NOVA IMS Information Management School

MDSAA

Mestrado em

Data Science and Advanced Analytics

The Impact of VAR on Effective Playing Time: Evidence from Portuguese Football

Luís Filipe Guerreiro dos Santos

Master Thesis

presented as partial requirement for obtaining a Master's Degree in Data Science and Advanced Analytics

NOVA Information Management School

Instituto Superior de Estatística e Gestão de Informação

Universidade Nova de Lisboa

NOVA Information Management School
Instituto Superior de Estatística e Gestão de Informação
Universidade Nova de Lisboa

The Impact of VAR on Effective Playing Time: Evidence from Portuguese Football

by

Luís Filipe Guerreiro dos Santos

Master Thesis presented as partial requirement for obtaining the Master's degree in Data Science and Advanced Analytics, with a specialization in Data Science.

Supervised by

Bruno Damásio, PhD, NOVA Information Management School, Universidade de Lisboa

June 2025

STATEMENT OF INTEGRITY

I hereby declare having conducted this academic work with integrity. I confirm that I have not used plagiarism, any form of undue use of information or falsification of results along the process leading to its elaboration. I further declare that I have fully acknowledged the Rules of Conduct and Code of Honor from the NOVA Information Management School.

Lisboa, June 2025

Luís Filipe Guerreiro dos Santos

ABSTRACT

The introduction of the Video Assistant Referee (VAR) has been one of the most significant technological advancements in modern football, aiming to enhance fairness and reduce human error in refereeing decisions. While its impact on total playing time has been widely studied, less is known about how VAR affects effective playing time, which refers to the minutes during which the ball is actively in play. This thesis examines the causal effect of VAR on effective playing time using Portuguese football as a case study, comparing matches from the First Division, where VAR was implemented in the 2017/2018 season, to those from the Second Division, which did not adopt the system.

To estimate the impact of VAR, the study applies a Difference-in-Differences approach, complemented by an event study design that explores how the effect unfolds over time and helps assess the validity of key assumptions. A descriptive analysis of match statistics is also included to provide context for the causal estimates.

The results show that the introduction of VAR is associated with a consistent and statistically significant decrease in effective playing time. Depending on the model specification, the reduction ranges from approximately 1.13 to 2.17 percentage points. This impact becomes more pronounced when accounting for match-specific characteristics such as goals, fouls, throw-ins, offsides, and corners. Overall, the findings suggest that while VAR enhances refereeing accuracy, it also contributes to a measurable decline in the time the ball remains in play. By focusing on a key aspect of match flow, this research offers new insight into how technological interventions can shape the tempo and experience of the modern game.

KEYWORDS

VAR; Effective Playing Time; Impact Evaluation; Causal Inference, Difference-in-Differences.

Sustainable Development Goals (SDG):

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS AND ACRONYMS

CIES	Centre International d'Etude du Sport
DiD	Difference-in-Differences
ES	Event Study
FIFA	Fédération Internationale de Football Association
FPF	Federação Portuguesa de Futebol
UEFA	Union of European Football Associations
VAR	Video Assistant Referee

1 INTRODUCTION

The introduction of the Video Assistant Referee (VAR) has been one of the most transformative changes in modern football. Designed to assist referees in making more accurate decisions, VAR has sparked widespread debate among players, coaches, analysts, and fans. Introduced globally in 2018 after extensive trials, VAR has reshaped the process of making critical decisions, such as goals, penalties, and red cards, by equipping officials with video review tools to minimize human error.

When first introduced, VAR was intended to enhance fairness and accuracy in football by providing referees with an additional layer of support for making difficult decisions. Its primary aim was to correct 'clear and obvious errors' and address 'serious missed incidents,' such as incorrect penalty calls or missed red cards (International Football Association Board, 2017a). While this objective is rooted in fairness and accuracy, the system's ability to pause play and trigger reviews has introduced new concerns. A primary concern is the potential impact on the flow and rhythm of matches. As VAR checks and on-field reviews take time, they may reduce what is known as effective playing time, the minutes during which the ball is actually in play.

This thesis does not intent to evaluate whether VAR decisions are correct, but rather investigates whether the presence of VAR has changed the tempo and structure of matches by affecting this key metric.

The Portuguese Football Federation (FPF) has played a pioneering role in the development and implementation of VAR. In March 2016, the International Football Association Board (IFAB) authorized the initial testing of VAR over a two-year period, with Portugal among the six countries selected for this experimental phase alongside Australia, Brazil, Germany, the Netherlands, and the United States. FPF subsequently conducted offline VAR trials during key domestic competitions, including the Supertaça Cândido de Oliveira and several Taça de Portugal matches, culminating in the live use of VAR during the 2017 Taça de Portugal final (Federação Portuguesa Futebol, 2017). In the 2017/18 season, Portugal became one of the first European nations to adopt VAR across all matches in its top-tier league (International Football Association Board, 2017b). This early adoption provides a valuable context for analysing how such technological interventions might influence key aspects of the game, including effective playing time.

In parallel, football's governing bodies have increasingly recognized the importance of maximizing effective playing time. Both FIFA and UEFA have stressed that the amount of time the ball is actually in play is essential to the quality of the game and the experience of spectators (Fédération Internationale de Football Association, 2022; Union of European Football Associations, 2022). As a measure of active gameplay, effective playing time is considered a crucial indicator of match quality and fan engagement.

Unlike total match duration, which includes every stoppage for injuries, substitutions, time wasting, or disciplinary checks, effective playing time isolates only the moments when the ball is actively in play. This distinction is increasingly important because the true quality and intensity of a football match depend on continuous action rather than on the nominal ninety-minute clock. According to reports by FIFA and the CIES Football Observatory (Fédération Internationale de Football Association, 2022; International Centre for Sports Studies, 2019), average effective playing time in elite competitions often falls below 60 minutes, raising concerns about lost entertainment value and fairness for spectators. In response, governing bodies have called for stricter timekeeping, more accurate added time, and potential rule changes to keep the ball in play for longer stretches. By centering on effective playing time, this thesis directly investigates whether VAR, while improving refereeing accuracy, might unintentionally contribute to stoppages that limit active play. Understanding this relationship is critical for informing future policy decisions about how to balance technological assistance with the natural flow that keeps the sport engaging.

Efforts to maximize this metric have included stricter time-wasting regulations, revised substitution rules, and even discussions around potential clock-stopping mechanisms (Díaz, 2023; International Football Association Board, 2024). Understanding how technological interventions like VAR may influence this metric is vital to evaluating its broader implications for football.

This study addresses the question of whether VAR has caused any measurable changes to effective playing time in Portuguese football. Specifically, it investigates how the introduction of VAR in the First Division has influenced the duration of active gameplay, compared to the Second Division, where VAR was absent. By analysing these differences, the study seeks to assess whether the introduction of constant checks and on-field-reviews has had any measurable impact on effective playing time, while accounting for potential influences from other underlying factors. The Second Division, sharing many of the same characteristics as the First Division, serves as a natural control group, mitigating the risk of confounding factors introducing bias. Additionally, the results are expected to contribute to the literature, as there are no known studies examining this type of comparison across both the First and Second Divisions of the same country.

The remainder of this thesis is organized as follows. Chapter 2 presents a review of the existing literature on VAR, effective playing time, and related aspects of match dynamics, providing the conceptual foundation for the study. Chapter 3 describes the data and outlines the methodological approach, with particular attention to the Difference-in-Differences (DiD) framework and event study design used to estimate the impact of VAR. Chapter 4 reports the results of the empirical analysis and offers a detailed discussion in light of the findings from the previous research. Finally, Chapter 5 summarizes the main conclusions, reflects on the study's limitations, and suggests directions for future research.

