

Video Assistant Referee and Home Advantage: The Case of Brazilian Soccer Championship^a

Árbitro assistente de vídeo e vantagem em casa: o caso do campeonato brasileiro de futebol

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Abstract: Home-field advantage is a well-documented feature of professional soccer and may partly reflect referee decisions made under social pressure. This study examines whether home advantage changed after the nationwide introduction of the video assistant referee (VAR) in the Brazilian Série A in 2019. The database covers all clubs that competed from 2017 to 2020 and is organized as an unbalanced panel of unordered club pairs by season. A two-step Difference Generalized Method of Moments estimator is used to account for outcome persistence, pair-specific heterogeneity and the potential endogeneity of crowd intensity. The lagged dependent variable and crowd intensity are instrumented with their levels dated $t-2$ and $t-3$, and a separate indicator controls for the atypical 2020 season. The post-VAR indicator is associated with 0.446 additional away-team goals per pair-season, no statistically significant change in home-team goals, a reduction in the home-away points differential of 1.305 points and a 10.7 percentage-point decline in the home share of available points. Crowd intensity is not statistically significant. The results are consistent with VAR constraining home-favoring discretion, but the nationwide rollout, the short time dimension and the absence of a significant marginal crowd effect prevent a strong causal or mechanism-specific interpretation.

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Keywords: Home Advantage. Video Assistant Referee. Referee Bias. Social Pressure. Dynamic Panel GMM.

Resumo: A vantagem de jogar em casa é uma característica amplamente documentada no futebol profissional e pode refletir, em parte, decisões arbitrais tomadas sob pressão social. Este estudo examina se a vantagem do mandante se alterou após a introdução nacional do árbitro assistente de vídeo (VAR) na Série A do Campeonato Brasileiro, em 2019. A base abrange todos os clubes que disputaram a competição entre 2017 e 2020 e é organizada como um painel desbalanceado de duplas não ordenadas de clubes por temporada. Estima-se um modelo *Difference GMM* em dois passos para controlar a persistência dos resultados, a heterogeneidade específica das duplas e a possível endogeneidade da intensidade da torcida. A variável dependente defasada e a intensidade da torcida são instrumentadas por seus níveis em $t-2$ e $t-3$, e uma *dummy* adicional controla a temporada atípica de 2020. O indicador pós-VAR está associado a 0,446 gol adicional dos visitantes por dupla-temporada, sem alteração estatisticamente significativa nos gols dos mandantes, a uma redução de 1,305 ponto no diferencial de pontos entre mandantes e visitantes e a uma queda de 10,7 pontos percentuais na parcela de pontos dos mandantes. A intensidade da torcida não é estatisticamente significativa. Os resultados são compatíveis com a hipótese de que o VAR restringe a discricionariedade favorável ao mandante, mas a adoção nacional, o curto horizonte temporal e a ausência de efeito marginal significativo do público impedem uma interpretação causal forte ou a identificação direta do mecanismo psicológico.

Palavras-chave: Vantagem de mando. Árbitro assistente de vídeo. Viés de arbitragem. Pressão social. Painel dinâmico GMM.

JEL: L83. C23. D91.

1. Introduction

Home advantage is one of the most persistent regularities in team sports. In soccer, home teams win more often, score more goals and receive a larger share of available points than away teams (Pollard, 1986; Nevill; Newell; Gale, 1996; Pollard; Prieto; Gómez, 2017). This pattern may reflect travel, familiarity with the venue, tactical choices and territorial behavior, but a central explanation is that referees make discretionary decisions while exposed to the reactions of a predominantly home crowd (Pollard, 2008; Dohmen; Sauermann, 2016).

The problem can also be understood through agency theory and third-party pressure. Referees act as agents of competition organizers and are expected to apply rules impartially, although their effort and judgment cannot be perfectly observed in real time. When decisions must be made quickly and under uncertainty, the crowd becomes a salient external constituency whose immediate approval or disapproval may affect the agent's behavior. Agency theory emphasizes that monitoring and information systems can constrain discretion when the principal cannot directly observe the agent's actions (Eisenhardt, 1989). Related work shows that decision makers may accommodate the demands of affected third parties to avoid complaints or sanctions (Prendergast, 2003), and soccer provides a setting in which such pressure can be observed repeatedly.

The video assistant referee (VAR) changes this institutional environment by adding an independent review stage for goals, penalties, direct red cards and mistaken identity. In the Brazilian Série A, VAR was adopted in all matches beginning in 2019 (CBF, 2019). By improving the information available to the on-field referee and making selected decisions reviewable, VAR can reduce both unintentional errors and discretion that would otherwise favor the home team. If this mechanism is relevant, the post-VAR period should exhibit a narrower gap between home and away performance, particularly through outcomes that are directly affected by decisive refereeing decisions.

Empirically isolating this change is difficult. Attendance is potentially endogenous because supporters are more likely to attend when they expect a strong performance, while team quality and recent results affect both attendance and match outcomes. In addition, excluding promoted and relegated clubs would condition the sample on survival in the first division and remove precisely the teams for which pressure and competitive stakes may be strongest. The revised

empirical design therefore retains all clubs and uses an unbalanced dynamic panel rather than restricting the analysis to teams continuously present in the league.

