling for league and season fixed effects. This mirrors findings from the "ghost game" literature (e.g.,

Dilger & Vischer 2022, Scoppa 2021), suggesting that the presence of a crowd and the general competitive atmosphere drive bias more than the precise number of spectators on a given day.

However, several limitations must be acknowledged. First, the inclusion of certain control variables, such as corner kicks and cards, is constrained by data availability at the match level rather than the half level. This limits the precision of the analysis regarding the immediate precursors to stoppage time decisions in each half. Second, the dataset does not capture events occurring during stoppage time itself, preventing the modelling of dynamic in-play responses by referees. Third, the match information is derived from live commentary data, which may be subject to reporting imprecision. As Butler et al. (2025) note, standard data sources like ours report stoppage time only to the minute level and cannot differentiate between a match stopped at exactly six minutes versus one stopped at six minutes and 59 seconds. This imprecision in available data could mask meaningful variation in referee behaviour. Future research should utilize precise tracking data to measure effective playing time more accurately and directly link stoppage time duration to goal-scoring opportunities created during that period.

Our data indicate a relationship between goal-scoring events during stoppage time and the length of stoppage time. However, a detailed analysis of this relationship is beyond the scope of the present paper, as it primarily reflects how teams respond to the amount of stoppage time rather than strategic behaviour by referees. A more detailed examination of goal-scoring dynamics during stoppage time therefore constitutes a promising avenue for future research.

7. Conclusion

This study examined whether referee discretion in stoppage time allocation contributes to home advantage in European professional football. Using 18,085 matches from the top five leagues across the 2014/15 to 2023/24 seasons, we showed that while first-half allocation appears comparatively stable and largely explained by observable interruptions, stoppage time in the second half is strongly context-dependent.

The central result is an asymmetric pattern across score states late in the match. We find systematic evidence that referees extend play in close matches when the home team is trailing. Stoppage time increases in both score states relative to a tie, but the effect is markedly stronger when the home team is trailing than when they are protecting a lead.

From a governance perspective, even small average differences can matter when they occur in decisive phases of close matches. If football authorities aim to reduce the scope for context-dependent allocation, the most direct lever is to further narrow discretion through standardised and auditable time-loss procedures or a broader shift toward effective playing time. Future research can build on recent regulatory attention to time-loss tracking to assess whether tightened procedures reduce the remaining asymmetries in stoppage time allocation.

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