2 LITERATURE REVIEW

Since its global introduction in 2018, the VAR system has been one of the most transformative developments in modern football. While it has significantly altered refereeing protocols and decision-making, it has also sparked criticism and concern. A 2019/2020 ethnographic study of fans attending English Premier League matches revealed widespread unease about VAR's effect on the flow of the game, its lack of transparency, and the emergence of anti-climactic moments that seemed to "ruin the moment" (Scanlon et al., 2022).

Recent qualitative research highlights how coaches and players themselves perceive VAR's influence on match flow. A study published in *Sport Management Review* (Lartey, 2024) found that while stakeholders acknowledged VAR's role in improving fairness, they repeatedly pointed to the frustration caused by frequent stoppages and the feeling that such interruptions disrupted the rhythm of the game. This perspective underlines that, even when effective playing time is only slightly reduced, the perceived impact on continuity and tempo remains an important aspect of how VAR shapes the modern match experience.

Our study does not focus on public opinion or fan perceptions. Instead, it aims to empirically evaluate whether VAR has affected the flow and continuity of play, particularly through changes in effective playing time.

According to the (International Football Association Board, 2017a), referees can be called to conduct a check or review in four specific match-changing situations: goals, penalty decisions, direct red card incidents, and cases of mistaken identity. These interruptions occur when the VAR identifies a 'clear and obvious error' or a 'serious missed incident' in the referee's decision. The process begins with a silent check by the VAR, who reviews the footage and communicates their findings to the referee. If necessary, the referee may stop the match and conduct an on-field review by viewing the incident on a pitch-side monitor. This ensures the referee retains the final decision-making authority while incorporating the additional perspective provided by video assistance. While these protocols are intended to improve accuracy and fairness, they also introduce interruptions that may alter the rhythm and duration of matches.

Beyond influencing match flow, VAR has had a measurable impact on refereeing accuracy. Spitz et al. (2021) analysed over 2,100 professional matches across 13 countries and found that VAR interventions significantly improved the quality of officiating. Of the nearly 10,000 checks conducted, only a small proportion led to full reviews, yet these interventions increased decision accuracy from 92.1% to 98.3%. On-field reviews lasted around 62 seconds on average, while VAR-only reviews were notably quicker, averaging 15 seconds. While these improvements support the use of technology to enhance fairness, the study also raises questions about how even brief interruptions might affect the continuity and tempo of the game.

Several empirical studies have explored VAR's broader impact on match duration. Carlos et al. (2019) analysing 1,024 matches from the Italian Serie A and German Bundesliga, found that the introduction of VAR led to an increase in total playing time, particularly during the first half. A similar pattern was observed in the Chinese Super League, where Han et al. (2020) reported a statistically significant increase in total match duration when comparing 240 matches played with and without VAR.

This trend has also been noted in international tournaments. (2022), studying the Women's World Cup, found a marked increase in match time between the 2015 (pre-VAR) and 2019 (post-VAR) editions. Likewise, (2024) also found a significant rise in total match time in the English Premier League following the 2018–2019 VAR rollout.

Further evidence from international tournaments strengthens the case that VAR alters game dynamics. A study comparing UEFA EURO 2016 (pre-VAR) and EURO 2020 (with VAR) found not only longer halves but also an increase in goals and a reduction in yellow cards (Bao et al., 2025). These findings suggest that VAR extends total match time and may influence aspects of disciplinary control and scoring patterns.

Although many studies suggest that VAR has led to an increase in total playing time, its specific impact on effective playing time, the duration the ball is actively in play, remains underexplored.

Major football institutions have increasingly recognized the importance of maximizing actual playing time to enhance the quality and fairness of the game. In a 2022 interview, Pierluigi Collina, chairman of FIFA's Referees Committee, highlighted a growing concern about lost time during matches due to injuries, goal celebrations, substitutions, and more recently, VAR checks. As a response, FIFA instructed referees at the 2022 World Cup to more accurately calculate stoppage time and ensure that these interruptions are properly accounted for, with the goal of increasing the minutes during which the ball is actually in play (Fédération Internationale de Football Association, 2022). This initiative reflects a broader institutional effort to shift focus from total match duration to effective playing time, recognizing that extended stoppages can undermine the flow, intensity, and spectator appeal of football. It also underscores how rule enforcement and timekeeping protocols are being adjusted to counterbalance the unintended consequences introduced by technologies like VAR.

Alongside this institutional focus, academic interest has also emerged around the role of effective playing time in shaping the way the game is played. Tojo et al. (2023) conducted an experimental study comparing traditional 45-minute halves with a stopped-clock format that paused time when the ball was out of play. Matches under the stopped-clock condition had significantly more effective playing time, leading to higher ball possession, more time in attacking areas, and increased physical demands such as high-speed runs and accelerations. Similarly, Lago-Penas (2012) analysing data from UEFA EURO 2008, found that players covered more distance in first halves compared to second halves, a difference explained in

part by slightly higher effective playing time. The authors concluded that accounting for effective time provides a more accurate understanding of match demands. Together, these findings highlight that effective playing time is not only relevant to fairness or flow but also has clear implications for player performance and match intensity.

A more detailed look at how VAR interacts with effective playing time comes from a study by Errekagorri et al. (2020), which examined 375 matches from the 2018–2019 Spanish LaLiga season. The matches were grouped according to the number of VAR interventions: none, one, or two or more. The study found that while total match duration increased slightly with more interventions, effective playing time actually decreased. Matches without any VAR involvement averaged 52.5 minutes of ball-in-play time, compared to just 51.5 minutes in matches with one or more interventions. The researchers also observed that games with more VAR use tended to have more goals but slightly less distance covered by players. These findings suggest that although VAR may extend match duration and influence certain game outcomes, its impact on actual ball-in-play time remains limited and somewhat inconsistent. This adds nuance to the broader understanding of VAR's role, indicating that its effect on match flow might be more subtle than often assumed.

A complementary perspective is offered by (Abbate et al., 2025) who examined the staggered introduction of VAR across 16 top domestic leagues between 2009 and 2019. Their large-scale study found that while VAR significantly improved officiating accuracy, it had negligible effects on home-field advantage, suggesting that the traditional home-team edge largely persisted despite the added technology. However, they did observe subtle shifts in game dynamics, including a slight decrease in total offsides and yellow cards following VAR implementation. These findings imply that while players and referees may adapt behavior in response to VAR oversight, the technology does not fundamentally change the competitiveness or overall flow of matches. This broader context supports the idea that VAR fine-tunes specific aspects of decision-making but does not fully transform the tempo or balance of the game.

A study from the Portugal Football Observatory (2022a) analysed the impact of VAR on referee decisions and overall match dynamics in the Portuguese First Division. Focusing on the 2020/2021 season, the study found that the time spent on VAR checks and reviews did not rank among the top five causes of game interruptions. Looking more broadly at data from the 2014/2015 to the 2020/2021 seasons, the study also observed that effective playing time increased in five of those seven years. On average, matches in the 2020/2021 season featured three more minutes of ball-in-play time than those in 2014/2015. Although the increase could not be directly attributed to the introduction of VAR, it pointed to a positive trend in match flow over time.

In a follow-up investigation, (Portugal Football Observatory, 2022b) looked more closely at the factors that contribute to non-playing time. Using data from the 2018/2019 to 2021/2022 seasons, the study found that fouls were the largest source of delay, followed by throw-ins,

goal kicks, and corners. Crucially, it concluded that the frequency of these events, rather than the time each one takes, is what drives most of the lost time. Moreover, the study found a strong correlation between higher effective playing time and better league performance, suggesting that teams able to keep the ball in play longer may benefit strategically over the course of a season.