This study examines the change in home advantage around the introduction of VAR using four Série A seasons: 2017 and 2018 as the pre-VAR period and 2019 and 2020 as the post-VAR period. Match data are aggregated by unordered club pair and season, and the models are estimated by two-step Difference Generalized Method of Moments (Difference GMM). This strategy removes pair-specific time-invariant heterogeneity and uses lagged levels of the outcome and crowd intensity as internal instruments, avoiding the disputed use of the away team's absolute league position as an external instrument.

The results show no statistically significant change in home-team goals after 2019, but an increase in away-team goals and significant reductions in points-based measures of home advantage. The consistency of these findings with the monitoring interpretation is noteworthy, but crowd intensity is not statistically significant and all clubs received VAR at the same time. Accordingly, the estimates are interpreted as adjusted post-2019 associations rather than definitive proof that marginal crowd pressure is the causal mechanism.

2. Literature on Home Advantage, Referee Bias and Monitoring

2.1 Home advantage across sports and its mechanisms

The study of home advantage predates the contemporary econometric literature. Schwartz and Barsky (1977) associated local teams with collective identification and examined whether the social environment surrounding the home side systematically changes sporting outcomes. Subsequent research documented home advantage in individual sports (Jones, 2013) and in several team settings, including baseball (Jones, 2015), American football (Jones, 2016), roller hockey (Arboix-Alió; Aguilera-Castells, 2019), rugby (Dawson; Massey; Downward, 2020), tennis (Koning, 2011), basketball (Mateus; Gonçalves; Sampaio, 2021) and association football (Nevill; Newell; Gale, 1996; Pollard; Prieto; Gómez, 2017). This breadth indicates that home advantage is not a peculiarity of a single league or scoring system, although its magnitude and channels vary across institutional environments.

The mechanisms proposed for this regularity are also diverse. Pollard (1986, 2008) emphasizes travel costs, familiarity with local conditions, territoriality, hormonal and psychological responses, tactical choices and rule-related factors. Coaches may also adjust expectations, goals and tactics according to venue (Staufenbiel; Lobinger; Strauss, 2015). In Brazil, Silva and Moreira (2008) report a comparatively strong home advantage, while Shikida, Carraro and Araújo Júnior (2018) study local derbies, where travel and venue unfamiliarity are attenuated, to focus more closely on pressure-related mechanisms. These studies imply that no single variable is sufficient to represent home advantage; empirical specifications should control for sporting strength and venue conditions while distinguishing crowd-related pressure from other home characteristics.

2.2 Social pressure, strategic interaction and referee bias

The crowd-pressure hypothesis has foundations in behavioral and institutional economics. Akerlof (1980) and Bernheim (1994) show how social customs, conformity and the pursuit of status can alter behavior, and Szymanski (2000) illustrates how persistent social mechanisms may affect outcomes in professional sport. In experimental games, Charness, Rigotti and Rustichini (2007) find that group membership and the presence of others change individual choices. From a game-theoretic perspective, referees, teams and supporters can be viewed as strategic decision makers whose actions respond to anticipated reactions (Osborne, 2004). If supporters believe that vocal protest can influence discretionary calls, an equilibrium may emerge in which crowds exert pressure and referees anticipate the cost of unpopular decisions. Felson (1982) further suggests that audiences can amplify aggressive or reputational behavior, which is relevant to both players and officials.

The empirical literature provides several direct tests of referee favoritism. Garicano, Palacios-Huerta and Prendergast (2005) show that Spanish referees awarded more stoppage time when the home side was narrowly behind than when it was narrowly ahead. Boyko, Boyko and Boyko (2007) identify referee-specific differences associated with home advantage in the English Premiership. Dohmen (2008) reports related evidence for German football, while Buraimo, Forrest and Simmons (2010) demonstrate that disciplinary decisions depend on crowd pressure, score and match time. Page and Page (2010) add that referees differ in

their ability to cope with crowd pressure, and Dohmen and Sauermann (2016) synthesize a broader body of evidence on favoritism in sports officiating. Together, these studies support the possibility that the home crowd affects not only players but also the agent responsible for enforcing the rules.

Matches played without spectators offer an especially informative comparison. Pettersson-Lidbom and Priks (2010) find more balanced refereeing in Italian matches played in empty stadiums. Cueva (2020) and Bryson *et al.* (2021) use the exceptional variation created by COVID-19 restrictions and document reductions in several dimensions of home advantage when crowds were absent or restricted. Belchior (2020), however, finds no evidence that marginal increases in attendance raised the home team's probability of winning in Brazil. These findings are not necessarily contradictory: a crowd may produce a level effect that is difficult to identify among normally attended matches, and final scores jointly reflect refereeing, player effort, tactics and strategic fouling. Consequently, the absence of a significant marginal attendance coefficient does not by itself prove that social pressure is irrelevant, but it does limit claims about the precise transmission mechanism.

