A Work Project, presented as part of the requirements for the Award of a Master's degree in Business Analytics from the Nova School of Business and Economics.

The Impact of VAR on Refereeing Behaviour in Football: A Study on Consistency and Change

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Work project carried out under the supervision of Michail Batikas

December 2024

STATEMENT OF INTEGRITY

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

Joaquim Correia Simão

Lisbon, 17th December 2024

ABSTRACT

In recent years, the introduction of new regulations and technologies across various sectors has prompted critical examination of their broader implications. This phenomenon is no different in the realm of professional football with the implementation of the Video Assistant Referee (VAR). This work seeks to analyse VAR's impact on various metrics such as referee behaviour. Through the use of a data-driven approach, utilizing methods such as Difference-in-Differences (DiD) approach, Event studies and general descriptive statistics which help paint a picture of results. The study was conducted on both the English Premier League and the English Championship, using the latter as a control group.

This work used infrastructure and resources funded by Fundação para a Ciencia e Jecaelesia (UID/ECO/00124/2013, UID/ECO/00124/2019 and Social Sciences DataLab, Project 22209). POR Lisboa (LISBOA-01-0145-FEDER-007722 and Social Sciences

DataLiab, Project 22209) and POR Norte (Social Sciences Datalab, Project 22209).

KEYWORDS

Football; Soccer; Sports; VAR; Video Assistant Referee; Referee; Football Betts; Betting Odds; Betting; Football Players; Defenders; Midfielders; Forwards; Premier League; English Championship; English Teams; Difference-in-Differences; DiD; Behaviour; Decision Making; Analysis; Performance.

AKNOWLEDGEMENTS

I would like to express my sincerest gratitude to professor Michail Batikas who was always available to provide clarifications and guidance during the entire process of research, analysis and writing process.

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1 Motivation and Research Objectives

In recent decades, the implementation of new legislation, technology innovations, and procedural reforms across diverse sectors, such as business, healthcare, and education, has frequently generated a significant necessity to comprehend their wider ramifications. Every innovation, regardless of its potential, has a range of possible outcomes that require scrutiny, it might transform current procedures, modify stakeholder behaviours, and affect important performance indicators. In this context, the domain of sports is certainly no exception. The implementation of innovative regulations and technologies in a sport can alter essential aspects of competition, equity, strategy, and perception. Football, as the most popular sport globally, offers a notably rich context for observing such processes. The recent implementation of the Video Assistant Referee (VAR) system represents a significant and contentious change in the officiating and experience of the game.

Historically, elite football matches have experienced countless controversial refereeing decisions, occasionally impacted the outcome of championships and subsequently influenced narratives that persist for decades. Notable incidents, such as Diego Maradona's "Hand of God" goal in the 1986 World Cup, Frank Lampard's disallowed shot that crossed the goal line against Germany in the 2010 World Cup and more recently the dismissal of referee David Coote after the English professional was caught badmouthing a club of which he had refereed with controversial incidents (2024), ignited fervent debates on the equity and precision of officiating.

Media outlets, like ESPN and many international sports networks, have consistently highlighted the constraints of human supervision in high-pressure competitions. Furthermore, club-level contests in Europe's premier leagues, such as the Premier League, La Liga, and the Bundesliga, have seen numerous contentious decisions that prompt fans, players, and coaches to scrutinize the integrity of the outcomes. The accumulated demands have progressively

generated momentum for the implementation of a technical solution intended to aid referees and, ideally, minimize significant errors.

The introduction of VAR, formally adopted in 2019-2020 by Premier League (England's top-tier football league), was designed as a tool to evaluate pivotal moments, goals, penalty calls, direct red-card situations, and instances of mistaken identity, via video analysis. Proponents contended that technology would improve equity and precision, equipping referees with a means to review critical plays and guarantee the correct decision is upheld.

Nonetheless, despite the various levels of enthusiasm for VAR among leagues, its actual impact remains ambiguous and complex. VAR can correct significant errors that may have impacted championship outcomes or relegation contests. Conversely, it has introduced additional complexities, such as extended match interruptions, confusion among spectators who may not understand the rationale behind decisions, and new controversies stemming from the interpretation of marginal offside lines or nuanced handball rulings.

The implementation of VAR exemplifies a widespread challenge: when a new policy, technology, or structure is introduced in a sector, it is essential to evaluate its impact on the sector's participants, stakeholders, and overall value proposition.

In business, the implementation of automation may transform staff responsibilities and efficiency. In healthcare, the implementation of novel diagnostic technologies may enhance accuracy while also raising concerns around practitioner autonomy and patient comprehension. Digital platforms in education might enhance access to knowledge and transform the roles of educators as well as the interaction between teachers and learners.

In sports, the VAR system similarly alters responsibilities, behaviours, and perceptions. Consequently, examining VAR's impact transcends ordinary sports interest, it exemplifies how a new operational component can reverberate throughout a multifaceted ecosystem.

Referees are a significant focus of this research. Before the implementation of VAR, individual referees occasionally cultivated reputations for being either more lenient or stricter in adjudicating fouls and administering disciplinary measures. Certain referees reportedly issued yellow or red cards with greater frequency, but others permitted a more physical style of play. Debates have persisted on whether these discrepancies arise from individuals officiating ideologies, implicit biases, or variances in match contexts. With VAR now functioning as an auxiliary decision-making instrument, it is possible that refereeing judgments have become more uniform. Referees throughout the league may now exhibit greater uniformity in their standards for fouls, yellow cards, and penalties with different profile teams as well and, therefore, we'll analyse if VAR has had a more pronounced effect on such variables.

Teams and their performance results provide another area of focus. Clubs may modify their tactical strategies if they perceive that VAR influences referees' enforcement of specific regulations. If teams believe that VAR heightens the probability of penalties for minor infractions in the penalty area, defenders may adopt a more cautious approach, remaining closer to their assignments and avoiding potentially hazardous tackles. The analysis explores how VAR influences critical moments and general discipline, potentially favouring teams with greater attacking presence or higher stakes in matches. Furthermore, changes in point distributions and competitive balance are assessed to determine whether VAR has contributed to a convergence in performance metrics, narrowing the gap between historically dominant clubs and mid-tier or lower-ranked teams. The league's competitive balance may be altered if specific playing styles are either rewarded or disadvantaged by VAR-related dynamics. This research seeks to uncover both the immediate and long-term effects of VAR. The findings aim to provide insights into how VAR shapes tactical behaviours and league competitiveness over time.

Players' behaviours are also amenable to quantitative analysis. Although alterations in thinking or attitude are challenging to quantify directly, variations in on-field statistics may indicate fundamental behavioural adjustments. If attackers believe that dives or attempts to mislead the referee are more likely to be detected through video review, we may observe a reduction in the occurrence of dubious penalty appeals. If defenders are aware that even slight contact in the penalty area would be examined, they may avoid certain challenges, hence potentially enhancing goal-scoring opportunities. Data-driven methodologies can identify patterns in shot locations, the mean distance from which players try goals, the frequency of penalty awards, or the recorded fouls.

In addition to the teams and players, another area of investigation is the predictability of match outcomes. It can be posited that minimizing significant officiating errors will render match outcomes more indicative of inherent team quality, hence enhancing predictability. If this is accurate, then season-long performance metrics like predicted points and betting market odds may exhibit a closer correlation with actual results in the VAR era. Conversely, VAR may add novel uncertainties delayed decision reversals, prolonged stoppage, and complex rule interpretations could generate scenarios that are more difficult to predict, at least until clubs, referees, and bettors get to the new equilibrium. Examining the evolution of outcome predictability over time can reveal if VAR is cultivating a more "lawful" environment or adding new complexities.

The primary objective of this research is to introduce empirical rigor to a discourse frequently characterized by anecdotal evidence and subjective perceptions. Although media coverage and match recaps offer a qualitative perspective on the perception of VAR, an economic and statistical evaluation enables us to quantify its effects. The applied methodologies will likely entail analysing extensive datasets across numerous seasons, comparing outcomes, referee decisions, and match occurrences prior to and following VAR deployment. This method

guarantees that the results are based on observable changes rather than conjectural or solely narrative descriptions.

This research seeks to offer a comprehensive, data-driven analysis of VAR's influence on contemporary football by scrutinizing officiating statistics, team performance measurements, player behavioural indicators, and predictability measures. These findings could influence policymakers and football governing bodies in contemplating modifications to VAR processes or directives for match officials. It may also be beneficial for clubs and coaching personnel to ascertain whether the introduction of VAR necessitates tactical adjustments. Furthermore, the findings may enhance public conversation, providing clarity in what can sometimes be an emotionally heated subject.

This study does not intend to portray VAR as either a definitive enhancement or a significant hindrance. It aims to comprehend the quantifiable alterations that have occurred since its inception. Should referees' judgments exhibit greater consistency, match results correspond more accurately with anticipated outcomes based on team quality, and players' on-field behaviours undergo observable changes, these transformations can be recorded and examined through data analysis. If VAR's impact is negligible or reveals unforeseen patterns—such as heightened uncertainty or minor biases in specific match situations—those results will also provide significant insights.

This study aims to do a qualitative assessment using evidence-based insights to assess the impact of VAR on referees, team plans, and player behaviours, as well as its potential to enhance fairness and predictability in the sport.