Further evidence comes from a study of the Turkish Süper Lig, which examined key match variables before and after the introduction of VAR across four seasons. The researchers found that after VAR was implemented, fouls, yellow cards, and offsides decreased significantly, while the number of awarded penalties increased (Akdağ et al., 2025). These findings support the idea that VAR directly affects certain match characteristics while leaving others, like throw-ins and corners, largely unaffected. This aligns with the decision in this thesis to exclude penalties and red cards from the control variables, since they are strongly linked to VAR interventions and could introduce post-treatment bias.

3 DATA AND METHODOLOGY

3.1 DATA

The dataset used in this study is sourced from Wyscout, a leading football data provider that tracks and records detailed match events across multiple competitions. The effective playing time for matches in both the First and Second Divisions of Portuguese football is derived from Wyscout's event-tagging system. Each match included in the dataset has been previously tagged, meaning that every significant game occurrence has been systematically tracked and timestamped. Tagging is the process of recording all relevant match events, such as when the ball goes out of play, fouls are committed, substitutions occur, or when the referee stops the game for a VAR review. This process enables the calculation of effective playing time by summing the intervals during which the ball remains in play.

Since tagging is performed manually by analysts, there is a potential for human error, leading to slight variations in recorded effective playing time depending on the individual responsible for tagging a given match. These discrepancies, while generally small, stem from subjective differences in assessing precise moments when play stops and resumes. While Wyscout follows standardized tagging procedures to ensure consistency, minor deviations remain an inherent limitation of manually collected event data.

In addition to effective playing time, the dataset includes other key match statistics that influence game interruptions. The selection of these variables is based on a study conducted by the FPF which identifies the events that contribute the most to non-playing time (Portugal Football Observatory, 2022a). These include occurrences such as fouls, throw-ins, goal kicks, corner kicks, and disciplinary actions (yellow and red cards), all of which significantly affect the flow of the game. By incorporating these factors into the analysis, the study ensures that any observed changes in effective playing time can be examined in relation to the most time-consuming match events.

To obtain the match data, XML files are extracted directly from Wyscout's database. These files contain detailed event logs for each match, structured in a machine-readable format. A Python script is used to process these XML files, extracting relevant match statistics, including effective playing time and the occurrence of key game events. The extracted data is then formatted and cleaned for use in the empirical analysis.

The set of match-level variables used in this study was chosen to capture the main factors that influence how long the ball stays in play and how matches unfold. Variables such as fouls, offsides, corners, and throw-ins represent typical interruptions that reduce active playing time, while goals and competitiveness account for match context that can shape the overall pace of play. The treatment and post indicators define the DiD approach by marking each match's group and whether it occurred before or after VAR was introduced. Effective playing time serves as the main outcome of interest, measured as the percentage of total match time

during which the ball is actively in play. Table 3.1 presents the full list of variables, their descriptions, and their measurement types.

Table 3.1 - Variables Description

Variable name	Description	Type
Season	The football season in which the match took place (e.g., 2017/18).	Nominal
Season Half	First half of the season (1), the second half (2).	Ordinal
Post	Either the match was played after the implementation of VAR (1), or it was played before (0).	Binary
Treatment	Either belongs to the treatment group (1), or the control group (0).	Binary
Goals	Total number of goals scored in the match.	Continuous
Competitiveness	Measure of match balance based on the goal difference, (up to 3 levels).	Nominal
Fouls	Total number of fouls committed in the match.	Continuous
Corners	Total number of corner kicks awarded in the match.	Continuous
Throw Ins	Total number of throw-ins taken during the match.	Continuous
Offsides	Total number of offside infractions called during the match.	Continuous
Effective Playing Time	Percentage of total match time during which the ball was actively in play.	Continuous

3.2 METHODOLOGY

3.2.1 DESCRIPTIVE ANALYSIS

The empirical analysis begins with a descriptive overview of the data to establish baseline patterns and contextualize the causal results. The focus is on understanding the distribution and seasonal evolution of effective playing time in both the First and Second Divisions, before and after the implementation of VAR.

To assess whether meaningful changes occurred within each group, independent samples t-tests are conducted comparing pre- and post-VAR periods. Prior to each test, Levene's test is used to check for equality of variances, ensuring that the appropriate version of the t-test is applied. In the First Division, where VAR was introduced, a significant decline in effective playing time is detected. In contrast, the Second Division shows no statistically significant change, reinforcing its suitability as a control group. These preliminary findings help motivate the use of a Difference-in-Differences strategy to formally estimate the causal impact of VAR.

3.2.2 DIFFERENCE IN DIFFERENCES

To evaluate the impact of VAR on effective playing time, this study employs the DiD methodology, a widely used econometric approach for estimating causal effects in non-experimental settings. The key advantage of DiD is its ability to isolate the effect of an intervention by comparing changes in outcomes over time between a treatment group, which is exposed to the intervention, and a control group, which is not. It calculates the effect of an intervention by measuring the difference in the average change in the outcome variable for the treatment group relative to the average change for the control group. In this case, the treatment group consists of matches from the Portuguese First Division, where VAR was implemented, while the control group consists of matches from the Second Division, where VAR was not introduced.

This study uses repeated cross-sectional data, where matches from various seasons before and after VAR implementation serve as observational units. Unlike panel data, which follows the same entities over time, cross-sectional data consists of different matches in each period, making it more suitable for analysing aggregate temporal trends. While panel data allows for individual fixed effects, cross-sectional data is particularly useful for assessing structural changes in outcome variables at the observational unit level across distinct observations.

The estimation strategy begins with a baseline DiD model that regresses effective playing time on an interaction term between a post-VAR period indicator and a treatment group indicator. The coefficient of this interaction term represents the DiD estimator, isolating the causal effect of VAR on effective playing time. To improve the precision of the estimates and account

for potential confounding variables, a second model is also estimated that includes match-level controls such as goals, offsides, throw-ins, corners, and fouls.

Based on the simple estimation of a linear regression model, the baseline DiD approach is specified as follows:

$$EPT_{it} = \beta_0 + \beta_1 FirstDivision_i + \beta_2 PostVAR_t + \beta_3 (FirstDivision_i \times PostVAR_t) + \varepsilon_{it}$$

where i indexes individual matches and t indexes time (pre/post-VAR period). The dependent variable, EPT_{it}, represents the effective playing time in match i at time t, which serves as the main outcome of interest. The variable $FirstDivision_i$ is a binary indicator that takes the value of 1 if the match belongs to the First Division, where VAR was implemented, and 0 if it belongs to the Second Division, where VAR was not introduced. Similarly, $PostVAR_t$ is a binary indicator that equals 1 for matches played after the introduction of VAR and 0 otherwise.

The key term in this specification is the interaction term, $FirstDivision_i \times PostVAR_t$, which captures the combined effect of being in the First Division after VAR was introduced. The coefficient associated with this interaction term, β_3, represents the DiD estimator, which quantifies the causal effect of VAR on effective playing time. This coefficient measures how much effective playing time changed in the First Division following VAR implementation, relative to how effective playing time changed in the Second Division over the same period. If $\beta_3 > 0$, this suggests that VAR increased effective playing time, whereas if $\beta_3 < 0$, it suggests that VAR reduced effective playing time.

The other parameters in the model account for various confounding factors. The constant term, β_0, represents the baseline level of effective playing time in the pre-VAR period for the Second Division (control group). The coefficient β_1 captures pre-existing differences between the First and Second Divisions, ensuring that any systematic differences in effective playing time before VAR are accounted for. Meanwhile, β_2 controls for general time trends that affect both divisions, ensuring that broader temporal shifts in match characteristics do not bias the estimated impact of VAR.

A second model extends this by including control variables:

$$EPT_{it} = \beta_0 + \beta_1 FirstDivision_i + \beta_2 PostVAR_t + \beta_3 (FirstDivision_i \times PostVAR_t) + X_{it} \cdot \gamma + \varepsilon_{it}$$

Where X_{it} includes match-level controls such as goals, offsides, throw-ins, corners, and fouls.