2.3 VAR as information, monitoring and institutional oversight

Agency theory provides a complementary interpretation of the officiating problem. Competition organizers delegate rule enforcement to referees, but the quality of real-time judgment is imperfectly observable. Monitoring and information systems can reduce agency problems by increasing the probability that errors or discretionary choices are detected (Eisenhardt, 1989). At the same time, agents may accommodate the demands of salient third parties when complaints, reputational costs or sanctions are asymmetric (Prendergast, 2003). The home crowd is not the principal, but it is an immediately observable constituency capable of imposing psychological costs. VAR changes this environment by making selected decisions reviewable and by adding another official to the information structure. Under the Brazilian implementation, review applies to goals, penalties, direct red cards and mistaken identity (CBF, 2019).

Evidence from other sports and leagues indicates that technological oversight can alter decisions and behavior. Dawson, Massey and Downward (2020) show that television match officials affect home advantage in rugby. Han

et al. (2020) find more balanced disciplinary outcomes after VAR adoption in the Chinese Super League, and Spitz *et al.* (2021) report improvements in decision accuracy across multiple competitions. VAR may also change player behavior: Veldkamp and Koning (2023) find that intervention affects penalty conversion, while the reviews by Silva *et al.* (2023) and Li, Wang and Zhang (2026) summarize effects on goals, fouls, offsides, cards and penalties. Scanlon, Griggs and McGillick (2022) show that the technology also affects the matchday experience and fans' perceptions of legitimacy. Therefore, a post-VAR change in final outcomes may operate through corrected decisions, altered referee discretion, player adaptation or tactical responses rather than through a single channel.

2.4 Economic relevance, outcome measurement and contribution

Changes in home advantage matter economically because clubs value sporting success even when profit is also part of the objective function. The literature considers win maximization, utility maximization and profit-oriented behavior under budget constraints (Sloane, 1971; Késenne, 2006; Dietl; Grossmann; Lang, 2011; Fort, 2015). This issue is particularly relevant in Brazil, where associative nonprofit structures historically coexisted with more business-oriented forms of club management (Nakamura; Cerqueira, 2021). A technology that changes expected home and away outcomes can therefore affect tactical decisions, competitive balance, managerial evaluation and the allocation of resources.

The empirical measure of performance also matters. Goal-based models retain the intensity of the result, whereas win/draw/loss measures map performance into the league scoring rule (Egidi; Torelli, 2021). García, Aguilar and Romero (2014) and Gómez and Pollard (2014) discuss points-based measures of home advantage under the three-points-for-a-win system. Count-data approaches, including bivariate Poisson models, are widely used for football goals because home and away scoring may be correlated (Karlis; Ntzoufras, 2003; Chowdhury; Islam, 2015; Islam; Chowdhury, 2017). The original version of this study followed that tradition. The revised analysis instead uses a linear dynamic-panel framework so that goals, goal differentials and points-based outcomes can be examined within a common specification while addressing persistence and endogenous crowd intensity.

The present study contributes by examining the nationwide introduction of VAR in a league with historically strong home advantage; by retaining promoted and relegated clubs rather than conditioning the sample on survival in the first division; and by comparing goal-based and points-based outcomes in a dynamic unbalanced panel. The combination of descriptive evidence, period-specific correlation matrices and GMM estimates allows the empirical patterns to be connected more directly to the theoretical expectation: if VAR constrains home-favoring discretion, away scoring should increase or home scoring should decline, and the home-away goal differential, points differential and home share of available points should fall.

3. Methodology

3.1 Data and sample

The Brazilian Série A contains 20 clubs per season. Each pair of clubs plays twice, once at each club's home venue, producing 380 matches per season. The database covers 2017, 2018, 2019 and 2020, for a total of 1,520 matches. All clubs that participated in each season are retained, including promoted and relegated teams. The resulting dataset is therefore an unbalanced panel across club pairs rather than a balanced sample restricted to teams that remained in the first division throughout the four-year window. This choice preserves observations involving clubs at the extremes of technical quality and relegation risk, where competitive pressure may be especially pronounced.

The unit of analysis is an unordered club pair in a given season. For each pair-season, the two reciprocal fixtures are aggregated. Home-team goals are the total goals scored by the two teams while acting as the home side, and away-team goals are defined analogously. The complete panel contains 760 pair-season observations and 345 unique pairs. Because Difference GMM requires consecutive lags, the estimating sample contains 182 first-differenced equations from 116 pairs observed for at least three consecutive seasons. Pair aggregation keeps the competitive matchup fixed while allowing the identity of the home team to alternate across the two fixtures.

Match results and match statistics were obtained from the public Campeonato Brasileiro datasets identified in the replication workbook. Team positions were reconstructed at the match level before aggregation. Attendance in

2017–2019 is represented by the season-level mean attendance of the home club because consistent match-level attendance was not available for every season; the workbook flags these values as proxies. Attendance is set to zero in 2020 because the league was played behind closed doors. The database also records coaching changes and neutral venues. The revised model does not use municipal income, population, precipitation or the away team's absolute position as instruments, thereby avoiding the exclusion-restriction concern raised for the original specification.