2 Literature Review

The advancement of technology has profoundly transformed decision-making processes for individuals, businesses, and institutions across diverse contexts Liu et al. (2012). In recent decades, innovations in artificial intelligence (AI), data analytics, decision support systems (DSS), and interactive digital platforms have expanded the array of inputs accessible to decision-makers. Decision-makers are increasingly utilizing advanced analytical tools that can process extensive datasets, discover patterns, and deliver evidence based on insights, rather than depending simply on intuition, personal experience, or fragmented data sources (Shorfuzzaman, 2017). This transition affects strategic planning, policy formulation, resource allocation, and problem-solving in various sectors, including healthcare, agriculture, transportation, and sports.

A crucial advancement in this shift is the emergent decision-support platforms intended to manage intricate information streams. Before their advent, decision-makers often contended with incomplete or difficult-to-interpret data. Contemporary systems now optimize and contextualize this information. Liu et al. (2012) emphasize that modern decision-making systems provide extensive, contextually rich data via intuitive interfaces, facilitating enhanced interpretation. These technologies do not supplant human expertise, instead, they function as instruments to enhance human judgment by offering a solid analytical framework.

The integration of AI signifies a substantial transformation in decision-making processes. Historically, data analysis frequently surpasses human capability, resulting in unnoticed intricate patterns. According to Yin (2024), AI-based decision aids enhance human decision-making by uncovering patterns across extensive datasets and providing recommendations that augment human reasoning. Significantly, these tools augment, rather than replace, human decision-makers, maintaining the crucial human function in guaranteeing ethical and contextual suitability.

As it is possible to understand, technology-driven tools have become essential to numerous decision-making processes. These enhance data analysis and promote human-machine cooperation. As these tools become increasingly integrated into other sectors, the problem is to sustain an adequate equilibrium among human judgment, transparency, accountability, and the complexity of evolving technologies (Burton, Stein, and Jensen 2019; Upadhyay 2023).

2.1. Technology in Assisting Human Decision Making

2.1.1 Types of Technology Helping Human Decision-Making

A variety of technological instruments have arisen to improve decision-making abilities across sectors. This encompasses machine learning (ML) algorithms, which are proficient in detecting concealed patterns, predicting results, and generating informed suggestions. For instance, in domains such as healthcare, ML models enhance the precision of cardiovascular risk evaluations (Weng et al. 2017) and forecast elevated intracranial pressure (Miyagawa, Sasaki, and Yamaura 2020). In doing so, they direct clinicians towards more prompt and accurate therapies. Clinical decision support systems (CDSS) that incorporate ML capabilities also assist in minimizing diagnostic errors and enhancing therapeutic strategies (Bolton et al. 2022).

Beyond healthcare, ML-driven approaches also transform sectors like transportation, where advanced analytics and cognitive information communication channels provide real-time operational alerts (Kaartinen and Jamsa 2016, 216). In this way, large volumes of data become actionable insights, granting policymakers and managers a clearer strategic perspective.
Interactive machine learning (IML) systems go further by involving human experts throughout the model training and refinement process. Before IML, model updates were often opaque and automated, but Amershi et al. (2014) highlight how IML ensures that algorithmic decisions

reflect both data patterns and expert judgment. This human-in-the-loop interaction fosters personalization, equity, and responsibility. Similarly, decision trees, another ML technique, have enhanced advancements in domains such as electric vehicle maintenance (Jiang 2024) and educational achievement prediction (Krishna 2021). These methods demonstrate that developing technologies improve human decision-making by augmenting accuracy, adaptability, and efficiency.

2.1.2 Frameworks of Technology Helping Human Decision-Making

Integrating technology with human expertise necessitates explicit frameworks that delineate the extent of human participation. Three principal paradigms such as Human-in-the-Loop (HITL), Human-on-the-Loop (HOLT), and Human-out-of-the-Loop (HOOTL) offer systematic methodologies.

In HITL models, human specialists consistently engage with automated systems. Prior to the complete implementation of automation, human feedback guarantees the maintenance of ethical, contextual, and professional standards. Maadi, Khorshidi, and Aickelin (2021) demonstrate that integrating human feedback into feature selection enhances transparency and trust, ensuring algorithmic alignment with human values and judgments.

The HOLT framework minimizes ongoing human engagement by enabling automation to manage regular decisions. Humans serve as overseers, intervening when circumstances alter, or intricate decisions are required. Inoue and Gupta (2019) assert that this is particularly advantageous in high-stakes settings such as aviation or healthcare, facilitating rapid adaptation while mitigating excessive dependence on automated results.

HOOTL models significantly reduce direct human involvement, delegating most operations to autonomous systems. While humans retain responsibility for periodic evaluations, accountability may prove difficult. Vouk (2012) emphasizes that diligent supervision and

regular human evaluations are essential to uphold ethical standards and public confidence in these more autonomous systems.

Finding the right balance between these paradigms is a recurring theme. Contextual adaptability ensures that decisions remain ethical, responsive, and grounded in human accountability, all while maximizing the strengths of advanced technological tools.

2.1.3 Use Cases of Technology Helping Human Decision Making

Technology-driven decision support is evident in multiple domains. In healthcare, decision aids enhance patient comprehension of treatment alternatives, customizing selections to personal values and circumstances. Healthcare is one of the sectors where technology is helping human decision-making the most, Robson, Say, and Thomson (2011) discuss how obstetric decision aids enhance comprehension of labour analgesia choices, while Wang et al. (2021) describe shared decision-making assistants guiding liver cancer patients toward more personalized treatment plans.

According to Stirling et al. (2012), caregivers of dementia patients also gain advantages from adaptive decision aids, which ensure that services are consistent with the changing needs of patients. Guille et al. (2019) demonstrate that collaborative decision-making tools assist women with prenatal opioid use disorder in navigating intricate treatment environments. Sajeev et al. (2016) introduce nutrition support decision assistance in paediatric oncology, emphasizing the necessity of assessing tools within practical settings.

Beyond healthcare, DSS are transforming other domains. In environmental management, DSS are critical for handling complex tasks such as flood control, where precision and timeliness are key, as noted by Chen et al. (2014, 161–177). In industrial contexts, the integration of automation with human intuition enhances precision and response times, according to Duncan-Reid and McCarley (2021, 96–100). Additionally, online decision aids empower consumers to navigate complex product information, improving their choices and

fostering evidence-based decisions (Virdi, Kalro, and Sharma 2020, 555–574). These examples illustrate how technology enhances decision-making by empowering individuals and promoting informed, data-driven choices across diverse fields.

2.1.4 Challenges, Transparency, and Ethical Considerations

As technology's influence on decision-making increases, questions over transparency, ethics, and accountability also escalate. Complex ML algorithms may operate as "black boxes", complicating users' comprehension of the decision-making process. Burton, Stein, and Jensen (2019) warn that opacity could compromise ethical oversight and erode confidence. Data privacy and algorithmic equity present other issues. If training data is biased, marginalized groups may be unjustly disadvantaged. Fan (2024) advocates for ethical frameworks to avert misuse, whereas Upadhyay (2023) underscores the necessity of stringent norms for privacy, bias reduction, and openness. Ko et al. (2022) assert that transparent information technologies enhance consumer trust in supply chains, whereas Ibrahim (2024) observes that blockchain technology may mitigate fraud.

Nevertheless, data security continues to be a recurring concern. Olorunsogo (2024) and Keller et al. (2020) emphasize that explainability and physicians' comprehension of AI suggestions are essential for ethical healthcare practice. Ayling and Chapman (2021) along with Dara, Fard, and Kaur (2022) promote responsible AI concepts based on human-centered design and explicit accountability frameworks. Interdisciplinary collaboration among policymakers, technologists, experts, and users is crucial to tackle these difficulties.

Guaranteeing that decision-support technologies adhere to human values, emphasize transparency, and preserve ethical integrity is fundamental to reliable AI and implementation of technology on supporting human decision making.

2.2. Technology in Sports

2.2.1 The Evolution of Technology in Sports

The sports industry illustrates how technology may significantly transform decision-making processes. Wearable devices, big data analytics, AI-driven scouting, and blockchain solutions have become essential components of training methodologies, performance assessments, fan interaction, and administrative operations. Coaches and scouts, who have historically depended on subjective perceptions and intuitive judgment to evaluate player performance and strategize for matches, are now transforming their approach by harnessing continuous data streams, enriched with real-time analytics, and utilizing advanced predictive models (Roumani, 2022). These tools enable a more objective, data-driven decision-making process that enhances their ability to identify talent, optimize strategies, and predict outcomes with unprecedented precision and reliability.

Wearable devices that monitor physiological data assist in customizing training regimens and identifying injury risks at an early stage. Claudino et al. (2021) demonstrates how big data analytics improve performance monitoring and inform risk evaluation. Similarly, blockchain projects can ensure the validity of tickets and merchandise, thereby enhancing confidence and operational integrity, as elucidated by Wang and Liu (2022).

The fan experience has evolved. Social media, streaming services, and immersive technologies like virtual reality (VR) have established interactive settings that enhance the connection between fans and teams or athletes (Glebova, Desbordes, and Géczi 2019). However, when sports organizations adopt new tools, they must uphold competitive equity and safeguard the sport's fundamental authenticity (Burkett 2010).