In specifying this second model with controls, care was taken to include only variables that are plausibly exogenous to the implementation of VAR. The match characteristics such as goals, offsides, throw-ins, corners, and fouls were included as controls, as they may influence effective playing time but are not themselves heavily affected by the presence of VAR. In contrast, variables like penalties and red cards were deliberately excluded. These events are

known to be significantly affected by VAR decisions and including them would introduce post-treatment bias by controlling for mechanisms through which VAR operates. Their exclusion ensures that the estimated treatment effect remains a strong measure of the overall impact of VAR on match fluidity.

While the regression specification provides a formal econometric representation of the treatment effect, it is helpful to consider how the DiD estimator β_3 operates in intuitive terms. The logic of this estimator can be visualized by comparing average effective playing time across groups and periods. The following framework summarizes how differences within and between groups are combined to isolate the causal impact of VAR:

Table 3.2 - Difference-in-Differences Estimation Framework

	Pre-Var	**Post-Var**	**Differences**
First Division (Treatment Group)	$EPT_{F,0}$	$EPT_{F,1}$	$EPT_{F,1} - EPT_{F,0}$
Second Divion (Control Group)	$EPT_{S,0}$	$EPT_{S,1}$	$EPT_{S,1} - EPT_{S,0}$
Differences	$EPT_{F,0} - EPT_{S,0}$	$EPT_{F,1} - EPT_{S,1}$	$(EPT_{F,1} - EPT_{F,0}) - (EPT_{S,1} - EPT_{S,0})$

The values in this framework represent the average effective playing time for both groups before and after VAR's introduction. By computing the difference within each group over time and then differencing these changes between groups, the DiD estimator isolates the impact of VAR while controlling for shared external influences. This is mathematically expressed as:

$$\beta_3 = (EPT_{T,1} - EPT_{T,0}) - (EPT_{C,1} - EPT_{C,0})$$

This estimator provides an unbiased measure of the causal effect of VAR on effective playing time, as long as the Parallel Trends Assumption holds. To ensure the validity of inference, all standard errors in these models are computed using heteroskedasticity-robust estimators, which adjust for any non-constant variance in the residuals and strengthen the reliability of the estimated standard errors.

3.2.3 PARALLEL TRENDS

This assumption is crucial because it implies that, in the absence of VAR, the First and Second Divisions would have continued to follow similar trends in effective playing time over time. In other words, for the Difference-in-Differences approach to yield credible estimates, any changes observed after VAR was introduced should not simply reflect pre-existing differences in how the two leagues were evolving. Although this assumption cannot be tested directly,

since the counterfactual scenario without VAR is unobservable, it can be evaluated indirectly through a combination of descriptive and statistical checks.

As an initial check, a figure showing the monthly averages for effective playing time in both divisions illustrates how the trends developed in the seasons leading up to the introduction of VAR. While the visual patterns point to generally similar trajectories, they alone cannot fully confirm that no underlying differences existed. To strengthen this check, a placebo regression was carried out as a more formal test. This placebo test artificially reassigns the introduction of VAR to the second half of the 2015/2016 season, when no actual intervention took place. If the model detects no significant change at this false cutoff, it supports the claim that the two divisions were indeed following comparable paths before VAR was introduced. The placebo results show no statistically significant effect, which reinforces the plausibility of the Parallel Trends Assumption.

Building on this, the next section introduces the event study approach. This method allows for an even more detailed examination of how effective playing time evolved both before and after VAR came into force. By estimating separate coefficients for each period, the event study makes it possible to see whether any meaningful differences emerged before the actual intervention, adding another layer of credibility to the Difference-in-Differences results.

3.2.4 EVENT STUDIES

Event studies are a robust econometric approach designed to assess the impact of specific events or interventions on an outcome variable over time. Originating in financial economics to evaluate how events like mergers or policy changes affect stock prices, this methodology has been widely adopted across various fields, including public policy, labor economics, and sports analytics. Its strength lies in its ability to estimate dynamic treatment effects and provide visual representations that reveal patterns of behavior before and after an event.

A critical advantage of the event study framework lies in its capacity to evaluate the parallel trends assumption, which underpins the validity of causal inferences in difference-in-differences analyses. By decomposing the pre-treatment period into multiple intervals, event studies allow for a granular examination of the trends in the outcome variable, effective playing time, across treatment and control groups before the intervention. Specifically, by estimating and plotting the coefficients for each pre-treatment period, researchers can visually and statistically assess whether the treatment group (First Division) and the control group (Second Division) exhibited similar trajectories prior to the implementation of VAR. If the estimated differences in effective playing time between the two groups are statistically insignificant and display no systematic pattern during the pre-treatment periods, this lends support to the parallel trends assumption. Conversely, significant or systematic differences would cast doubt on this assumption, suggesting that the groups were on divergent paths

even before the intervention. Thus, the event study approach not only estimates the dynamic effects of VAR but also provides a robust diagnostic tool for validating the key assumption necessary for credible causal inference.

To estimate the dynamic effects of VAR, each match is assigned an event-time index indicating its position relative to the implementation of the system in the 2017/2018 season. The dataset spans eight half-season periods from 2015/2016 to 2018/2019, allowing for a balanced examination of both pre- and post-treatment trends. The second half of the 2016/2017 season (t=0) is used as the reference period, and all effects are interpreted relative to this baseline. The primary regression model is specified as:

$$EPT_{it} = \alpha + \sum_{k \neq 0} \beta_k \cdot 1(t = k) + \varepsilon_{it}$$

In this specification, EPT_{it}, denotes the effective playing time for match i at time t. The terms $1(t = k)$ are indicators variables for each event time period, excluding the reference period $(t = 0)$. The coefficient β_k capture the estimated Effect of being in period k relative to the baseline, while ε_{it} represents the error term.

As well as in the DiD estimations, to control for potential confounding factors, a second model incorporates match-level covariates that could influence effective playing time but are not directly affected by VAR. These include the number of goals, offsides, throw-ins, corners, fouls, and a categorical variable for match competitiveness. The extended model is:

$$EPT_{it} = \alpha + \sum_{k \neq 0} \beta_k \cdot 1(t = k) + \gamma_1 \cdot Goals_{it} + \gamma_2 \cdot Offsides_{it} + \gamma_3 \cdot ThrowIns_{it} + \gamma_4 \cdot Corners_{it} + \gamma_5 \cdot Fouls_{it} + \gamma_6 + \varepsilon_{it}$$

Both models are estimated using Ordinary Least Squares (OLS), with standard errors clustered at the match level to account for potential heteroskedasticity and within-match correlation. This methodological approach enables a comprehensive assessment of VAR's impact on the flow of the game, accounting for both temporal dynamics and match-specific characteristics.

By combining a DiD framework with an event study design, this methodology is structured to isolate the causal effect of VAR on effective playing time. The approach carefully accounts for differences between the two divisions, controls for key match characteristics, and takes into consideration how effective playing time was evolving before the intervention. Together, these steps provide a solid foundation for the empirical analysis that follows, ensuring that any identified changes in effective playing time can be meaningfully linked to the introduction of VAR rather than to unrelated factors.

4 RESULTS AND DISCUSSION

4.1 DESCRIPTIVE ANALYSIS

Tables 4.1 and 4.2 present descriptive statistics for the treatment group (First Division) and the control group (Second Division), broken down by the periods before and after the introduction of VAR. The main focus is on effective playing time, the key variable of interest, along with other match characteristics that will later be included as control variables in the regression analysis.

In the First Division, the average effective playing time slightly decreased following the introduction of VAR, dropping from 52.77% to 51.46%, with a corresponding increase in standard deviation (from 4.72 to 5.50). Other variables show modest shifts as well: goals per match rose slightly (from 2.57 to 2.72), while the number of throw-ins and fouls declined. These changes may reflect subtle shifts in match dynamics post-VAR, including more interruptions or altered player behavior.