3.2 Variables

Five dependent variables are considered. Home-team goals and away-team goals are the respective totals across the two fixtures in each pair-season. Home-away goal differential equals home-team goals minus away-team goals. Home-away points differential equals the points obtained by home sides minus those obtained by away sides across the two fixtures. Home points share equals home points divided by the six points potentially available to the two home sides. Combining these measures follows the distinction between goal-based and result-based approaches (Egidi; Torelli, 2021) and the points-based measurement of home advantage discussed by García, Aguilar and Romero (2014) and Gómez and Pollard (2014).

Table 1 – Construction, treatment and expected direction of the model variables

Variable	Calculation	Treatment in the model	Expected practical association
Lagged dependent variable	One-season lag of each outcome	Endogenous; instrumented with levels dated $t-2$ and $t-3$	Captures persistence; sign estimated empirically
VAR	1 in 2019–2020; 0 in 2017–2018	Main post-intervention indicator	Home goals: $-/0$; away goals: $+$; home-advantage gaps: $-$.
COVID-19 season	1 only in 2020	Separate time control.	Ambiguous because it combines closed doors and other disruptions
Crowd intensity	$\log(1 + \text{attendance})$, centered over positive-attendance observations; 0 in 2020	Endogenous; instrumented with levels dated $t-2$ and $t-3$	Home goals and home-advantage gaps: $+$; away goals: $-$
Position differential	Mean pre-round home position minus away position across the two fixtures	Time-varying control	At match level, a positive value means the home side is relatively worse; after reciprocal aggregation, sign is less clear
New coach — home	Count of fixtures in which the home side was in the first three league matches under a new coach	Time-varying control	Ambiguous: motivation versus information loss
New coach — away	Count of fixtures in which the away side was in the first three league matches under a new coach	Time-varying control	Ambiguous: motivation versus information loss
Neutral stadium	Count of fixtures played outside the home club's state	Time-varying control	Home goals and gaps: $-$; away goals: $+$

Source: own elaboration.

Note: Time-invariant pair characteristics, including same-state status, are removed by first differencing. Expected signs refer to a reduction in home advantage and are theoretical rather than imposed by the estimator.

VAR is a league-wide intervention indicator. It equals zero in the two seasons before adoption and one in the two seasons in which every Série A match used video review. Based on the institutional rules and prior evidence (CBF, 2019; Han *et al.*, 2020; Spitz *et al.*, 2021), the practical hypothesis is not necessarily a fall in home scoring alone. A reduction in home-favoring discretion may appear as more away goals, fewer home goals, or a narrower home-away gap in goals and

points. The 2020 indicator is included separately because that season combined closed doors, calendar disruption and other pandemic shocks documented in the absent-crowd literature (Cueva, 2020; Bryson *et al.*, 2021).

Crowd intensity is computed as $\log(1 + \text{attendance})$. For positive-attendance observations, the transformed value is centered around the mean log attendance for 2017–2019; 2020 observations are set to zero, while the COVID-19 dummy absorbs the exceptional closed-door season. The logarithm limits the influence of very large crowds and reflects the expectation of diminishing marginal pressure. Attendance is treated as endogenous because expected performance, recent form, star players and match attractiveness can affect both demand and outcomes. This treatment is consistent with the ticket-demand considerations of Bortoluzzo *et al.* (2017) and with the broader literature linking attendance and social pressure to match outcomes (Garicano; Palacios-Huerta; Prendergast, 2005; Buraimo; Forrest; Simmons, 2010; Belchior, 2020).

Position differential is calculated at the match level as the home team's league position before the round minus the away team's position and then averaged across the two reciprocal fixtures. Because a smaller numerical rank denotes a better position, a positive match-level value indicates that the home side is relatively worse. In the pair-season panel, however, the identity of the home team reverses between fixtures, so the average captures the relative ranking at the two match dates rather than a fixed quality gap between two permanently designated home and away teams. It is retained as a time-varying control for sporting strength, but its coefficient should be interpreted with this aggregation in mind.

The new-coach variables count the number of pair-season fixtures in which the relevant side was within its first three Série A matches under a newly appointed coach; interim coaches are treated as new appointments, following the operational definition used in the original database. The expected effect is ambiguous. A change can increase motivation, but it can also destroy accumulated information and coordination (De Paola; Scoppa, 2012). The control is especially relevant in Brazil because coaching turnover is unusually frequent and may be jointly related to poor performance and subsequent tactical changes (Galdino; Wicker; Soebbing, 2021).

Neutral stadium is the number of fixtures in the pair-season played outside the home club's state. This definition is deliberately stricter than merely playing

in a different stadium within the same state, because nearby venues may preserve crowd access and familiarity. The variable captures the loss of venue familiarity, local support and other home conditions emphasized by Pollard (1986, 2008). Same-state status is not included in the differenced GMM equation because it is constant for a given club pair, but its conceptual role remains relevant: local derbies reduce travel and unfamiliarity and may isolate crowd-related mechanisms more closely (Shikida; Carraro; Araújo Júnior, 2018).