2.2.2 Enhancing Athlete Performance and Training

Modern performance enhancement techniques frequently depend on data-driven feedback mechanisms. Coaches, trainers, and sports scientists integrate wearable sensors,

sophisticated information and communication technologies (ICTs), data analytics, genetic studies, and VR simulations to optimize training.

Wearable technologies are essential in contemporary sports training, providing ongoing assessment of critical physiological metrics like heart rate and mobility to develop customized training programs suited to individual requirements (Simbolon 2023). Advanced sensor technologies and data analytics collaborate to detect biomechanical inefficiencies, enabling athletes and coaches to enhance tactics and reduce injury risks (Claudino et al. 2021, 6479). The use of Information and Communication Technologies (ICTs) significantly improves the efficiency of data gathering and processing, providing real-time insights that facilitate immediate modifications and strategic planning (Varmus 2024).

Simultaneously, VR simulations offer athletes immersive, game-like experiences within regulated settings, facilitating the refinement of tactical decision-making and technical execution without the physical demands of actual gameplay (Zhao, Mao, and Tan 2022). Genetic research, albeit in early stages, possesses the capacity to transform training by customizing programs according to an individual's genetic predispositions, hence facilitating highly specific methods for athletic development (Varillas-Delgado et al. 2022).

Notwithstanding these technical breakthroughs, it is imperative to acknowledge the persistent significance of human intuition, adaptability, and inventiveness in sports. Habibi (2023) emphasizes that technology should augment, not eclipse, the human aspect, ensuring it serves as a tool to enhance rather than supplant the strategic and emotional components that characterize sporting performance.

2.2.3 Technology in Officiating and Match Analysis

Technological innovations have transformed officiating and match analysis in sports. Tracking technologies and video analysis tools are now essential in aiding referees, allowing for more precise and informed decision-making while diminishing dependence on subjective

judgment (Cunningham et al., 2023). An exemplary instance of this growth is the adoption of the Video Assistant Referee (VAR), a technology intended to assess pivotal occurrences, including goals, penalties, or possible red cards. VAR has aimed to improve fairness and accuracy in decision-making processes by addressing and mitigating significant errors (Bordner 2019; Bordner 2014).

Another significant breakthrough is Hawk-Eye, a computer vision system extensively employed in sports like tennis and cricket. This technology offers accurate visual tracking to aid with line calls and other complex judgments, highlighting the increasing dependence on technological tools in sports (Collins and Evans, 2011).

Technology has significantly transformed the formulation of strategies and the allocation of player roles for coaches and analysts. Empirical data currently informs these processes, providing insights that supplant the conjecture of previous methodologies. Moreover, simulation technologies have arisen as essential instruments in referee training, establishing controlled conditions for officials to critically evaluate previous decisions and foresee future circumstances. These techniques not only improve individual performance but also foster a wider culture of precision and uniformity in officiating (Cunningham, Mergler, and Wattie 2022).

2.2.4 Technological Engagement with Fans

Sports fandom is experiencing digital transformation. Social media platforms have converted supporters from passive observers into active "prosumers," who participate in team narratives (Köse, Argan, and Hedlund 2020; Sturm 2020). VR and Augmented Reality (AR) technologies offer immersive experiences, presenting fans with diverse perspectives and interactive interaction possibilities (Pickman 2023).

These technologies were implemented at significant events such as the Tokyo 2020 Olympics. Over-the-top (OTT) media services, non-fungible tokens (NFTs), and blockchain

applications augment loyalty and generate new revenue streams (Mahajan 2023). Digital twin stadiums enable fans to virtually navigate venues (Takata and Hallmann 2022). Nonetheless, as teams address worldwide audiences and embrace contemporary methods, achieving a balance between technical innovation and maintaining the emotional, community character of live sports is a difficulty.

2.2.5 Specific Challenges of Technology Integration in Sports

Despite its advantages, the incorporation of technology in sports encounters opposition and practical constraints. Certain stakeholders express concern that enhanced instruments jeopardize conventional skills and spontaneity (Uzor 2023). Financial constraints may limit access to premier inventions, thus creating a competitive disparity between well-capitalized and resource-limited firms (Glebova, Desbordes, and Géczi 2022). It is imperative to train coaches, players, and officials in the proper utilization of these technologies, as noted by Turcu, Burcea, and Diaconescu (2021).

The continuous technological progress necessitates perpetual learning and adaptation, administrators must guarantee that the adoption of innovation does not undermine the human essence of competitiveness and genuine emotional experience (Viduka, Ilić, and Dimitrijević 2021). The essential factor is the deliberate integration that utilizes technology's advantages while preserving the core of the activity.

2.3 Technology in Football

2.3.1 Technology Evolution in Football

Football exemplifies data-driven revolution. Advanced measures like Expected Goals (xG) provide more refined evaluations of attacking efficacy compared to mere goal tallies. By considering variables such as shot distance, angle, and defensive pressure, xG allows coaches,

analysts, and fans to assess strategy and player performances with greater precision (Hewitt and Karakuş 2023).

ML algorithms enhance these measurements by integrating contextual factors, leading to improved predictions of match results and individual performances. Fernández-Navarro et al. (2019) demonstrate that the integration of different indicators provides a comprehensive perspective on team dynamics, informing decisions on tactics and player selection. Goal-line technology has also emerged as a groundbreaking innovation in football, utilizing advanced sensors to determine with absolute precision whether the ball has fully crossed the goal line. This system plays a crucial role in assisting referees with accurate goal decisions, eliminating ambiguity in critical moments of the game (Zglinski, 2020).

The evolution of football facilitating has taken significant strides in recent years too, particularly with the introduction of the VAR. Designed to minimize human error in crucial decisions, VAR has transformed how matches are officiated by providing referees with the tools to review and rectify clear and obvious mistakes in real time. Its approval by the International Football Association Board (IFAB) in 2016 and subsequent implementation during the 2018 FIFA World Cup marked a watershed moment in the sport's history. This milestone not only highlighted the growing role of technology in enhancing the fairness and accuracy of decision-making but also reinforced the commitment of football's governing bodies to uphold the integrity of the game (Kubayi, Larkin, and Toriola 2021; Zhang et al. 2022).

2.3.2 Introduction of VAR in Football

The implementation of the VAR technology aimed to improve impartiality and precision in football refereeing. VAR enhances the integrity of match outcomes by enabling referees to assess important moments from various angles, hence diminishing the probability of clear and obvious errors. Research demonstrates that VAR functions as a safety-net for referees while also reducing incorrect choices, so enhancing the idea of fairness in the sport. Nonetheless, its

execution has introduced new obstacles, including extended interruptions and discussions regarding subjective interpretations of certain judgments (Holder, Ehrmann, and König).

VAR was implemented in the Premier League in the beginning of 2019/2020 season to improve officiating and resolve problems related to pivotal decisions. Its implementation has significantly influenced the league, providing officials with an extra instrument to guarantee equity, while concurrently inciting discussions on its impact on the pace and dynamics of the game. Investigations have examined the concerns surrounding VAR in the Premier League, especially its impact on fan sentiment and the difficulties it poses in ensuring uniformity across matches (Kolbinger and Knopp, 2020; Hamsund and Scelles, 2021; Zglinski, 2020).

Conversely, the English Championship, the second tier of professional football in England, has not implemented VAR, maintaining reliance solely on conventional officiating methods. This decision sharply contrasts with the Premier League, prompting inquiries on the impact of VAR's absence on the fairness and accuracy of officiating at this level. Although the theoretical advantages and disadvantages of VAR in the Championship are acknowledged, the consequences of its non-implementation have not been thoroughly examined in academic literature.

The disparity between the Premier League's implementation of VAR and the Championship's dependence on conventional officiating creates a distinctive framework for analysing the wider effects of officiating technology. Comparative analyses may elucidate the merits and demerits of VAR, providing critical insights into its function in promoting equity and consistency while confronting the operational and subjective issues it presents.

2.3.3 VAR Effects on Referees, Players, Teams, and Other Stakeholders

The impact of VAR extends to everyone involved in or observing the sport, reshaping experiences on and off the field. For referees, VAR provides a valuable safety net, boosting their confidence in decision-making by offering a mechanism to correct clear and obvious

errors. However, this assurance comes with increased scrutiny, as referees are acutely aware that their judgments are subject to review and potential criticism (Samuel et al.2020).

Players, too, have adapted their behaviour in response to VAR. With infractions now more likely to be caught on replay, they are often more cautious in their actions, knowing the likelihood of detection has significantly increased (Holder, Ehrmann, and König 2021). Teams have integrated VAR into their strategic planning, anticipating how contentious decisions might be reviewed and potentially affect the flow or outcome of matches (Han et al. 2020).

Fans, however, have exhibited mixed reactions to the introduction of VAR. While many appreciate the fairness it brings to the game by minimizing errors, others criticize the interruptions it causes, arguing that it disrupts the natural rhythm of the match and diminishes the emotional spontaneity that defines football's appeal (Hamsund and Scelles 2021; Frandsen and Landgrebe 2022). These contrasting perspectives underscore the complexity of VAR's influence, balancing its role in improving equity with its impact on the sport's experience and essence.