Table 4.1 - Descriptive Statistics – First Division

	First Division (Treatment Group)											
	Pre VAR						Post Var					
	Count	Mean	Median	Max	Min	SD	Count	Mean	Median	Max	Min	SD
Effective Playing Time	516	52,77	52,75	67,75	39,62	4,72	544	51,46	51,47	69,92	34,92	5,50
Goals	516	2,57	2	8	0	1,62	544	2,72	2,5	10	0	1,74
Corners	516	4,01	4	14	0	2,39	544	3,96	3,5	14	0	2,49
Fouls	516	32,74	33	54	13	6,57	544	32,73	32,5	52	13	6,63
Offsides	516	10,48	10	23	1	3,68	544	10,45	10	26	2	3,43
Throw Ins	516	51,4	51	84	25	10,1	544	48,94	49	81	26	9,46
N	516						544					

In contrast, the Second Division, shows relatively stable values across the pre and post-periods. Effective playing time remained virtually unchanged, averaging 52.79% before and 52.61% after, with similar variability. Goals, corners, and fouls also show minor changes, but no strong directional trends.

Table 4.2 - Descriptive Statistics – Second Division

	Second Division (Control Group)											
	Pre VAR						Post Var					
	Count	Mean	Median	Max	Min	SD	Count	Mean	Median	Max	Min	SD
Effective Playing Time	263	52,79	52,96	65,61	39,31	5,21	293	52,61	52,72	69,50	39,7	5,17
Goals	263	2,33	2	7	0	1,53	293	2,45	2	8	0	1,61
Corners	263	4,63	4	20	0	2,81	293	4,46	4	15	0	2,65
Fouls	263	32,64	32	51	18	6,50	293	35,84	36	55	17	6,55
Offsides	263	10,16	10	22	3	3,65	293	10,43	10	21	2	3,5
Throw Ins	263	54	52	98	26	11,92	293	50,47	50	88	25	10,12
N	263						293					

This comparison suggests that while effective playing time declined slightly in the treatment group after VAR, it remained stable in the control group. This early descriptive evidence hints at a potential VAR effect, which is later confirmed and quantified through the DiD and event study models.

The following Boxplots (Figures 4.1 and 4.2) further illustrate the distributional changes in effective playing time across seasons and divisions, visually reinforcing the trends observed in the summary statistics.

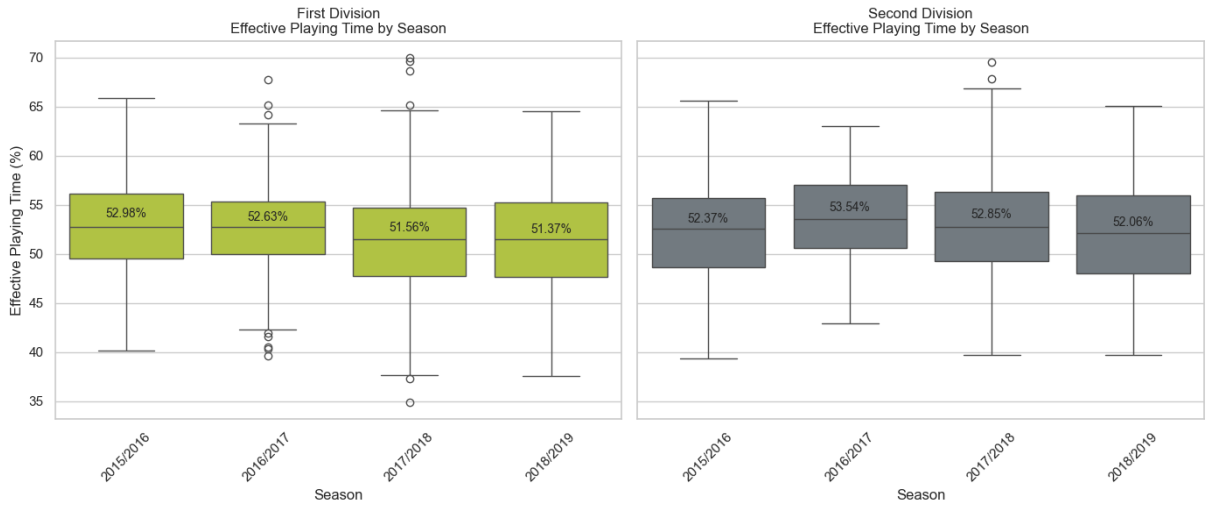

Figure 4.1 - Effective Playing Time by Season and Division

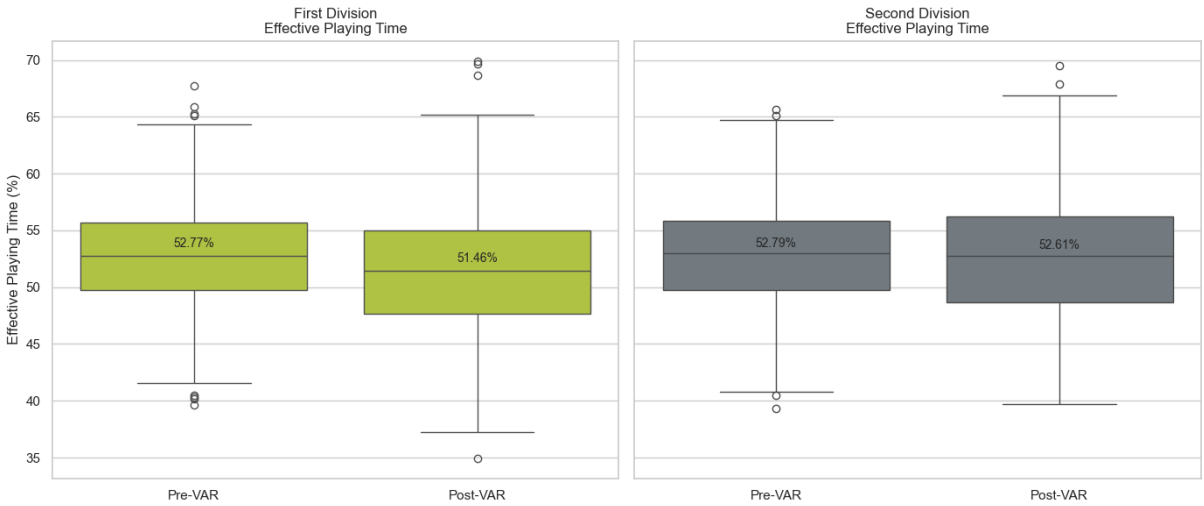

Figure 4.2 - Effective Playing Time Before and After VAR, by Division

To statistically evaluate whether effective playing time changed within each division before and after the introduction of VAR, independent samples t-tests were conducted separately for the First and Second Divisions. These tests help determine whether the differences observed in the summary statistics are statistically meaningful rather than due to random variation.

Before running each t-test, a Levene's test for equality of variances was performed. This step is necessary because the standard t-test assumes that the two groups being compared (pre-VAR and post-VAR) have equal variances. If this assumption does not hold, the results of the test could be misleading. Levene's test allows us to choose the appropriate form of the t-test: either the standard version (equal variances assumed) or the Welch's t-test (unequal variances), which is more robust in the presence of heteroscedasticity.

In the First Division, where VAR was implemented, Levene's test returned a statistically significant result ($p < 0.001$), indicating that the variances of effective playing time differed between the pre- and post-VAR periods. Consequently, the Welch's t-test was applied. The test revealed a statistically significant decline in effective playing time, with the mean dropping from 52.77% to 51.46% ($t = 4.17$, $p < 0.001$). This confirms that the reduction observed in the descriptive statistics may be associated with the introduction of VAR.