Finally, the one-season lag of each outcome captures persistence in the competitiveness of a club pairing and in the distribution of home and away results. Because the lagged dependent variable is mechanically correlated with the pair-specific effect in a short panel, it is treated as endogenous and instrumented with deeper lags under Difference GMM (Arellano; Bond, 1991). The same internal-instrument strategy is used for crowd intensity, and the instrument matrix is collapsed to limit proliferation (Roodman, 2009).

3.3 Dynamic-panel specification

For each outcome, the baseline model relates the current pair-season result to its one-season lag, the post-VAR indicator, the 2020 indicator, crowd intensity and a vector of time-varying controls. Let i index unordered club pairs and t index seasons. The level equation is:

$$y_{it} = \rho y_{i,t-1} + \beta \text{VAR}_t + \gamma \text{COVID2020}_t + \delta \text{Crowd}_{it} + x'_{it}\theta + \mu_i + \varepsilon_{it} \quad (1)$$

where μ_i captures time-invariant pair heterogeneity and x_{it} contains the position differential, new-coach counts and neutral-stadium count. The lagged dependent variable is correlated with the pair effect, while crowd intensity may respond to expected team performance. Direct fixed-effects estimation would therefore be biased in a short dynamic panel.

The model is estimated in first differences using the Arellano-Bond Difference GMM framework (Arellano; Bond, 1991). First differencing removes μ_i :

$$\Delta y_{it} = \rho \Delta y_{i,t-1} + \beta \Delta \text{VAR}_t + \gamma \Delta \text{COVID2020}_t + \delta \Delta \text{Crowd}_{it} + \Delta x'_{it}\theta + \Delta \varepsilon_{it} \quad (2)$$

Levels of the dependent variable dated $t-2$ and $t-3$ instrument the differenced lagged outcome, while levels of crowd intensity dated $t-2$ and $t-3$ instrument its first difference. The remaining time-varying controls are treated as exogenous. Instruments are collapsed to limit proliferation, and the principal estimates use a two-step weighting matrix with robust standard errors clustered by club pair and a finite-group adjustment. The number of instruments is kept below the number of groups, following the cautions discussed by Roodman (2009).

Model diagnostics include the Hansen test of overidentifying restrictions and the Arellano-Bond test for first-order serial correlation in differenced residuals. Significant AR(1) is expected after differencing. With only four annual periods, an informative AR(2) test cannot be computed in this specification, which is an important limitation. Moreover, because VAR was introduced simultaneously for the entire league, VAR also acts as a general post-2019 indicator. The coefficient is therefore interpreted as an adjusted post-VAR association rather than as a fully isolated causal effect.

4. Results

Table 2 compares the complete pair-season panel before and after VAR adoption and states the practical direction expected if home advantage declined. Home-team scoring is almost unchanged, increasing by only 0.026 goal across the two fixtures of a pair-season, whereas away-team scoring rises by 0.158 goal. Consistent with the central hypothesis, the home-away goal differential falls by 0.132, the home-away points differential falls by 0.276 point and the home share of available points falls by 2.1 percentage points. These differences are unadjusted and cannot be attributed to VAR alone, but they indicate the pattern that the dynamic models must explain: the raw reduction in home advantage comes primarily from improved away outcomes rather than a visible decline in home scoring.

Table 2 – Descriptive statistics and expected post-VAR pattern

Variable	Expected under lower home bias	Pre-VAR 2017–2018 Mean (SD)	Post-VAR 2019–2020 Mean (SD)	Raw difference
Home-team goals (two matches)	Decrease or no change	2.766 (1.548)	2.792 (1.564)	0.026
Away-team goals (two matches)	Increase	1.839 (1.341)	1.997 (1.457)	0.158
Home-away goal differential	Decrease	0.926 (1.955)	0.795 (1.957)	–0.132
Home-away points differential	Decrease	1.508 (3.359)	1.232 (3.269)	–0.276
Home points share	Decrease	0.579 (0.294)	0.557 (0.287)	–0.021
Mean attendance	Not a VAR outcome	17,400 (7,067)	10,618 (11,901)	–6,782

Source: own elaboration.

Note: The descriptive table uses all 760 pair-season observations. The post-period attendance mean includes the zero-attendance 2020 season and therefore should not be interpreted as a response to VAR.

Control variables also changed between periods, which reinforces the need for adjustment. The mean position differential moved from 0.374 to 0.108, new-coach counts increased from 0.403 to 0.545 for home sides and from 0.400 to 0.532 for away sides, and neutral-venue fixtures remained rare, rising from 0.008 to 0.021 per pair-season. Because these controls have no common post-VAR direction and may reflect changing club composition, relegation, managerial instability and scheduling, the raw comparisons should be treated as descriptive benchmarks rather than causal estimates.

Tables 3 and 4 present Pearson correlations for the principal outcomes and time-varying controls in the pre- and post-VAR periods. Home points share is omitted from the matrices because it is an algebraic transformation of home points and is almost perfectly correlated with the points differential (0.985 before VAR and 0.984 after VAR). The matrices are descriptive and do not replace the dynamic-panel estimates, but they reveal whether the unconditional relationships have the signs anticipated by the proposed mechanisms.