2.3.4 The Influence of VAR on Match Results and Fairness, Controversies and Limitations

By addressing evident and significant errors, VAR is essential in aligning match results more accurately with genuine on-field performance, hence improving the sense of justice in football (Kubayi, Larkin, and Toriola 2021). This increased sense of equity not only bolsters the integrity of the sport but also reassures players, teams, and fans that pivotal moments are adjudicated with greater accuracy (Karafil 2023). Nevertheless, the impact of VAR transcends mere error repair, quietly influencing the conduct of players and referees, so affecting the inherent speed and spontaneity that characterize the core of football. The persistent goal is to achieve a delicate equilibrium, maintaining the sport's emotional intensity and flow while reducing significant blunders.

Notwithstanding its commendable aims, VAR is not devoid of shortcomings. The review process can cause considerable interruptions during matches, exasperating people who appreciate the continuous flow and rhythm of football (Hamsund and Scelles 2021). Moreover, the subjectivity in evaluating specific instances remains a continual concern, with biases like home-field advantage still affecting decisions (Han et al. 2020). Furthermore, the perpetual presence of video surveillance can exacerbate referee anxiety, imposing an emotional strain on an already high-pressure position (Samuel et al. 2020).

These constraints underscore the intrinsic challenges of incorporating technology into a sport rich in history. Although VAR has progressed in minimizing significant officiating errors, technology cannot entirely eradicate the inherent uncertainties of football or the subjective aspects of human judgment. Rather, it functions as a technological instrument to help in the decision-making process, while the overarching issue of equilibrium between precision and passion remains an ongoing conversation.

3 Methodology

3.1 Research Design

The research employs a mixed-methods approach to examine the transformative influence of the Video Assistant Referee (VAR) on English football. Central to this inquiry is a comparative framework contrasting two distinct competitive settings: the Premier League, where VAR was introduced, and the Championship, which continues to operate without it. While the study aims to capture long-term trends starting from the 2014/2015 season, the availability of data varies across analyses, with some beginning in later seasons. This approach aims at connecting observable shifts in refereeing standards, team strategies, betting markets, and player behaviour to the onset of VAR. In support of this, a preliminary descriptive analysis will be conducted to present key summary statistics (such as average goals, fouls, cards, or shots per match) across both leagues and over multiple seasons. These descriptive snapshots serve to familiarize the reader with the data landscape, highlight basic patterns, and guide subsequent econometric modelling.

At the core of our empirical strategy lies a Difference-in-Differences (DiD) estimation, a method that identifies treatment effects by exploiting variations over time and between groups. The "treated" group consists of Premier League matches played after VAR's implementation. In contrast, the "control" group comprises Championship matches over a similar time frame but without VAR.

The DiD approach assumes that absent the intervention, both leagues would have followed parallel trajectories. Any deviation observed in the Premier League after VAR's introduction can be interpreted as the intervention's effect, provided the parallel trends assumption holds. This technique offers a structured, reliable means of dissecting whether VAR truly reshaped the footballing landscape or merely coincided with independent changes that would have occurred regardless.

In addition to the Difference-in-Differences estimation, the study employs Event Studies, a class of econometric techniques that focus on the timing and magnitude of responses to a particular event, in this context, the introduction of VAR. Event Studies examines how key outcome variables evolve before and after a specific "event window," allowing researchers to visualize and quantify dynamic treatment effects over time. By plotting changes in outcomes at various points preceding and following VAR's introduction, it becomes possible to confirm whether observed shifts occur precisely when VAR takes effect and to gauge how these effects persist, intensify, or diminish as more time passes. This event-based temporal mapping complements the DiD estimates and enhances the study's ability to isolate VAR's impact with greater temporal resolution.

However, for some aspects of the analysis, particularly those related to: “Shifting Strategies: The influence of VAR on Player Behaviour in Football” such as the “Study on Shots”, the data constraints limit the causal identification strategy. In this sub-analysis, only a single pre-VAR period is available, making a full DiD approach less feasible. Without multiple pre-treatment points, it is challenging to establish a robust counterfactual trend or to confirm that pre-VAR trajectories in the Premier League and Championship would have remained parallel. As a result, the estimation strategy for the “Shots” subpart relies on separate regressions conducted for the Premier League and the Championship.

By comparing how trends in shot-taking evolve independently within each league and then contrasting these patterns, the analysis can still yield insights into whether VAR’s introduction coincided with notable shifts in player behaviour. However, the inability to anchor these patterns in a more robust multi-period DiD framework means that these findings should be interpreted more cautiously, as indicative correlations rather than definitive causal effects.

This mixed-method research aims to maximize the utility of the available data. Despite certain limitations, such as those affecting the analysis of shots, the methodological approach

strives to make the most of the gathered data to understand how VAR has influenced English football.

3.2 Analytical Methods and Tools

The research relies on a robust computational framework implemented within a Python environment, leveraging the power of Python notebooks to ensure replicability and transparency in data processing and analytics. Our data acquisition integrates web scraping techniques using packages, such as Selenium and BeautifulSoup, to extract detailed match-level observations and Elo ratings from online data repositories like SofaScore, FBref and ClubElo. Once collected, the raw data was cleaned and standardized when necessary to facilitate subsequent modelling.

The analysis was carried out using Python libraries like pyfixest, Pandas, and Matplotlib (for visualizations), which provided effective tools for implementing DiD regressions and event study analyses. These libraries enabled flexible model specifications, robust standard errors, and proper handling of fixed effects, ensuring the results accurately captured the causal relationships. This process, built on thorough data collection, preparation, and analysis, provided a solid foundation for drawing credible conclusions about the impact of VAR on various aspects of English football.

3.3 Data Collection

3.3.1 Overview of the Two Main Datasets

The core empirical backbone of this study consists of two primary datasets, that can be comprehended immediately bellow on figure 1 and figure 2. It is important to note that the variables in Figure 1 cover the period from 2013 to 2024, whereas in Figure 2, the variables span from 2017 to 2024, except for xG and Distance, which are only available from 2018 to 2024.

Figure 1 - **Match Level Dataset**

Variable	Description	Type	Data Source
Home Team	Home Team of the match	String	Sofascore
Game	Combination of home and away teams for unique match identification	Object	Sofascore
FullTimeResult	Full-time result in goals derived from combining the FTHG and FTAG columns	Object	Sofascore
FTHG	Full-time Home goals	Float	Sofascore
FTAG	Full-time Away goals	Float	Sofascore
FTR	Indicates the full-time outcome (H, D, A)	Object	football-data.co.uk
Post_VAR	Indicates if the match was played after VAR implementation (True: Yes, False: No)	Boolean	Sofascore
Season	Season of the Game	String	Sofascore
Season_Start	First year for each season	int	Sofascore
Away Team	Away Team of the match	String	Sofascore
Date	Date of the match	String	Sofascore
Referee	Name of the referee officiating the match	String	Sofascore
Year	Year in which the game was played	int	Sofascore
rel_year	Difference between the year the match is played and the year VAR was introduced	int	Sofascore
treatment	Indicates if a match was played in Premier League after VAR implementation (1: Yes, 0: No)	int	Sofascore
Div	Division of the match: E0 for Premier League, E1 for Championship	Object	football-data.co.uk
Premier_league	Indicates if the match was in the Premier League (True: Yes, False: No)	Boolean	Sofascore
Fouls Committed	Count of fouls committed by the Home Team per match	int	Sofascore
Fouls Conceded	Count of fouls committed by the Away Team per match	int	Sofascore
Fouls	Total fouls in the game for both teams	int	Sofascore
Yellow Cards Committed	Count of Yellow Cards committed by the Home Team per match	int	Sofascore
Yellow Cards Conceded	Count of Yellow Cards committed by the Away Team	int	Sofascore
Yellow Cards	Total Yellow cards in the game for both teams	int	Sofascore
Home VAR Decisions Count	Count of VAR decisions for the Home Team per match	int	Sofascore
Away VAR Decisions Count	Count of VAR decisions for the Away Team per match	int	Sofascore
Home VAR Decision	VAR decisions for the Home Team per match	object	Sofascore
Away VAR Decisions Count	VAR decisions for the Away Team per match	object	Sofascore
Home Elo Rating	Elo rating of the Home Team a day before the match	float	Elorating.net
Opponent Elo Rating	Elo rating of the Away Team a day before the match	float	Elorating.net
B365H	Pre-match odds of Home team win	float	football-data.co.uk
B365D	Pre-match odds of Draw	float	football-data.co.uk
B365A	Pre-match odds of Away team win	float	football-data.co.uk
ExpectedOutcome	Predicted outcome based on the lowest odds (Home Win, Draw, or Away Win)	float	football-data.co.uk
ActualOutcome	Actual outcome of the match	int64	—
Odds_Accuracy	Indicates whether the predicted outcome matched the actual outcome (1: Yes, 0: No)	int	—
P_H_raw	Raw implied probability of Home team win	float	—
P_D_raw	Raw implied probability of Draw	float	—
P_A_raw	Raw implied probability of Away team win	float	—
Total_P_raw	Raw implied total probability (can exceed 1)	float	—
P_H	Probability of Home team win (P_H_raw / Total_P_raw)	float	—
P_D	Probability of Draw (P_D_raw / Total_P_raw)	float	—
P_A	Probability of Away team win (P_A_raw / Total_P_raw)	float	—
Is_Close_Match	Indicates if a match is close (1: Yes, 0: No)	Boolean	—

