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Effects of the video assistant referee on games in the Bundesliga

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Tom Böttger/Lars Vischer

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Abstract

Referees and their assistants are faced with the challenge of making correct decisions in complex and high-speed game situations. Subconscious bias on the part of referees and the resulting systematic favouring of teams have already been shown many times in sports economics and impair fairness in football. Since the 2017/2018 season, the video assistant referee (VAR) has been used as a technical support for referees to correct clearly incorrect decisions. Based on 2,448 games and 1,880 match situations reviewed by the VAR from the 2019/2020 to 2022/2023 seasons, this study examines whether the VAR is a suitable instrument to counteract the bias of referees on the field. The analyses carried out reveal that the VAR is only able to accomplish this to a limited extent. Even with technical support, human bias remains in the decision-making process.

JEL Codes: D83, D91, L83, Z20, Z21

Keywords: Bias, Decision, Football, Rule, VAR

Auswirkungen des Videoschiedsrichters auf Spiele der Fußball-Bundesliga

Zusammenfassung

Schiedsrichter und ihre Assistenten stehen vor der Herausforderung, in komplexen und in hoher Geschwindigkeit stattfindenden Spielsituationen korrekte Entscheidungen zu treffen. Unterbewusste Voreingenommenheit von Schiedsrichtern und die daraus resultierende systematische Bevorzugung von Teams wurden in der Sportökonomik bereits vielfach nachgewiesen und beeinträchtigen die Fairness im Fußball. Seit der Saison 2017/2018 wird der Videoschiedsrichter (VAR) als technische Unterstützung für Schiedsrichter genutzt, um klare Fehlentscheidungen zu korrigieren. Anhand von 2.448 Partien und 1.880 vom VAR überprüften Spielsituationen der Spielzeiten 2019/2020 bis 2022/2023 wird untersucht, ob der VAR ein geeignetes Instrument ist, um dem Bias von Schiedsrichtern entgegenzuwirken. Die durchgeführten Analysen offenbaren, dass der VAR hierzu nur begrenzt in der Lage ist, denn auch mit technischer Unterstützung verbleibt menschlicher Bias im Entscheidungsprozess.

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Effects of the Video Assistant Referee on Games in the Bundesliga

1. Introduction

Referees make around 137 perceptible decisions during a football match (Helsen/Bultynck 2004). The task requires the quick analysis of complex match situations, which are often characterised by limited visibility and this increases the difficulty of correctly assessing the situation (Lex et al. 2015). Wrong decisions can lead to emotional discussions and influence the outcome of a game as well as the financial interests of interested stakeholders (Colwell 2000 and Kolbinger/Lames 2017). The use of visual material in sport has a long history. For the first time cameras were used in horse racing in 1890 (Kiernan 2019).

In German football, a video assistant referee (VAR) is used since 2017/2018 to improve the fairness of refereeing decisions. A VAR makes it possible to correct certain controversial match situations by reviewing video recordings. As another referee outside the pitch, the VAR monitors critical scenes in slow motion from various camera angles. The VAR provides the referee on the field with additional information via headset in order to make more informed decisions. This is seen both as a means of improving the quality of referee's decisions and as a control tool.

Although there were initial concerns, experienced referees such as Dr. Felix Brych consider VAR to be indispensable (ran.de 2023). Since the introduction of VAR, however, there have been controversial discussions about whether it can reduce incorrect decisions by Bundesliga referees (Spitz et al. 2021). Although the introduction of a VAR has not fundamentally changed football, influences such as a reduction in goals and offside calls and a higher number of red cards have been identified (Spitz et al. 2021). Although criticism such as the negative influence on the flow of the game could only be empirically confirmed to a limited extent (Errekagorri et al. 2020), the lack of transparency in decisions leads to a negative attitude and lower acceptance among the public (Winand et al. 2021).