Table 3 – Correlation matrix, pre-VAR period (2017-2018)

	HG	AG	GD	PD	CROW D	POS	NCH	NCA	NEUT
HG	1.000								
AG	0.090	1.000							
GD	0.730	-0.615	1.000						
PD	0.560	-0.623	0.871	1.000					
CROWD	-0.032	-0.020	-0.012	0.063	1.000				
POS	0.060	-0.131	0.138	0.162	-0.008	1.000			
NCH	-0.035	0.031	-0.049	-0.051	-0.143	0.164	1.000		
NCA	0.034	-0.088	0.087	0.097	-0.023	-0.024	0.049	1.000	
NEUT	-0.025	0.055	-0.058	-0.040	0.124	0.036	0.043	-0.010	1.000

Source: own elaboration.

Note: HG = home goals; AG = away goals; GD = home-away goal differential; PD = home-away points differential; CROWD = centered crowd intensity; POS = position differential; NCH/NCA = new-coach counts; NEUT = neutral-stadium count. N = 380 pair-seasons.

Table 4 – Correlation matrix, post-VAR period (2019-2020)

	HG	AG	GD	PD	CRO WD	POS	NCH	NCA	NEUT
HG	1.000								
AG	0.162	1.000							
GD	0.678	-0.615	1.000						
PD	0.540	-0.566	0.852	1.000					
CROWD	0.065	0.027	0.032	0.048	1.000				
POS	0.024	0.007	0.015	0.096	0.018	1.000			
NCH	0.043	0.025	0.016	-0.015	-0.056	0.046	1.000		
NCA	0.054	-0.010	0.051	-0.004	-0.005	-0.138	0.217	1.000	
NEUT	-0.027	0.076	-0.078	-0.055	0.171	0.006	-0.069	-0.007	1.000

Source: own elaboration.

Note: variable abbreviations follow Table 3. N = 380 pair-seasons. Correlations involving crowd intensity should be interpreted together with the 2020 indicator because that season was played without spectators.

Before VAR, home and away goals are only weakly positively correlated (0.090), while the goal differential is strongly related to home goals (0.730) and negatively related to away goals (-0.615). The goal and points differentials are highly correlated (0.871), confirming that both capture a common home-advantage dimension while retaining different information. Crowd intensity has correlations close to zero with home goals (-0.032), away goals (-0.020), the goal differential (-0.012) and the points differential (0.063). This weak unconditional relationship anticipates the possibility that crowd intensity will be imprecisely estimated in the

GMM models. The remaining controls display only small correlations with the main outcomes, reducing concerns that the descriptive pattern is driven by a single observable covariate.

After VAR adoption, the correlation between home and away goals rises modestly to 0.162, while the goal differential remains positively related to home scoring (0.678) and negatively related to away scoring (-0.615). The correlation between the goal and points differentials remains high (0.852). Crowd intensity continues to display weak correlations with the outcomes: 0.065 with home goals, 0.027 with away goals, 0.032 with the goal differential and 0.048 with the points differential. Neutral venues are weakly associated with more away goals (0.076) and a smaller goal differential (-0.078), which is in the expected direction but too small to support a strong descriptive conclusion. Position differential and coaching changes also remain weakly correlated with the principal outcomes. Overall, the matrices suggest that the clearest raw post-VAR change is the shift in outcome distributions rather than a strong contemporaneous relationship between attendance and performance.

Table 5 reports the dynamic-panel estimates for home-team goals, away-team goals and the home-away goal differential. The descriptive evidence suggested almost unchanged home scoring and higher away scoring after 2019. The adjusted estimates preserve this asymmetry: the post-VAR coefficient for home-team goals is -0.122 and is not statistically significant ($p=0.571$), whereas the coefficient for away-team goals is 0.446 and significant at the 5% level ($p=0.047$). Because the dependent variable sums the two reciprocal fixtures, the latter corresponds to approximately 0.223 additional away-team goal per match. The adjusted effect is larger than the raw increase of 0.158 goal per pair-season, indicating that dynamics and observed controls had partially masked the post-2019 shift in away scoring.

Table 5 – VAR, home-team goals, away-team goals and the goal differential

Term	Home-team goals	Away-team goals	Home-away goal differential
Lagged dependent variable	−0.161* (0.088)	−0.007 (0.113)	−0.111 (0.088)
VAR (2019–2020)	−0.122 (0.215)	0.446** (0.224)	−0.481* (0.271)
COVID-19 season (2020)	0.177 (0.346)	0.154 (0.296)	−0.037 (0.428)
Crowd intensity	−0.164 (0.756)	−1.013 (0.684)	0.620 (0.992)
Position differential	0.033 (0.030)	−0.006 (0.036)	0.039 (0.048)
New coach — home team	0.115 (0.227)	0.323 (0.237)	−0.186 (0.323)
New coach — away team	−0.176 (0.185)	−0.367* (0.198)	0.229 (0.244)
Neutral stadium	−0.820 (0.699)	0.653 (0.865)	−1.602** (0.847)
Observations	182	182	182
Pairs	116	116	116
Instruments	10	10	10
Hansen J p-value	0.398	0.376	0.841
AR(1) p-value	< 0.001	< 0.001	< 0.001
AR(2)	Not estimable	Not estimable	Not estimable

Source: own elaboration.