Figure 2 - **Player Level Dataset**

Variable	Description	Type	Data Source
Player	Name of the player	String	FBref
Pos	Player's position(s) as listed in the raw data (e.g., DM, CB, LB)	String	FBref
macro_pos	Broad positional category (D = Defenders, M = Midfielders, F = Forwards), grouped based on the "Pos" column	String	Calculated (FBref)
Min	Minutes played by the player in the match	Integer	FBref
Total_playing_time	Total accumulated minutes played	Integer	Calculated (Min)
log_Gls	Logarithm of goals scored, log(Gls + 1)	Float	Calculated (FBref)
log_Ast	Logarithm of assists made, log(Ast + 1)	Float	Calculated (FBref)
log_Sh	Logarithm of shots taken, log(Sh + 1)	Float	Calculated (FBref)
log_SoT	Logarithm of shots on target, log(SoT + 1)	Float	Calculated (FBref)
log_Fls	Logarithm of fouls committed, log(Fls + 1)	Float	Calculated (FBref)
log_Fld	Logarithm of fouls suffered, log(Fld + 1)	Float	Calculated (FBref)
log_Off	Logarithm of offsides, log(Off + 1)	Float	Calculated (FBref)
log_Crs	Logarithm of crosses attempted, log(Crs + 1)	Float	Calculated (FBref)
log_TklW	Logarithm of tackles won, log(TklW + 1)	Float	Calculated (FBref)
log_Int	Logarithm of interceptions made, log(Int + 1)	Float	Calculated (FBref)
binary_CrdY	Binary indicator for yellow cards (1 = received, 0 = not received)	Boolean	Calculated (FBref)
binary_CrdR	Binary indicator for red cards (1 = received, 0 = not received)	Boolean	Calculated (FBref)
binary_OG	Binary indicator for own goals (1 = scored, 0 = not scored)	Boolean	Calculated (FBref)
binary_PK	Binary indicator for penalties scored (1 = scored, 0 = not scored)	Boolean	Calculated (FBref)
binary_PKatt	Binary indicator for penalties attempted (1 = attempted, 0 = not attempted)	Boolean	Calculated (FBref)
binary_PKcon	Binary indicator for penalties conceded (1 = conceded, 0 = not conceded)	Boolean	Calculated (FBref)
binary_PKwon	Binary indicator for penalties won (1 = won, 0 = not won)	Boolean	Calculated (FBref)
xG	xG from all player attempts during the match	Float	FBref
Distance	Average distance of all shot attempts made by the player in yards	Float	FBref
Date	Date of the match	Date	FBref
Week	Match week number	Integer	FBref
Season_Week	Season and week combined as a single identifier (e.g., "2017-2018_1")	String	Calculated (FBref)
Home_Team	Name of the home team	String	FBref
Away_Team	Name of the away team	String	FBref
Elo	Elo rating of the Player team, one day before the match	Float	ClubElo
Season	Season in which the match occurred	String	FBref
premier_league	Indicates if the match was in the Premier League (1 = Premier League, 0 = Championship)	Boolean	FBref
post_VAR	Indicates if the match occurred after (1) or before (0) the 2019-2020 season when VAR was implemented	Boolean	Calculated
relative_year	Relative year compared to the introduction of VAR	Integer	Derived

The first is a match-level dataset that enables comparisons across the Premier League and Championship.

This dataset encompasses a broad timespan and integrates multiple facets of the game. Referee information, including the frequency and nature of their decisions, was aligned with each match to determine if VAR altered officiating standards or decision-making consistency. Betting odds,

sourced and linked to the same set of matches, provided insight into betting markets' efficiency, accuracy, and responsiveness to the presence or absence of VAR. Data on team performance, informed by metrics such as Elo ratings and outcome measures, were likewise incorporated to ascertain how strategic adjustments or competition dynamics shifted in a VAR-governed environment.

The second dataset focuses on player-level information. This dataset captures individual player performance and behavioural metrics from the pre-VAR and VAR-implemented seasons. By situating each player's records within a temporal framework that extends before and after VAR's adoption, it becomes possible to detect whether this technological intervention influenced disciplinary patterns, skill displays, risk-taking behaviour, or consistency of effort. The integration of player-level data can be important as it may reflect micro-level responses that might not be fully discernible at the match level, this second dataset complements the broader structural insights drawn from the first dataset.

3.3.2 Data Sources and Acquisition Process

In order to build the match-level dataset (Figure 1), the research relied on publicly accessible football statistics repositories. SofaScore provided essential match details, while specialized platforms such as ClubElo offered Elo ratings that capture the evolving competitive strength of each team prior to every match. Odds were obtained from reputable databases such as football data, ensuring that pre-match bookmaker expectations accompanied each fixture prediction.

Since the analytical frameworks hinge on contrasting Premier League and Championship matches, compiling a unified dataset that consistently identified league affiliations, seasons, and match outcomes was necessary.

Building the player-level dataset (Figure 2) required a similar approach. This involved tracking players across multiple seasons and extracting metrics through web scraping

techniques from websites such as FBref. Ensuring these data points were recorded before and after the match events prevents the temporal ordering from being compromised. Pre-match Elo ratings and other contextual measures were matched to player-level observations to maintain a temporal alignment that mirrors real-world decision-making processes.

In consolidating these two datasets, the study implemented a thorough cleaning protocol. Where discrepancies emerged, such as variations in team naming conventions or incomplete player records. We performed different cleaning methods and cross-validated our data to ensure its accuracy, completeness, integrity, validity, timeliness, and uniqueness. This careful curation ensured that by the time modelling occurred, the datasets accurately represented the historical trajectory of English football under both VAR and non-VAR conditions.

3.4 Data Manipulation

3.4.1 Common Preprocessing Steps

Before conducting the estimations, the study integrated these two primary datasets, match-level and player-level datasets, into distinct yet interoperable frameworks. The match-level dataset underwent harmonization procedures to ensure that each observation was uniformly coded, with team identifiers matched to their respective leagues and seasons. Given the temporal structure of the analysis, all matches were classified as pre- or post-VAR while retaining identifiers that allowed cross-referencing with associated referee decisions, odds, and team-level measures. Additionally, data filtering measures were implemented for different phases of analysis with different objectives, where on a referee level, exclusivity of the professional to each league was ensured; on the team's level only teams who have exclusively played for a league will be considered; lastly, on a player level, league exclusivity was also

imperial. This uniform coding ensured that the DiD and event study methods could be applied without ambiguity.

For this specific dataset, the player-level data required alignment and merging with the ClubElo information to incorporate the team strength at the time of each match. The Elo rating for the player's team was extracted and matched to the corresponding match date, specifically using the team's Elo rating as it stood one day before the match occurred. This ensured that the dataset accurately reflected the team's strength leading into the game. Furthermore, metrics such as shots, xG (expected goals), and distance had to be aggregated at the player level per match, as the original records extracted from FBref were detailed at the shot level within each match. By combining temporal consistency with aggregated performance metrics and contextualizing them with team strength, the manipulation stage prepared a dataset capable of robustly testing whether, at the micro-level, players responded to the heightened scrutiny and altered flow of the game that VAR may have introduced.

3.4.2 Feature Engineering for Referee-level analysis

To examine how refereeing behaviour adapted following the introduction of VAR technology, the initial dataset required refinement. This process started with a comprehensive collection of match-level data from both the English Premier League (PL) and the EFL Championship, spanning multiple seasons. Raw measures included fouls, yellow cards, red cards, and penalties, as well as identifiers for the officiating referee and the teams involved.

The variable "Referee_League_Exclusivity" indicates whether a referee is exclusive to the league of which the match is taken place. As well as an additional conditional was added to include referees of which predominantly officiate in one league, instead of full exclusivity.

Certain variables exhibited skewed distributions and frequent zeros. To address these issues, log transformations were applied. Fouls, which rarely appeared as zero, were directly log-transformed. For yellow cards, red cards, and penalties, a $\log(x + 1)$ transformation

handled zero values effectively. These transformations reduced the impact of outliers and ensured a more consistent scale, allowing subtle changes in refereeing patterns to be interpreted proportionally rather than absolutely.

Binary indicators were introduced to distinguish pre- and post-VAR eras, enabling a clear comparison of refereeing decisions before and after the technology's implementation in the PL. A "Premier_League" indicator captured whether a match belonged to the VAR-treated Premier League or the non-VAR Championship. Identifying matches featuring "Top 6" teams added further context, considering potential differences in officiating behaviour for high-profile clubs.

Additionally, a series of descriptive statistics was conducted, where we summarize frequencies of various VAR related incidents in control groups. Visualizations such as bar charts were used to understand raw data patterns.

Through these steps, the dataset was transformed into a structured, well-scaled resource. It enabled a thorough referee-level analysis, revealing how VAR's introduction aligned with shifts in decision-making across different competitive and temporal dimensions.

4 Analysis

4.1 The Impact of VAR on Refereeing Behaviour in Football: A Study on Consistency and Change

On the 11th of November 2024, news broke out that Premier League and EFL Championship referee David Coote, had been suspended over video of “foul-mouthed Klopp [and Liverpool] rant” (Paul MacInnes, 2024). This one video showed the international referee being asked by a man for his opinion on the then Liverpool F.C. manager, where the English referee replies with highly disrespectful remarks not only towards the German manager, but as well as insults towards the club of Liverpool and to scousers alike. Later, on December 9th, 2024, this same referee which was picked as one of the VARs for Euro 2024 with a similarly high regard for his abilities at PGMOL (Dan Sheldon, Philip Buckingham, et al., 2024) (Professional Game Match Officials Board (English Football Association, 2024)) was found to be “in serious breach” of his terms of employment and had been removed from his position with immediate effect, by the refereeing body PGMOL (Paul MacInnes, 2024).