Sport provides an ideal environment to test economic theories (Bradbury 2019). In sports economics, the behaviour of referees was studied before the introduction of aVAR. Various factors were identified that influence referees in their decisions and can cause wrong decisions, such as favouring home teams and supposedly stronger teams, social pressure in the stadium and compensation for previous decisions (Nevill et al. 2002, Schwarz 2011 and Lago-Peñas/Gómez-López 2016). These factors are referred to as referee bias. While the in-

fluence of VAR on general factors such as goals, offside positions and red cards has been investigated, the influence on existing referee bias has been little researched. Therefore, the research question of this study is: *To what extent does the use of the VAR change the influence of referee bias on games in the German professional football leagues?*

Based on 2,448 games from the first and second Bundesliga, this study investigates whether a VAR helps to reduce systematic problems with refereeing decisions and minimises the influence of bias on the course of the match. Data from the live tickers of the four seasons from 2019/2020 to 2022/2023 were analysed by systematically filtering out VAR interventions using a Python 3 script. The aim is to advance the debate on the VAR and his role in modern professional football. In the following, we will first create the conceptual framework (Chapter 2), then derive hypotheses (Chapter 3) and describe the data basis (Chapter 4). We will empirically test our hypotheses (Chapter 5), discuss the results (Chapter 6) and conclude (Chapter 7).

2. Conceptual Framework

2.1. Principal-Agent Theory

The principal-agent theory of new institutional economics deals with the problems that arise in relationships between principals and contractors due to unequal information and incentives. According to Jensen and Meckling (1976), the principal (client) hires an agent (contractor) to fulfil an order. Normally, the principal is modelled as risk-neutral and the agent as risk-averse (Jost 2001). Through the contract, the principal transfers the decision-making power and the executive function to the agent (Jensen/Meckling 1976). Both parties contractually commit themselves to performance and consideration (Alparslan 2006). As both parties strive to maximise their own utility, opportunism can be assumed, which is why the agent does not always act in the interests of the principal but often maximises his own utility regardless of the principal. To prevent this, the principal should set incentives so that the agent acts in the interests of the principal, too (Jensen/Meckling 1976). Examples of such relationships are those between employer and employee, seller and buyer or doctor and patient. The relationship between the German Football Association (DFB) and referees can also be regarded as a principal-agent relationship (Sutter/Kocher 2004 and Frick et al. 2009).

Principal-agent theory identifies problems that result from information asymmetry between the client and contractor. These are categorised as the problem types hidden characteristics,

hidden action and hidden information (Jost 2001). However, solving these problems causes agency costs (Jensen/Meckling 1976). Hidden characteristics refer to properties of the agent that exist before the contract is concluded, such as performance capacity and individual preferences (Jost 2001). Hidden action describes the lack of information about the agent's actions and the unclear impact of external factors on the outcome (Alparslan 2006). Hidden information refers to asymmetric information about external factors due to the principal's distance from the task fulfilment (Alparslan 2006).

In first and second Bundesliga football, the problem of hidden characteristics is addressed by the prior appointment of referees at amateur level and the fulfilment of fitness and knowledge tests before reaching the professional level (Frick et al. 2009). This study addresses the problems of hidden action and hidden information that can lead to moral hazard (Jost 2001). Agents have room for manoeuvre, which can lead to performance restraint and conflict with the interests of the principal (Klinkert 1999 and Alparslan 2006). Financial incentives show no correlation with performance improvement of the referee (Frick et al. 2009), therefore alternative instruments are needed to align the interests of the principal and agent. Monitoring systems are an option (Kiener 1990), but they may impair the efficiency of the relationship (Ebers 2001). Technical tools such as video cameras could reduce costs and improve monitoring and thus performance (Tabak/Smith 2005 and Chen/Ross 2007), but they could also increase mistrust and reduce the desired effect (Falk/Kosfeld 2006).

Since the interests of the DFB and the referees do not always coincide, the DFB should try to design the referees' incentive structure in such a way that they avoid opportunistic behaviour and minimise their error rate in their own interest (Frick et al. 2009). One instrument for this is the control of dubious decisions through video review (Frick et al. 2009). The introduction of a video assistant in sport offers the opportunity to observe the reactions of professional referees to the new monitoring system. Holder et al. (2022) investigated the effects of VAR as a monitoring tool for football referees and its influence on known inefficiencies in refereeing decisions. In addition to traditional monitoring, the study revealed further effects in line with the principal-agent theory: Referees benefit from the use of a VAR because their reputation is protected and the responsibility for errors is reduced (Holder et al. 2022).