In contrast, the Second Division, which serves as the control group, showed no evidence of unequal variances ($p = 0.924$), allowing the use of the standard t-test. The difference in means (from 52.79% to 52.61%) was not statistically significant ($t = 0.42$, $p = 0.678$). This stability in effective playing time in the control group over the same period provides important contextual validation for the causal inference strategy adopted in this study. It suggests that broader structural or temporal trends are unlikely to account for the changes observed in the treatment group.

Table 4.3 - Mean Comparison Tests for the Effective Playing Time

Division	Pre Mean	Post Mean	Levene p-value	t-statistic	t-test p-value	Equal Variance Assumed
First Division (VAR)	52.77	51.46	0.001	4.17	0.000	FALSE
Second Division (No VAR)	52.79	52.61	0.924	0.42	0.678	TRUE

Overall, these preliminary statistical tests reinforce the descriptive evidence and lend further support to the DiD and event study analyses presented in the following sections.

4.2 Difference in Differences Estimation

The analysis proceeds with the estimation of two DiD models. The first is a baseline specification that includes only the key treatment variables (treatment, post, and their interaction), and the second is an extended model that incorporates additional match-level control variables.

In the baseline model, the interaction term captures the DiD estimator. It is negative and statistically significant ($\beta = -1.127,\ p = 0.037$), indicating that the introduction of VAR was associated with a 1.13 percentage point decrease in effective playing time in the first division, relative to the control group and the pre-treatment period. However, the model's explanatory power is limited, with an R-squared of just 0.014.

To refine this estimate and account for differences in match dynamics, a second specification includes the following control variables: goals, offsides, throw-ins, corners, and fouls. These variables are expected to influence effective playing time but are not caused by the implementation of VAR.

In the DiD model with controls, the estimated treatment effect becomes more pronounced ($\beta = -2.17$, $p < 0.001$), suggesting a 2.17 percentage point decrease in effective playing time post-VAR. The explanatory power of the model increases substantially ($R^2 = 0.352$), indicating that much of the variation in effective time can be explained by the included match-level characteristics.

Both estimations use heteroskedasticity-robust standard errors to ensure that inference remains valid even in the presence of non-constant variance in the residuals.

Table 4.4 - Difference-in-Differences Estimation Results

Model	Treatment (β_1)	Post (β_2)	DiD (β_3)	P-value (Interaction)	R-squared
Baseline	-0.019	-0.183	-1.127	0.037	0.014
With Controls	-0.318	0.455	-2.166	< 0.001	0.352

These results demonstrate that VAR is associated with a significant and robust reduction in effective playing time. The fact that the estimated effect increases after controlling for match context reinforces the interpretation that the observed decrease is not driven by confounding factors such as game intensity or volume of events. Instead, it is likely attributable to VAR-specific disruptions, such as referee reviews and stoppages.

4.3 Parallel Trends Assumption

Following the main DiD estimation, it is essential to examine whether the Parallel Trends Assumption holds in practice. A first look at this assumption is provided by Figure 4.3, which shows the average effective playing time for the First and Second Divisions across the study period. The trajectories appear broadly similar during the pre-treatment period, suggesting that both groups evolved in parallel before VAR was introduced. However, visual evidence alone cannot fully rule out the possibility of underlying differences.

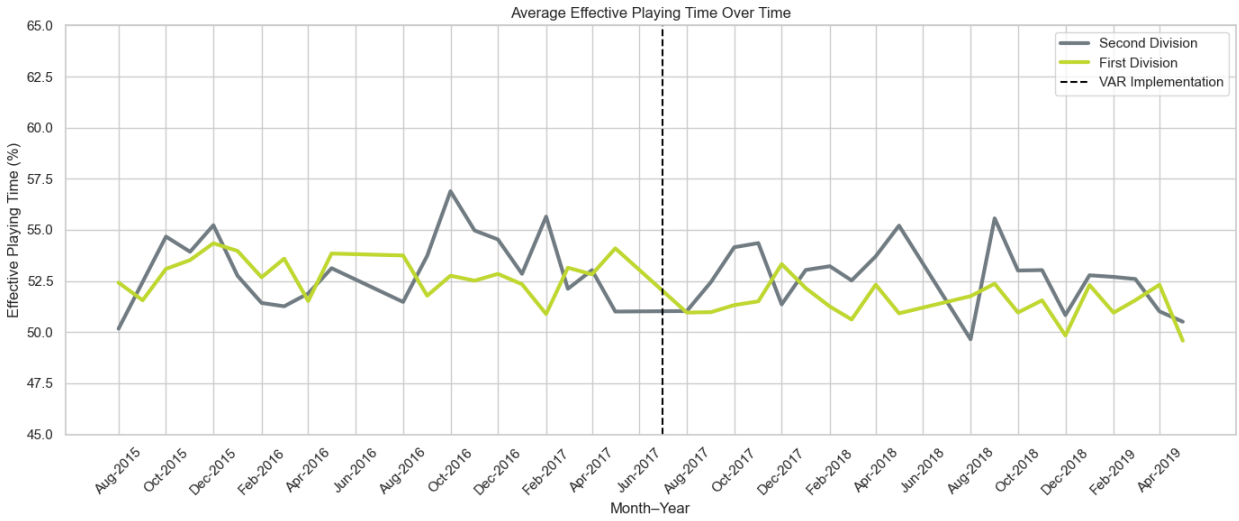

Figure 4.3 - Average Effective Playing Time Over Time by Division

To strengthen this check, a placebo regression was conducted using an artificial treatment date in the middle of the 2015/2016 season, with January 1, 2016, as the cutoff point. The estimated placebo DiD interaction term is 0.048 with p-value of 0.964, confirming that the model does not detect a significant effect where none should exist. This outcome reinforces the idea that, prior to VAR, the two divisions were on comparable trajectories in terms of effective playing time. Together, the descriptive figure and the placebo regression provide additional evidence that the Parallel Trends Assumption is reasonable, reinforcing the credibility of the DiD estimates.

4.4 EVENTS STUDY

To build on the DiD findings and to examine the dynamics of VAR's impact in greater detail, an ES model is estimated. This approach allows for a closer look at how effective playing time changed before and after the introduction of VAR, using separate coefficients for each period relative to the intervention. By showing how the treatment and control groups evolved over time, the ES provides an additional check of the Parallel Trends Assumption and reveals whether the effect of VAR persisted, increased, or diminished in the seasons that followed its implementation.

Figure 4.4 displays the coefficients from the baseline ES model (without controls), with 95% confidence intervals. The estimates for the pre-treatment periods (t = -2 and t = -1) are statistically insignificant and close to zero, providing support for the parallel trends assumption.