For decades, referees have been criticized and pressured by fans and media alike, getting scrutinized for all decisions made on the field, either being bigger decisions that directly and undoubtedly affect the course of a match by giving away an early red card, or a controversial penalty, but not only this, smaller actions which may snowball into bigger punishments, for example a double yellow card, where the first action was not considered clear by fans and media. No action by a referee, big or small, is overlooked, making some referees be labelled as biased for or against certain teams.

This news comes at a time when Video Assistant Refereeing technology has been under great pressure by controversial decisions, reaching the point of the Premier League having had a vote on the 6th of June 2024 over the continuation of operation of VAR on the league, with

the Premier League clubs voting in favour for the continuation of the use of technology, however, agreeing that major improvements must be made (Premier League, 2024).

VAR technology was implemented as a means of providing a tool to referees to have more reliable decisions, especially on key moments in matches, namely in events such as goals and red cards. David Coote's controversial video has brought up a discussion of if VAR does indeed make the game more reliable and provide an ease of mind to football fans which wish to not be on the receiving end of a controversial refereeing decision. With some reporters and journalists such as Paul MacInnes, from The Guardian, commenting how "David Coote has made a fool of himself – but worse, he has undermined referees" (Paul MacInnes, 2024). Therefore, we wish to come to a conclusion to understand if all controversy surrounding the topic of VAR, is warranted, looking specifically at a study on refereeing decision making.

This study utilizes a comprehensive dataset with matches from before the introduction of Video Assistant Referee, starting from the 2014-2015 season of both Premier League and EFL Championship until the most recent completed season (2023-2024). This will allow for the comparison of refereeing decisions after the implementation of the technology in the PL in the 2019-2020 season.

For an accurate assessment of the impact of the introduction of VAR, two main methods were employed, the Difference-in-Differences (DiD) method which will allow for the comparison of changes over time between treatment group (PL matches) and the control group (Championship Matches) which will allow for trend analysis between treated and untreated groups. Furthermore, an event study analysis was conducted to quantify and visualize how refereeing decisions evolve over time, relative to the VAR implementation year, with this, we can observe whether any shifts in referee behaviour occur since the technology's implementation.

Additionally, a descriptive statistics analysis was implemented on VAR incidents across the three groups (Premier League, Top 6, Non-Top6). These are implemented in raw data and aren't as conclusive as previous data analysis, yet could paint a relevant picture on VAR usage. These results may be used in another, more extensive, analysis to get more significant results, however it could be significant in displaying outputs that may or may not corroborate results of Difference-in-Differences (DiD) and Event Study analysis.

4.1.1 Motivation for the Model

The introduction of VAR technology was intended to enhance the accuracy and consistency of refereeing decisions by providing officials with access to video replays for critical match incidents. However, whether VAR's existence translates into changes in referees' decision-making patterns remains an open question.

From a theoretical perspective, if VAR improves accuracy, we might observe a conversion and standardization of refereeing standards. Alternatively, VAR could introduce new dynamics, such as referees relying too much on video reviews to confirm close decisions, which might alter the frequency and severity of punishment (e.g., giving penalties more confidently if uncertain calls can be reviewed).

Motivated by this, we seek to identify whether VAR's implementation shifted refereeing behaviour in a measurable way. The Difference-in-Differences framework is particularly suitable for this scenario, since it takes advantage of the implementation of VAR in the Premier League but not in the comparable Championship, thereby controlling for time-varying factors that affect both leagues equally.

The event study approach supports this analysis by enabling a more granular look at timing. If VAR's influence on refereeing behaviour manifests gradually, or if adjustments to VAR procedures occur over multiple seasons, the event study design will uncover patterns that a simple before-and-after comparison might miss.

4.1.2 Difference in Difference model Top 6 vs Championship

The model considers four transformed outcome variables: $\log(Fouls)$, $\log(Reds)$, $\log(Yellows)$ and $\log(penalties)$ applying a log or $\log(x+1)$ transformation to address zero counts and skewness. The estimation clusters standard errors at the referee level account for correlation in residuals within referees. The DiD formula takes the following form:

$$Yi,m = \alpha + \beta\,(premier\_league_m \times Post\_VAR_m) + \boldsymbol{\mu}\{Season) + \mu\{HomeTeam\} + \mu\{AwayTeam\} + \mu\{Referee\} + \varepsilon\{i,m\}$$

Here, $(premier\_league_m \times Post\_VAR_m)$ captures the interaction between playing in the Premier League and being in the post-VAR period, while fixed effects $\mu_{Season}, \mu_{HomeTeam}, \mu_{AwayTeam}, \mu_{Referee}$ control for unobserved heterogeneity at multiple levels, ensuring that the estimated treatment effect isolates the VAR-related shifts from other confounding factors.

Results wise on Top 6 vs Championship, concerning fouls, the coefficient on the interaction between premier league and post-VAR is approximately -0.041, with a p-value around 0.087. This is suggestive, though not strictly statistically significant at conventional 5% levels, of a slight reduction in fouls post-VAR in matches involving top-tier clubs or the Championship. Similarly, yellow cards ($\log(Yellows)$) show a coefficient of about -0.075 ($p \approx 0.172$), again not reaching conventional significance.

For red cards ($\log(Reds)$), the estimate is near zero (-0.009, $p \approx 0.569$), indicating no discernible change in red card issuance attributable to VAR implementation in these match contexts. In contrast, the analysis of penalties ($\log(penalties)$) stands out as we can see in Figure 3. The post-VAR interaction is significantly positive (+0.064, $p < 0.01$), suggesting that in matches involving Top 6 clubs, penalties awarded increased after VAR's introduction.

Figure 3 - **Regression Results for log_penalties (Top 6 vs Championship)**

Coefficient	Estimate	Std. Error	t value	Pr(>|t|)	95% CI
premier:Post_VAR	0.064	0.021	2.995	0.003*	[0.022, 0.106]
Observations			4537		
Fixed Effects			Season, HomeTeam, AwayTeam, Referee		
R^2			0.066		
RMSE			0.263		

* Significant at $p < 0.05$.

Penalties are high-impact events, their increased frequency under VAR may indicate that referees feel more confident awarding penalties knowing that controversial calls can be reviewed. This is especially plausible in high-profile or heavily scrutinized matches, such as those involving Top 6 teams, where referees could've been especially reserved for big incidents like this, as if they were to make a wrong call, they would get heavily criticized by media and fans and, worst case scenario, a possible one game suspension from refereeing.

4.1.3 Difference in Differences model for Non-Top 6 vs Championship

Turning to the subset of Non-Top 6 Premier League teams versus the Championship, the patterns differ somewhat. For fouls, as portrayed in Figure 4, the post-VAR interaction is -0.040 (p = 0.050), hovering at the threshold of statistical significance. This suggests a slight decline in fouls called post-VAR for these matches as well, albeit weaker than in the Top 6 subset.

Figure 4 - **Regression Results for log_fouls (Non-Top 6 vs Championship)**

Coefficient	Estimate	Std. Error	t value	Pr(>|t|)	95% CI
premier:Post_VAR	-0.040	0.020	-1.978	0.050*	[-0.079, 0.000]
Observations			3911		
Fixed Effects			Season, HomeTeam, AwayTeam, Referee		
R^2			0.165		
RMSE			0.217		

* Significant at $p < 0.05$.

Yellow cards, red cards, and penalties in this subset show no strong or significant shifts attributable to VAR. For instance, log($Yellows$) is nearly zero (-0.004, p ≈ 0.936), log($Reds$)

is -0.032 ($p \approx 0.138$), and $\log(penalties)$ is 0.008 ($p \approx 0.767$). These results imply that while VAR may have marginally influenced how certain fouls are called, it does not appear to have led to systemic changes in other types of referee decisions for matches not involving the highest-profile teams. Compared to the Top 6 analysis, the absence of a significant increase in penalties is notable, suggesting that VAR's effect on penalty calls may be context-dependent and more pronounced in matches involving prestigious clubs or higher stakes, for reasons mentioned previously. For Non-Top 6 sides, referees don't typically suffer from as great of pressure as when dealing with big fan-bases which also move media coverages, therefore, the pronunciation of penalties is not as noticeable on the Non-Top 6.

4.1.4 Interpreting the Differences Between Top 6 and Non-Top 6 Findings

The presence of a significant positive impact on penalties awarded in Top 6 vs. Championship matches, but not in the Non-Top 6 subset, suggests VAR's influence may interact with the prominence and stakes of the match. High-profile matches draw greater attention, and VAR usage might be more thorough or cautious, leading referees to rely on video evidence to confirm penalty calls they might have hesitated over previously.

For mid- and lower-tier matches, the results are less prominent. While we see a borderline reduction in fouls, the other categories remain stable. This difference could be due to several factors: (1) top-tier matches may feature more contentious penalty-area incidents, since Top 6 sides, generally, have bigger control of games, therefore, spend more time in the opposition's penalty area; or (2) the psychological environment of high-stake matches may lead referees to utilize VAR interventions more decisively, as explained previously.