The DFB wants referees to officiate games impartially and to have little influence on the result. A well-known case is the betting scandal surrounding referee Robert Hoyzer in 2005, who caused the elimination of Hamburger SV from the DFB Cup through deliberately wrong decisions (Frick et al. 2009). Although deliberate wrong decisions are rare, various physical

and psychological effects can lead to unintentional errors that are contrary to the interests of the principal.

2.2. Stakeholder Theory

According to Freeman (2010), stakeholders are all persons or groups that are influenced by or can influence the goals of an organisation. Stakeholder theory extends the shareholder value approach by focusing on the needs, goals and motivations of all interaction partners in an organisation (Freeman 1984). This is in contrast to the neoclassical approach that a company and its management are only committed to shareholders and thus to the goal of profit maximisation (Argandoña 1998). Mitchell et al. (1997) emphasise that the characteristics “power”, “legitimacy” and “urgency” determine the interests of a stakeholder. There are three main lines of research on stakeholder theory. Descriptive research describes the actual handling of stakeholder interests by those responsible, normative research deals with the ideal handling of these interests, and instrumental research examines stakeholder management in connection with the achievement of an organisation’s objectives (Donaldson/Preston 1995).

Stakeholder theory identifies four basic criteria for defining stakeholders. Firstly, there must be a connection to the organisation, and secondly, there must be a clearly definable interest (Starik 1994). In the sports context, both enthusiastic fans and disinterested local residents are potential stakeholders, as they are affected by sporting events (Friedman et al. 2004). Thirdly, it is sufficient to be in the vicinity of the organisation or to have a unilateral interest (Donaldson/Preston 1995). Fourthly, stakeholders do not necessarily have to be natural persons (Starik 1994).

In German football, the licensors (DFB and DFL, Deutsche Fußball Liga GmbH) have various stakeholders, such as fans, investors, clubs and politicians. The objectives of these groups can vary greatly and pose challenges for licensors (Friedman et al. 2004). Radical changes in sport can trigger conflicting objectives, as organisations may struggle to meet the needs of stakeholders after the change (Thompson/Parent 2021). Stakeholders can react positively or negatively to change, e.g. with acceptance, resistance or ambivalence (Peachey/Bruening 2011 and Wagstaff et al. 2016). In order to resolve conflicting goals efficiently, it is important to prioritise stakeholders. Freeman et al. (2007) distinguish between primary and secondary stakeholders, with the former ensuring the survival of the organisation and the latter influencing the organisation but not endangering or ensuring its survival (see also Clarkson 1995). The assignment of stakeholders to primary or secondary groups depends on the specific situa-

tion of the organisation (Freeman et al. 2007). The introduction of a VAR brings changes for stakeholders in professional football. According to Kolbinger and Knopp (2020), fans as an important stakeholder group show a predominantly negative attitude in a Twitter sentiment analysis on the English Premier League. Other stakeholders such as associations (e.g. FIFA) and football clubs must utilise the advantages of a VAR without coming into conflict with the fans (Märtins et al. 2023).

2.3. Technology Acceptance Model

The Technology Acceptance Model (TAM) by Davis et al. (1989) explains the user behaviour of computer technologies. The third version (TAM3) reflects the current state of research (Venkatesh/Bala 2008). The TAM is based on the Theory of Reasoned Action (TRA), which states that a behavioural intention is necessary for behaviour (Ajzen/Madden 1986). The willingness to use a technology is primarily influenced by two variables, the perceived usefulness and the perceived ease of use (Davis 1989). In the second version of the TAM, additional factors such as social pressure, status, voluntariness, experience, job relevance, output quality and clarity of results are added (Venkatesh/Davis 2000). The third version of the Technology Acceptance Model (TAM3) contains six additional constructs that influence perceived ease of use. These are self-efficacy expectation, facilitating conditions, concerns, technology enjoyment, technology-specific enjoyment and objective ease of use (Venkatesh/Bala 2008).