Note: Two-step Difference GMM with collapsed instruments. Robust standard errors clustered by club pair are in parentheses. The lagged outcome and crowd intensity are instrumented using levels dated $t-2$ and $t-3$. * $p < 0.10$; ** $p < 0.05$; *** $p < 0.01$.

The post-VAR coefficient for the goal differential is -0.481 and significant at the 10% level ($p=0.076$), compared with a raw decline of only 0.132 goal. This is consistent with a narrower scoring gap after controlling for persistence and time-varying characteristics. The result is substantively driven by the increase in away scoring rather than by a statistically detectable fall in home scoring. That pattern is compatible with evidence that video review can correct decisions or alter behavior in ways that particularly benefit visiting teams (Han *et al.*, 2020; Spitz *et*

al., 2021), but final goals do not reveal whether the channel is refereeing, defensive behavior, attacking behavior or tactical adaptation.

Crowd intensity is not statistically significant in any of the three goal models, matching the near-zero correlations in both periods. This result is consistent with Belchior (2020), who did not identify a marginal attendance effect on winning in Brazil, but it differs from studies that exploit the sharper contrast between normal attendance and empty stadiums (Pettersson-Lidbom; Priks, 2010; Cueva, 2020; Bryson *et al.*, 2021). The distinction is important. The present attendance measure is largely a club-season proxy, most pre-pandemic matches have substantial crowds, and the 2020 dummy combines closed doors with other shocks. The estimates therefore reject a simple proportional mechanism in which each additional increase in crowd size directly changes scoring, but they do not establish that the presence, noise or salience of the crowd is irrelevant.

Table 6 shows that the adjusted post-VAR association is stronger for points-based measures than the raw descriptive differences. The home-away points differential falls by 1.305 points across the two reciprocal fixtures ($p=0.006$), compared with an unconditional decline of 0.276 point. Home points share falls by 0.107 ($p=0.011$), or 10.7 percentage points, compared with a raw decline of 2.1 percentage points. Thus, the finding does not rely only on away scoring: it also appears in the allocation of league points, the outcome most directly connected to standings, relegation risk and club objectives (Sloane, 1971; Késenne, 2006; Fort, 2015).

Table 6 – Alternative measures of home advantage

Term	Home-away points differential	Home points share
Lagged dependent variable	−0.129 (0.095)	−0.091 (0.105)
VAR (2019–2020)	−1.305*** (0.478)	−0.107** (0.042)
COVID-19 season (2020)	0.179 (0.729)	0.009 (0.065)
Crowd intensity	1.733 (1.627)	0.120 (0.153)
Position differential	0.119* (0.061)	0.011** (0.005)
New coach — home team	−0.655 (0.499)	−0.060 (0.045)
New coach — away team	0.359 (0.455)	0.033 (0.041)
Neutral stadium	−1.793 (1.493)	−0.143 (0.124)
Observations	182	182
Pairs	116	116
Instruments	10	10
Hansen J p-value	0.881	0.785
AR(1) p-value	<0.001	<0.001
AR(2)	Not estimable	Not estimable

Source: own elaboration.

Note: the points differential is home points minus away points across the two matches of each pair-season. Home points share is home points divided by the six potentially available points. Other notes follow Table 5.

The Hansen tests do not reject the instrument sets in any of the five models, and the 10 instruments remain well below the 116 pair groups, consistent with the instrument-proliferation caution in Roodman (2009). Significant AR(1) is expected after first differencing. With only four annual periods, an informative AR(2) test is not estimable, which remains the principal diagnostic limitation. These tests are supportive rather than conclusive: nonrejection of the Hansen

statistic does not prove instrument validity, and the short time dimension limits the amount of internal variation available for dynamic identification.

4.1 Robustness and Discussion

Table 7 evaluates whether the central results depend on the weighting matrix or the instrument window. The direction and economic magnitude of the post-VAR coefficients are stable across one-step and two-step estimators and when the instrument set is restricted to lag 2. Statistical significance for away-team goals varies between the 5% and 10% levels, whereas the two points-based measures remain significant in every specification. This stability strengthens the conclusion that the post-2019 period is associated with lower home advantage, although it does not create an untreated control group or solve the short-panel limitation.

Table 7 – Post-VAR coefficient under alternative GMM implementations

Outcome	One-step; lags 2– 3	Two-step; lags 2– 3	Two-step; lag 2 only
Home-team goals	–0.120 (0.219)	–0.122 (0.215)	–0.145 (0.220)
Away-team goals	0.402* (0.224)	0.446** (0.224)	0.406* (0.226)
Home-away goal differential	–0.500* (0.275)	–0.481* (0.271)	–0.511* (0.280)
Home-away points differential	–1.300*** (0.483)	–1.305*** (0.478)	–1.303*** (0.483)
Home points share	–0.108** (0.043)	–0.107** (0.042)	–0.110** (0.043)

Source: own elaboration.

Note: each cell reports the post-VAR coefficient and its robust standard error. The lag-2-only specification is exactly identified and therefore does not produce an overidentification test.