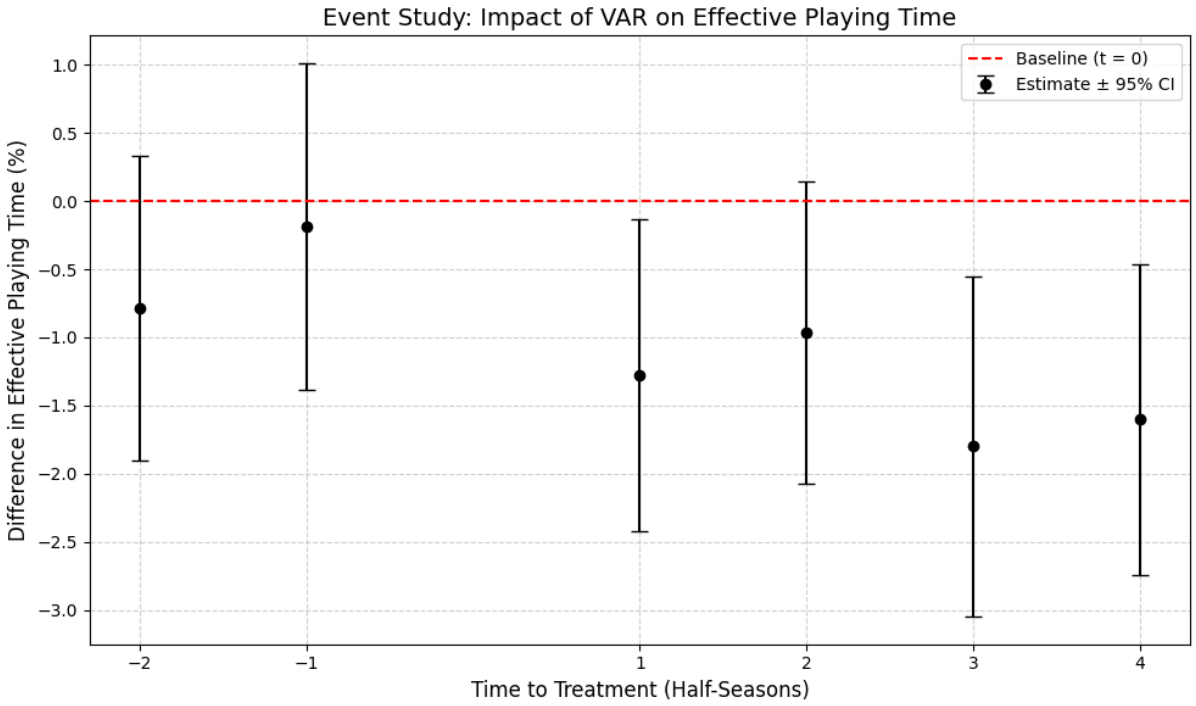

Figure 4.4 - Event Study Estimates of VAR's Impact on Effective Playing Time (Baseline Model)

Figure 4.5 plots the results of the model that includes match characteristics as controls. The pattern remains consistent, but the estimated effects become slightly larger and more precisely estimated. For instance, at t = 4, the estimated reduction in effective playing time increases to 2.45 percentage points, with a narrow confidence interval.

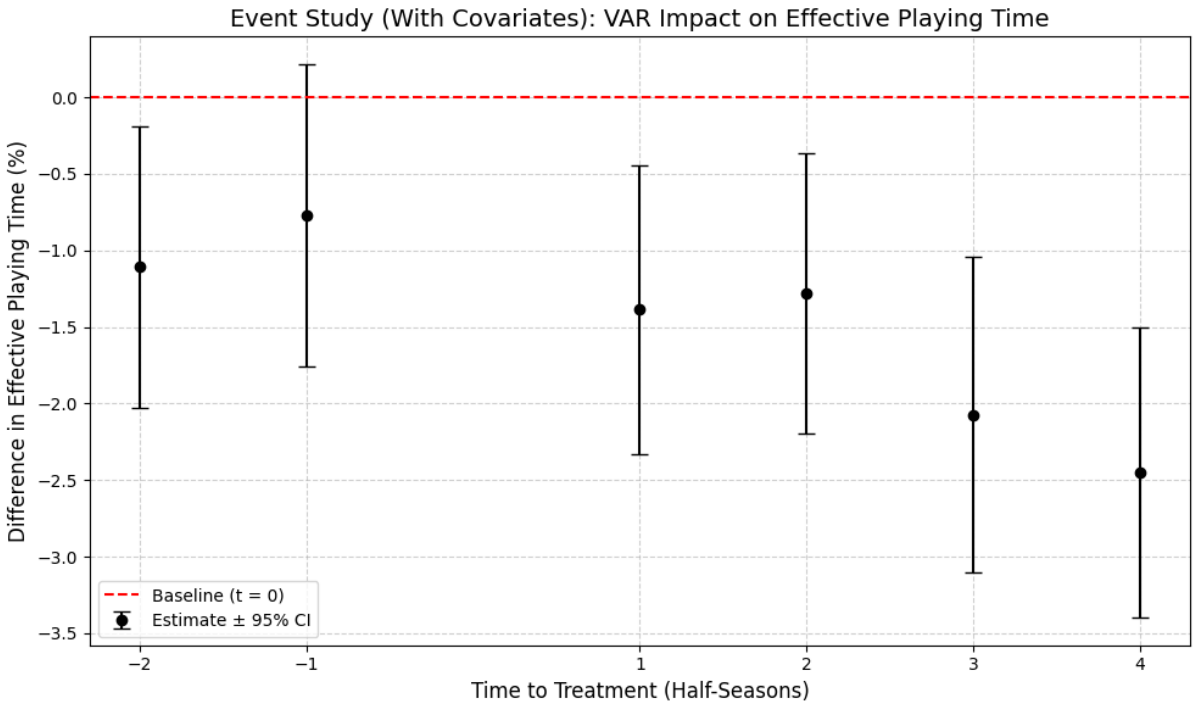

Figure 4.5 - Event Study Estimates of VAR's Impact on Effective Playing Time (With Covariates)

Interestingly, the estimate for t = -2 becomes statistically significant in the covariate-adjusted model, suggesting that there may have been a small pre-trend. This nuance should be noted, though the general support for the parallel trends assumption remains reasonably strong.

Table 4.5 summarizes the estimated coefficients and 95% confidence intervals for each half-season relative to the baseline period (t = 0), both for the baseline event study model and the covariate-adjusted version. In the baseline model, the pre-treatment coefficients (t = -2 and t = -1) are statistically insignificant and centered around zero, providing support for the parallel trends assumption. From the first post-treatment period onward (t = 1), the estimates become negative and statistically significant, indicating a sustained decrease in effective playing time following the implementation of VAR. The effects peak in t = 3 and t = 4, reaching reductions of 1.80 and 1.60 percentage points, respectively.

Table 4.5 - Event Study Estimates of VAR's Impact on Effective Playing Time

Time (t)	Coef (No Covariates)	95% CI	Coef (With Covariates)	95% CI
-2	-0.79	[-1.90, 0.33]	**-1.11**	**[-2.03, -0.19]**
-1	-0.19	[-1.39, 1.01]	-0.77	[-1.76, 0.21]
1	**-1.28**	**[-2.42, -0.14]**	**-1.39**	**[-2.33, -0.44]**
2	-0.96	[-2.07, 0.14]	**-1.28**	**[-2.19, -0.36]**
3	**-1.80**	**[-3.05, -0.55]**	**-2.07**	**[-3.11, -1.04]**
4	**-1.60**	**[-2.74, -0.46]**	**-2.45**	**[-3.40, -1.51]**

When match-level controls are added (goals, offsides, throw-ins, corners, fouls and competitiveness), the estimated impact of VAR becomes even more pronounced. The treatment effect increases in magnitude across all post-treatment periods, with the final half-season (t = 4) showing a reduction of 2.45 percentage points in effective playing time. Notably, in this specification, even the pre-treatment period t = -2 becomes statistically significant, suggesting a small downward trend that warrants caution but does not fully undermine the overall parallelism in the earlier period. These findings reinforce the conclusion that VAR has had a sustained and statistically robust negative effect on match fluidity.

5 CONCLUSION

5.1 SUMMARY OF FINDINGS

This dissertation set out to investigate the impact of the implementation of the VAR system on effective playing time in professional football matches. Focusing on the Portuguese context, the analysis drew on match-level data from the country's First and Second Divisions over a four-season period, spanning from 2015/2016 to 2018/2019. To identify the causal effect of VAR, the study employed a DiD estimation strategy, complemented by an event study approach to explore the timing and evolution of the treatment effect.

The results obtained throughout the empirical analysis point consistently to a negative and statistically significant relationship between the introduction of VAR and the share of match time during which the ball is in play. Depending on the model specification, the estimated reduction in effective playing time ranged from approximately 1.13 to 2.17 percentage points. This effect was observed to be more pronounced when controlling for additional match-level variables such as goals, offsides, fouls, and other indicators of match intensity. Furthermore, the event study provided additional support for the DiD findings by confirming the absence of strong pre-treatment differences between the First and Second Divisions while also illustrating that the decline in effective time occurred immediately after VAR was introduced and persisted across subsequent seasons. Complementary hypothesis testing showed that this reduction was statistically significant only in the First Division, whereas effective playing time in the Second Division remained stable over the same period.