A further development of the TAM is the Unified Theory of Acceptance and Use of Technology (UTAUT), which explains user intention with variables such as performance expectancy, effort expectancy, social influence and facilitating conditions. These are moderated by experience, voluntariness of use, social gender and age (Venkatesh et al. 2003). In traditional industries such as sport, the acceptance of new technologies such as the VAR is crucial to their success (Schelling/Robertson 2020). Lack of acceptance is a key reason for the ongoing debate about the VAR (van den Berg/Surujlal 2020). Players, clubs and fans are among the stakeholders who are directly affected by the technology and whose acceptance is crucial (Märtins et al. 2023). The way decisions are made also influences the acceptance of the VAR (van den Boos 2005).

2.4. Referees in Football

2.4.1. Role of the Referee in Football

In most sports, a referee is required to ensure compliance with the rules. In football an impartial referee conducts the match in accordance with the rules (DFB 2023). The referee can penalise players who break the rules, for example through verbal warnings, yellow or red cards (Frick et al. 2009). Refereeing decisions often favour one team and disadvantage the other (Märtins et al. 2023). The performance of the referee directly influences the success of players and clubs as well as their social and economic goals (Spitz et al. 2021). It is in everyone's interest that refereeing decisions influence the course of the game as little as possible (Helsen et al. 2019). Ideally, no one should question the objectivity and correctness of refereeing decisions (Tamir/Bar-eli 2021).

The referee is supported on the pitch by assistants and together they form the refereeing team (DFB 2023). Their performance depends on physical and cognitive factors, which have already been the subject of numerous studies. The physical strain can push referees to their limits (Armenteros et al. 2018), which led to age limits for referee licences (Sportschau.de 2023a). Following a lawsuit, this limit was relaxed and now only serves as a guide (Sportschau.de 2023b). Studies on cognitive factors show that inaccuracies in refereeing decisions can be explained by bias (Helsen et al. 2019). To investigate bias, an objectively correct decision must be defined. This requires the precise application of the rules as well as game management to ensure the flow of the game (Bar-Eli et al. 2011). These requirements can lead to conflicts of interest, e.g. when referees are reluctant to show cards early to avoid escalation (Tamir/Bar-eli 2021). Weighing up these aspects is a challenge and makes it difficult for referees to make objective decisions (Tamir/Bar-eli 2021). In football games, there are situations such as offside or goals that can be assessed objectively, while referees make subjective decisions in other areas (such as stoppage time, fouls, cards) because the rules leave room for interpretation. Players therefore have an incentive to influence the referee in order to gain an advantage (Tamir/Bar-eli 2021). These subjective decisions have a significant influence on the outcome of the game and can conflict with the interests of stakeholders. Nevertheless, to ensure objective decisions, referees must be comprehensively trained, both professionally and pedagogically (Holder et al. 2022).

The main task of assistant referees is to recognise offside situations, but this is made more difficult by the movements of the game and leads to errors. According to Oudejans et al. (2002), assistant referees are not optimally positioned in 86.5 % of offside decisions. The so-

called flash-lag effect partly explains the sub-optimal positioning, whereby the assistants perceive players before their actual position (Helsen et al. 2007). This often occurs in situations where forwards and defenders are moving in opposite directions (Baldo et al. 2002). In offside situations, assistant referees only have 250-300 milliseconds to calculate an imaginary offside line, which leads to a high error rate (Sanabria et al. 1998; Tamir/Bar-eli 2021). At 12.7 %, this error rate is just below that of the main referee (14.2 %). The position of the main referee influences the quality of his decision, while the distance of the linesman from the ball is irrelevant to his quality. It is more common for a linesman not to recognise an offside situation than to incorrectly indicate it (Mallo et al. 2012). As offside situations can strongly influence the outcome of a match, these decisions are particularly important (Armenteros et al. 2018).

Decision-making for referees has become more challenging as the sport has evolved. The increased speed of play and improved athleticism of players make it difficult to correctly assess situations in real time (Han et al. 2020). Additional challenges arise from visual obstructions and other factors that can interfere with objective decision-making (Tamir/Bar-eli 2021). The increased speed of play also requires a higher level of fitness for referees and assistants to position themselves optimally (Krustrup et al. 2002). Referees are assessed not only on their physical fitness and positioning, but also on their knowledge of the rules, body language, game control and cooperation with assistants, which determines their promotion to higher leagues (DFB 2015).