4.1.4 Difference in Differences model for Premier League vs Championship

Combining all Premier League teams (Top 6 and non-Top 6) and comparing them to the Championship provides a holistic view. For fouls, the interaction estimate is about -0.038 (p =

0.050), as indicated in Figure 5, indicating a modest but statistically significant reduction in fouls called post-VAR across the board.

Figure 5 - **Regression Results for log_fouls (All Premier League vs Championship)**

Coefficient	Estimate	Std. Error	t value	Pr(>|t|)	95% CI
premier:Post_VAR	-0.038	0.019	-1.982	0.050*	[-0.076, 0.000]
Observations			5298		
Fixed Effects			Season, HomeTeam, AwayTeam, Referee		
R^2			0.132		
RMSE			0.228		

* Significant at $p < 0.05$.

For yellow cards and red cards, the estimates remain small and statistically insignificant. The absence of large shifts in bookings is informative, it may suggest that while VAR might refine critical decisions like penalties or goals, it does not uniformly change the standard rate of cautions or expulsions. This could imply that referee calibration on borderline cautions remains stable or that VAR intervention for yellow card incidents is less influential.

Importantly, the results for penalties when all Premier League teams are included mimic the Top 6 pattern. The post-VAR coefficient for penalties is +0.045 ($p < 0.05$) (Table 4), confirming that more penalties are awarded in the VAR era compared to the Championship and pre-VAR periods. This aligns with the notion that VAR primarily affects match-defining decisions rather than minor infractions.

Figure 6 - **Regression Results for Penalties (All Premier League vs Championship)**

Coefficient	Estimate	Std. Error	t value	Pr(>|t|)	95% CI
premier:Post_VAR	0.045	0.020	2.295	0.023*	[0.006, 0.084]
Observations			5299		
Fixed Effects			Season, HomeTeam, AwayTeam, Referee		
R^2			0.054		
RMSE			0.267		

* Significant at $p < 0.05$.

4.1.5 Event Study for Premier League

To complement the DiD results, the event study examines how these effects evolve over time. With this method, we can analyse season-by-season estimates relative to the VAR introduction year. The outcome variables remain the same set of logged measures as for Difference-in-Differences (DiD): $\log(Fouls)$, $\log(Reds)$, $\log(Yellows)$ and $\log(penalties)$. Standard errors are again clustered at the referee level. The event study formula:

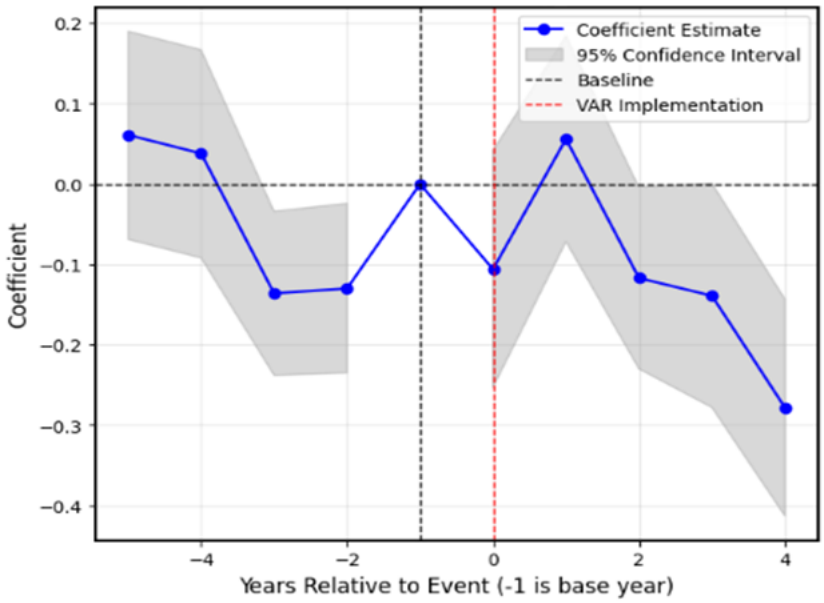
$$Y_{i,m} = \alpha + \sum_{j=-1} \delta_j [\mathbb{1}(relative\_year_m = j) \times premier\_league_m] + \mu_{Referee} + \mu_{Season} + \mu_{HomeTeam} + \mu_{AwayTeam} + \varepsilon_{i,m}$$

Incorporates an interactive term between $premier\_league_m$ and a series of relative-year indicators, using the season immediately prior to VAR as the reference period ($relative\_year_m = -1$).

By including fixed effects for $\mu_{Season}, \mu_{HomeTeam}, \mu_{AwayTeam}, \mu_{Referee}$ the approach accounts for a time-invariant and match-specific unobserved factors, enabling a dynamic view of how the VAR treatment effect emerges, stabilizes, or changes relative to the baseline year (one year before VAR) in the "Premier League vs. Championship" dataset to reveal the trajectory of differences over multiple seasons.

The event study for fouls suggests that while there are fluctuations, the confidence intervals are wide. After VAR introduction, coefficients for fouls eventually become slightly negative, consistent with the DiD results. However, large confidence intervals indicate uncertainty, and one should be cautious in drawing strong conclusions from these noisy patterns.

Figure 7 – **Event Study Plot for log_Yellows Premier League**

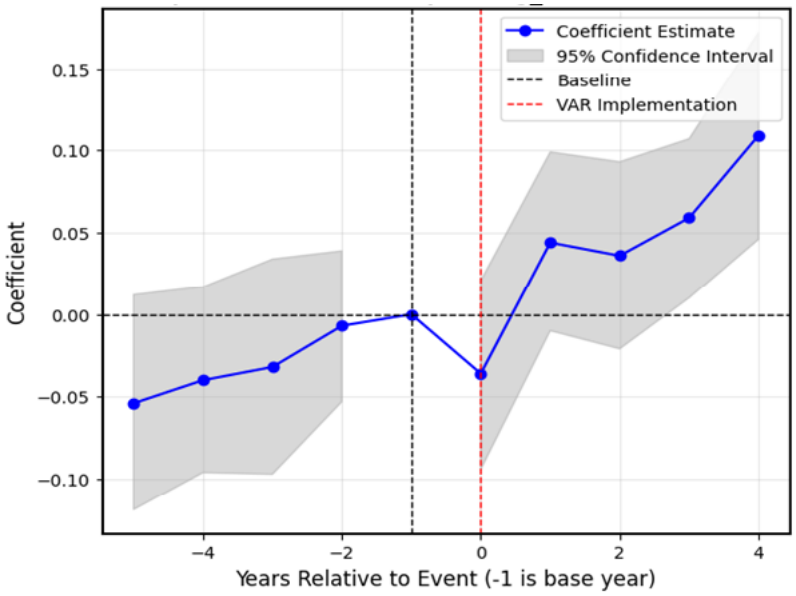


Regarding the yellow cards study, the results oscillate over time, with no clear sustained shift immediately after VAR introduction, however, after a couple of seasons of VAR being in effect, there is a consistent downward trend in the PL compared to the Championship (Figure 7). In fact, the trajectories can suggest that referees and players may have taken some seasons to fully adjust to the response of VAR.

Red cards show no robust pattern in the event study. The estimates and confidence intervals do not reveal a systematic upward or downward trend associated with VAR implementation.

The penalty event study stands out. Initially, as we can see in Figure 8, coefficients around VAR introduction might be modest, but as seasons progress, we observe a trend towards more positive coefficients for the Premier League relative to the Championship. By several years after introduction, the event study plots show a rising trend for penalty awards in VAR-treated matches, supporting the DiD finding of increased penalties in the VAR era.

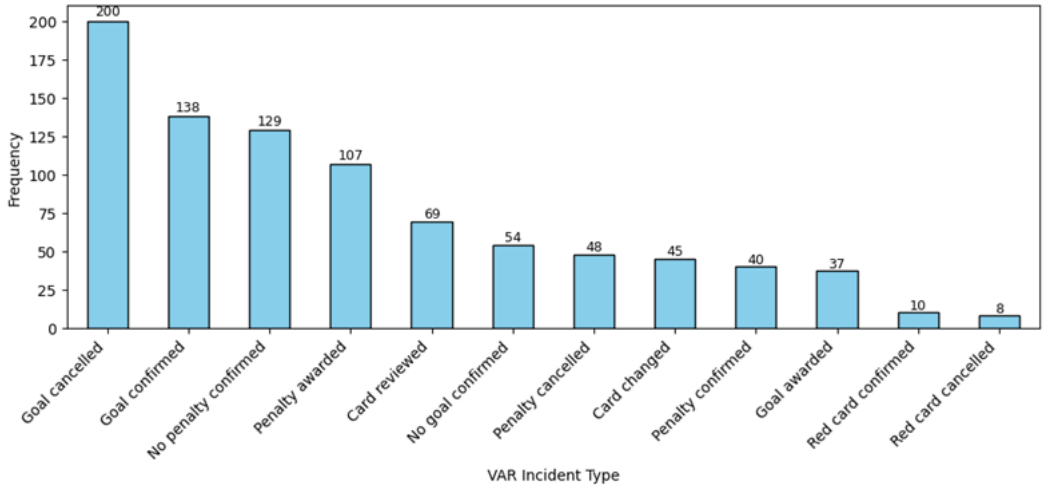
Figure 8 - **Event Study Plot for log_Penalties Premier League**



4.1.6 Descriptive Analysis on VAR incidents

As mentioned previously, the descriptive statistics analysis was implemented on VAR incidents across the three groups (Premier League, Top 6, Non-Top6). These results could be significant in displaying outputs that may or may not corroborate results of Difference-in-Differences (DiD) and Event Study analysis. Here a summarization of frequencies and proportions of various VAR-related incidents for Top 6 and Non-Top 6 Premier League sides, as well as a holistic view of the whole league. Visualizations such as bar charts and event study plots further aid in understanding the raw data patterns.