Taken together, these findings offer compelling evidence that the introduction of VAR in the Portuguese First Division was associated with a measurable reduction in effective playing time. Rather than improving or preserving the fluidity of the game, VAR appears to have contributed to longer interruptions and additional stoppages, ultimately reducing the overall time that the ball was actively in play during matches.

5.2 LIMITATIONS AND FUTURE WORKS

Although the findings presented in this study are robust across different model specifications and supported by various tests and visualizations, several limitations must be acknowledged. First, the time span covered by the dataset is relatively short, capturing only four seasons around the implementation of VAR. Expanding the analysis to include more recent seasons would allow for the identification of longer-term patterns and the potential stabilization of VAR-related effects as referees, players, and officials adapt more fully to the system. Over time, rule clarifications or protocol changes may also affect how and when VAR is used, possibly leading to changes in its impact on match dynamics.

Second, the analysis is confined to the Portuguese case. While this context provides a clear natural experiment due to the staggered introduction of VAR across divisions, it also limits the applicability of the findings. VAR protocols, enforcement standards, and match styles can vary significantly across countries. Extending this research to include other European leagues or conducting a cross-country comparison using a similar methodology would provide a more comprehensive understanding of how VAR affects effective playing time in different footballing cultures and regulatory environments.

Finally, it is important to note that this study focused exclusively on effective playing time as the outcome of interest. While this variable captures an important dimension of match fluidity, it represents only one of several ways to evaluate the broader impact of VAR. Future studies could expand the analysis to include additional outcomes, such as the number of controversial decisions, crowd reactions, player discipline, or even fan engagement, in order to paint a more holistic picture of how VAR is reshaping the sport.

6 BIBLIOGRAPHICAL REFERENCES

Abbate, C., Cross, J., & Uhrig, R. (2025). Video assistant referee and home field advantage: Implications for referee bias. *Southern Economic Journal*, *91*(3), 1176–1196. https://doi.org/10.1002/soej.12731

Akdağ, E., Işın, A., Calvo, A. L., Alonso Pérez Chao, E., & Jiménez Sáiz, S. L. (2025). Evaluating the Impact of Video Assistant Referee Implementation in Football: A Four-Season Analysis of Match Performance Trends. *Applied Sciences*, *15*(9), 4789. https://doi.org/10.3390/app15094789

Bao, R., & Han, B. (2024). The influence of the video assistance referee (VAR) on the English Premier League. *International Journal of Performance Analysis in Sport*, *24*(3), 241–250. https://doi.org/10.1080/24748668.2023.2291236

Bao, R., Ruano, M. Á. G., Shi, R., Wang, X., & Han, B. (2025). The influence of the video assistant referee on the UEFA European Championship. *BMC Sports Science, Medicine and Rehabilitation*, *17*(1), 65. https://doi.org/10.1186/s13102-025-01118-1

Carlos, L.-P., Ezequiel, R., & Anton, K. (2019). How does Video Assistant Referee (VAR) modify the game in elite soccer? *International Journal of Performance Analysis in Sport*, *19*(4), 646–653. https://doi.org/10.1080/24748668.2019.1646521

Díaz, J. F. (2023, March). *Football heads towards a stopped clock system*. https://www.marca.com/en/football/2023/03/01/63ff79b422601d6f658b45e4.html

Errekagorri, I., Castellano, J., Echeazarra, I., & Lago-Peñas, C. (2020). The effects of the Video Assistant Referee system (VAR) on the playing time, technical-tactical and physical performance in elite soccer. *International Journal of Performance Analysis in Sport*, *20*(5), 808–817. https://doi.org/10.1080/24748668.2020.1788350

Federação Portuguesa Futebol. (2017). *IFAB oficializa vídeo-árbitro em Portugal*. https://www.fpf.pt/pt/News/Todas-as-not%C3%ADcias/Not%C3%ADcia/news/12927

Fédération Internationale de Football Association. (2022, November). *Collina: We've asked referees to calculate stoppage time more accurately* [Interview]. https://inside.fifa.com/refereeing/news/collina-weve-asked-referees-to-calculate-stoppage-time-more-accurately

Han, B., Chen, Q., Lago-Peñas, C., Wang, C., & Liu, T. (2020). The influence of the video assistant referee on the Chinese Super League. *International Journal of Sports Science & Coaching*, *15*(5–6), 662–668. https://doi.org/10.1177/1747954120938984

International Centre for Sports Studies. (2019, October). Effective playing time: Records per league and club. *Weekly Post*. https://football-observatory.com/IMG/sites/b5wp/2019/wp272/en/

International Football Association Board. (2017a). Video Assistant Referee (VAR) protocol. *Https://Www.Theifab.Com/*. https://www.theifab.com/laws/latest/video-assistant-referee-var-protocol/#principles

International Football Association Board. (2017b, August). Experiments with Video Assistant Referees (VARs) enter next stage. *IFAB*. https://www.theifab.com/news/experiments-with-video-assistant-referees-vars-enter-next-stage/

International Football Association Board. (2024, November). Goalkeeper holding the ball for too long. *IFAB*. https://www.theifab.com/trials/goalkeeper-holding-the-ball-for-too-long/

Lago-Penas, C. (2012). The Influence of Effective Playing Time on Physical Demands of Elite Soccer Players. *The Open Sports Sciences Journal*, *5*(1), 188–192. https://doi.org/10.2174/1875399X01205010188

Lartey, S. (2024). *Analyzing the Challenges and Benefits of VAR Usage in Football: A Comprehensive Examination*.

Portugal Football Observatory. (2022a, July). *The Impact of the VAR on Referee Decisions and on the Game*. https://indd.adobe.com/view/9c350db0-e439-4898-add1-52f833325112

Portugal Football Observatory. (2022b, October). Effective Playing Time—Characterisation and Influencing Factors. *Portugal Football Observatory*. https://indd.adobe.com/view/53d8c658-5e3e-43df-9b7b-9277dc265e74

Scanlon, C., Griggs, G., & McGillick, C. (2022). 'It's not football anymore': Perceptions of the video assistant referee by english premier league football fans. *Soccer & Society*, *23*(8), 1084–1096. https://doi.org/10.1080/14660970.2022.2033731

Spitz, J., Wagemans, J., Memmert, D., Williams, A. M., & Helsen, W. F. (2021). Video assistant referees (VAR): The impact of technology on decision making in association football referees. *Journal of Sports Sciences*, *39*(2), 147–153. https://doi.org/10.1080/02640414.2020.1809163

Tojo, Ó., Spyrou, K., Teixeira, J., Pereira, P., & Brito, J. (2023). Effective playing time affects technical-tactical and physical parameters in football. *Frontiers in Sports and Active Living*, *5*, 1229595. https://doi.org/10.3389/fspor.2023.1229595

Union of European Football Associations. (2022, September). *European referees primed for a new campaign* [Interview]. https://it.uefa.com/news-media/news/0279-160366f9e5a0-9e2236b56ada-1000--european-referees-primed-for-a-new-campaign/

Zhang, Y., Li, D., Gómez-Ruano, M.-Á., Memmert, D., Li, C., & Fu, M. (2022). The effect of the video assistant referee (VAR) on referees' decisions at FIFA Women's World Cups. *Frontiers in Psychology*, *13*, 984367. https://doi.org/10.3389/fpsyg.2022.984367

NOVA Information Management School
Instituto Superior de Estatística e Gestão de Informação

Universidade Nova de Lisboa