The increase in away-team goals and the decline in goal- and points-based home advantage are broadly consistent with prior evidence that technological oversight can make decisions more balanced. Han *et al.* (2020) report a convergence of home and away disciplinary outcomes after VAR adoption, and Spitz *et al.* (2021) find improved decision accuracy. Dawson, Massey and Downward (2020) similarly show that video review changes home bias in rugby.

The present results extend this literature to Brazilian league outcomes: the post-VAR pattern appears not only in a disciplinary or decision-level measure but also in away scoring and the distribution of championship points.

At the same time, the results do not establish that corrected referee errors are the only channel. Veldkamp and Koning (2023) show that VAR intervention can affect penalty takers, and the reviews by Silva *et al.* (2023) and Li, Wang and Zhang (2026) document changes in player behavior, fouls, offsides and match rhythm. A visiting team may attack differently when decisive incidents are reviewable, while home defenders may behave more cautiously. The estimates are therefore consistent with a monitoring effect, but goals and points aggregate decisions by officials, players and coaches. Referee-level data on penalties, cards, stoppage time, overturned goals and review duration would be required to separate these channels.

The agency interpretation clarifies what the technology plausibly changes. VAR increases the observability of selected decisions and creates an *ex-post* check on the on-field official, reducing the informational advantage of the agent (Eisenhardt, 1989). It may also shield the referee from the immediate demands of a salient third party by allowing an unpopular decision to be justified through a formal review process (Prendergast, 2003). The points results are compatible with this logic. However, because crowd intensity is not significant, the paper cannot claim that VAR operates by neutralizing the marginal effect of larger crowds. A more defensible interpretation is that review constrains a broader home-favoring discretion or norm that may exist whenever a predominantly home crowd is present.

The nonsignificant crowd coefficient should also be read alongside the descriptive correlations. Crowd intensity is weakly related to goals and points in both periods, so its lack of significance is not produced only by the GMM transformation. This contrasts with the sharp empty-stadium effects reported by Pettersson-Lidbom and Priks (2010), Cueva (2020) and Bryson *et al.* (2021), but it is compatible with Belchior (2020). The difference may reflect measurement: the present variable uses club-season attendance proxies and identifies marginal variation among normally attended matches, whereas closed-door studies compare qualitatively different social environments. Thus, the findings speak more clearly

to the post-VAR change in home advantage than to the elasticity of outcomes with respect to crowd size.

Most additional controls are statistically weak, which is informative but should not be overinterpreted. The negative away-team new-coach coefficient at the 10% level is compatible with the information-loss mechanism discussed by De Paola and Scoppa (2012), yet the corresponding home-team effect is not significant and the result is not a central finding. Neutral venues reduce the goal differential at the 10% level in the baseline model, in the direction predicted by the loss of familiarity and local support (Pollard, 1986, 2008), but neutral fixtures are rare. Position differential is positive in the points equations, contrary to the simple match-level expectation that a worse-ranked home side should earn fewer points. Because the variable averages two reciprocal fixtures with changing home identities, this coefficient is best treated as a control rather than as a structural estimate of team quality.

Finally, treatment coincides with calendar time because all clubs adopted VAR in 2019. Other league-wide changes after 2018 may therefore contribute to the estimated coefficients, and the 2020 indicator cannot isolate closed doors from calendar, health and regulatory disruptions. For this reason, the discussion avoids statements that VAR definitively caused the observed changes. The strongest conclusion supported by the data is that home advantage declined in the post-VAR period after controlling for outcome dynamics, the 2020 shock, endogenous crowd intensity, relative position, coaching changes and neutral venues, and that this decline is robust across several outcome definitions and GMM implementations.

5. Conclusion

This study reassesses the relationship between VAR and home advantage in the Brazilian Série A using all clubs that competed between 2017 and 2020. By retaining promoted and relegated teams and estimating a dynamic unbalanced panel, the revised design avoids the survival-based sample restriction of the earlier specification. Difference GMM also replaces the inconsistent practice of inserting first-stage fitted attendance directly into a nonlinear second stage and removes the theoretically problematic away-position instrument.

The main result is stable in direction but broader than in the original analysis. The post-VAR indicator is not significant for home-team goals, is positive and significant for away-team goals, and is associated with lower home-away goal and points differentials. The home share of available points declines by 10.7 percentage points. These findings are consistent with VAR limiting home-favoring discretion and making outcomes more balanced.

The evidence nevertheless does not identify a simple marginal crowd-pressure mechanism. Crowd intensity is not significant, attendance is partly measured by club-season proxies, the 2020 indicator combines closed doors with several other disruptions, and the short panel does not allow an informative AR(2) test. Most importantly, the entire league adopted VAR simultaneously, so the post-VAR coefficient may also capture other changes over time. The conclusions should therefore be understood as robust associations rather than definitive causal estimates.

Future research can extend the panel backward and forward, exploit staggered or competition-specific variation, and link match outcomes to referee-level decisions and VAR interventions. Expected goals (xG), penalties, cards, fouls and stoppage time would help distinguish changes in team performance from changes in officiating. Such evidence would clarify whether video review operates mainly as an information technology, a monitoring device or a psychological shield against third-party pressure.

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