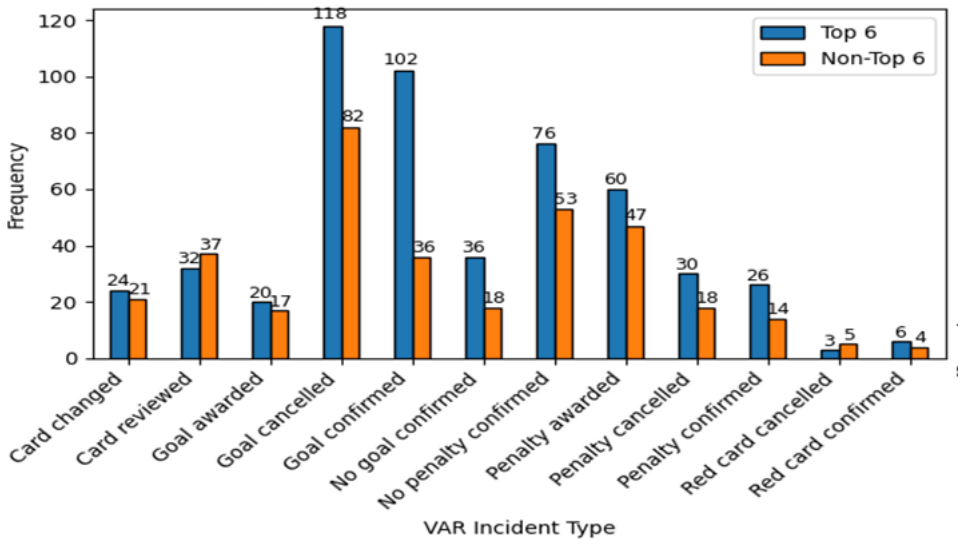
Figure 9 – **Frequency of VAR Incidents (Premier League)**



For the Premier League, on Figure 9, we observe a variety of VAR-related outcomes such as goals cancelled, goals confirmed, penalties awarded, penalties cancelled, and card decisions reviewed. Frequency distributions indicate that “Goal Cancelled” and “Goal Confirmed” are two of the most frequent VAR interventions, this is due to a rule in the Premier League, where all goals scored are reviewed by VAR (Premier League, 2024). More importantly, “No Penalty Confirmed” and “Penalty Awarded” also appear prominently, showing how Video Assistant Referee analyses more crucial events in matches. It is important to note how there are more penalties cancelled than awarded, showing how referees seem to have adapted to the presence of technology in the game, as referees may have an increasing trust in their decisions, as these can be reviewed, this increased confidence may make referees more prone to incorrect callings, but since these can be reviewed, referees may feel a bigger sense of serenity in case of incorrect judgement.

These descriptive statistics align with the regression findings: VAR significantly influences match-changing decisions (goals and penalties) rather than bookings. The relatively lower frequency of card-related VAR interventions, such as card changed or red card confirmed, suggests that while VAR can be used to review potential red cards, it remains less impactful for fouls and card decisions.

Figure 10 – **Frequency of VAR Incidents: Top 6 vs NON-Top 6**



When comparing Top 6 vs. non-Top 6 teams (Figure 10), the frequency and proportion plots show that top-tier matches have a slightly different profile of VAR interventions. Incidents like “Goal Cancelled” or “Goal Confirmed” dominate, showing how referees may be more thorough with Top 6 match events, as big impact events as goals, and these events seem to be analysed more precisely so as to avoid controversies. As we see for Non-Top 6 matches, goals don’t seem to be analysed to the extent “bigger teams” do, providing a base for this assumption. We also see notable frequencies of “No Penalty Confirmed” and “Penalty Awarded”, going on the same trend as goal analysis, where Top 6 seem to get more scrutiny for events which are crucial to the match result.

4.1.7 Overview of VAR Influence on Referees

The econometric evidence and descriptive analyses suggest a nuanced picture of VAR’s impact on refereeing behaviour. While VAR does not drastically alter the overall count of fouls, yellow cards, or red cards, it is associated with a notable increase in penalties awarded in the Premier League after its introduction. This effect is more pronounced in matches involving Top 6 teams, where scrutiny and stakes are higher. Top 6 clubs comprise most fans not only nationally, but also internationally, with the Premier League being one of the most watched football leagues in the world, as well as, using Facebook as a basis for online fanbase, the Top 6 teams with most followers correspond to the Top 6 analysed in our study.

This additional pressure from fans and media could be making referees more thorough with their analysis of match defining moments, such as penalties, to avoid backlash from a possible wrong call.

The event study findings which provide a temporal dimension, show that the penalty awarding difference emerged and persisted over multiple post-VAR seasons, corroborating the Difference-in-Differences (DiD) study. Meanwhile, differences in other disciplinary metrics

remain modest or insignificant, indicating that VAR's influence is most potent in pivotal, outcome-defining decisions, such as penalties.

Descriptive statistics of VAR incidents support these findings, with goal and penalty-related incidents dominating the VAR intervention landscape, particularly in top-tier matches. Being especially thorough with goal analysis for Top 6 matches, rather than Non-Top 6.

Over time, as familiarity with VAR grows, one might expect the football ecosystem such as referees, players, bookmakers, and fans to better anticipate VAR's role, potentially stabilizing outcomes and reducing uncertainty. For now, the evidence points to VAR as a catalyst for more rigorous enforcement of penalty-area infringements, thereby subtly reshaping the balance of power and strategy in elite English football matches.

Reflecting on the David Coote incident introduced earlier, while VAR can help correct errors on the field, it cannot address deeper issues of referee conduct and fairness that arise off the pitch. Coote's remarks highlight that the quality and impartiality of officiating depend not only on the presence of sophisticated review systems, but also on the character and professionalism of those who wield them. VAR may enhance the consistency and precision of decisions, but trust in the system ultimately hinges on the integrity of referees. Thus, the promise of VAR is best realized when technological innovation is paired with a steadfast commitment to ethical standards, transparency, and accountability.

5 Results Discussion

The implementation of Video Assistant Referee (VAR) technology in the major league of England marks a significant change in the sport's outlook of refereeing standards, which affect multiple stakeholders, more directly, examples such as referees, players and teams which are part of this landscape, as well as less direct stakeholders, such as football betting companies.

This discussion seeks to interpret the results and findings presented in the previous analysis of this pivotal time in football. Evaluating the extent of which VAR has achieved its intended objectives and, not only this, if there were new findings associated with each stakeholder previously mentioned. This way, we may find new ways of looking at this technology and what our findings could mean on a broader perspective of, not only, the scale of the sport, but for research purposes.

5.1 The impact of VAR in Refereeing Behaviour

The study of the Impact of VAR on referees' behaviour seems to have led to some primary findings.

Firstly, the analysis seems to indicate that VAR has contributed to a pronounced increase in penalty calls, especially in matches involving the Premier League's Top 6 sides. This may suggest that referees seem to feel more confidence in their decision making, when they know that such decisions can be reviewed and confirmed through VAR technology. This increased scrutiny for higher stake matches associated with top teams in the English top division, rather than mid to lower teams in the competition, seems to have amplified referees' reliance on VAR, to ensure fairness, reducing the likelihood of controversies generated by wrong calls in high stake matches.

Conversely, marginal changes in the issuance of fouls, yellow and red cards post-VAR, seem to indicate how the technology doesn't seem to significantly affect referee's behaviour with smaller calls within a match.

Descriptive statistics seem to corroborate this idea, where its seems that goal analysis gets more scrutiny for Top 6 matches, rather than Non-Top 6, which may show how referees behaviour has changed particularly in higher stakes decisions. Not only that, the bigger scrutiny of bigger sides, may indicate how referees rely more on VAR actions, so as to avoid controversies which is more likely to stem from teams with bigger fan bases, like the Top 6 of England, which move media tabloids.

5.2 Contributions and Future Directions

In the future, this study could open new routes for further academic exploration and analysis of the topics introduced. Future research could delve into different topics such as the psychological factors influencing referee behaviour with the existence of VAR, as well as with different style of players. Additionally, examining VAR's impact across various leagues beyond the English Premier League would enable to determine whether the effects observed in the Premier League are consistent globally or vary significantly according to regional playing styles and cultural contexts.

Moreover, the unpredictability of betting odds suggests new opportunities for the improvement of models that can better account for the influence of VAR on odds. Additionally, the unpredictability of betting odds suggests new opportunities for the improvement of models that can better account for the influence of VAR on odds.

The introduction of VAR shows just how technological advancements can change and directly transform, not only different aspects of the sport, but also have diverse impacts on a strategic and different stakeholders. Like every industry in today's society, sports and, in this case football, will continue to adapt itself to new technology whilst, at the same time, trying to strike a balance between innovation and fairness, tradition and the spontaneous and charming world of the beautiful game.

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