The use of technology can help to reduce the inaccuracies and bias of referees and thus increase fairness in sport (Tamir/Bar-eli 2021). With the changing media landscape, where millions of viewers are equipped with still images, replays and different perspectives, the support of technological tools is inevitable (Collins 2019). Despite the introduction of the VAR, it remains important that referees make the most accurate decisions possible to minimise the use of the VAR (Spitz et al. 2021).

2.4.2. Bias of Referees

The rules of football allow for a certain degree of interpretation, which means that different referees can make different decisions in similar situations. One hundred per cent accuracy in decision-making is not achievable for referees, regardless of aids (Spitz et al. 2021). Erroneous decisions can arise if the referee does not see the situation clearly, does not fully consider the context or is influenced by unconscious bias. Various studies have shown that different

factors can influence the referee, including the stadium atmosphere, previous decisions in the game, the reputation of the teams or players and verbal comments made by players after a foul (Plessner/Betsch 2001, Jones et al. 2002, Nevill et al. 2002, Garicano et al. 2005 and Lex et al. 2015). The home bias in football has been analysed in numerous studies and identified as a multifactorial phenomenon. Explanations for this include factors such as travelling time (Pace/Carron 1992), increased testosterone levels at home games (Neave/Wolfson 2003), advantages of the familiar environment (Loughead et al. 2003) and the possible influence of a referee bias (Nevill et al. 2002).

The atmosphere and fan chants in the stadium can influence the referee bias in favour of the home team, as studies have shown (Nevill et al. 2002). This bias can also be seen in decisions on injury time, penalties and goals in the Bundesliga (Dohmen 2008). The psychological hurdles for referees to decide against the home team are high, which can lead to a bias in favour of the home team (Balmer et al. 2007). The absence of spectators in “ghost games” during the coronavirus pandemic has shown that the home bias is weakened without an audience (Dilger/Vischer 2022). Despite the same number of home and away games in a season, the home bias is not equally pronounced for every team (Peeters/Ours 2021). In addition, some referees are more susceptible to influences than others, so the advantage is not the same for every game (Page/Page 2010).

Studies have shown that referees have a bias with regard to stoppage time and in close games. If the home team is behind, more stoppage time tends to be granted (Garicano et al. 2005). In addition, referees often favour the supposedly stronger team in close games (Lago-Peñas/Gómez-López 2016). The reputation of a team and a referee’s knowledge of the team have a psychological influence on their decisions. In a study by Jones et al. (2002), a group of referees that had the information that the team is aggressive were significantly more likely to show yellow and red cards in comparable situations. These referee biases contradict the ideal of the referee as an impartial match official who applies the rules of football objectively (DFB 2023). Football associations should therefore take measures to counteract this systematic favouritism. One such instrument for improving fairness could be the VAR.

2.4.3. VAR in Football

The use of (technical) aids in sport can increase fairness in the game and reduce human inaccuracies caused by individual referee perceptions (Oudejans et al. 2002). These aids can be divided into three categories: those that support the referee, those that replace decisions (such

as goal-line technology) and those that help to enforce the rules (such as the free-kick spray) (Collins/Evans 2011 and Kolbinger/Lames 2017). According to Lago-Peñas et al. (2019), video evidence falls into the first category and was introduced to football in 2018. There are four situations in which the VAR may intervene: goal decisions (including offside), penalty decisions, red cards (excluding yellow-red) and administrative errors, such as cautioning the wrong player (DFB 2023).

In order to use the VAR, a video review room and a referee video area are required (Chatrath 2022). The video footage of the match is continuously monitored in the video review room, with the main VAR being supported by an assistant VAR and a replay operator, who together form the video match officials (DFB 2023). If the referee makes a clearly incorrect decision, the video assistant intervenes and informs the referee on the pitch via headset (Lago-Peñas et al. 2019). Fact-based decisions such as offside are corrected directly (VAR-only review), while in situations where there is room for interpretation, the referee may review the match scene on a monitor on the sidelines after the VAR's advice and then makes a decision (on-field review, OFR) (Spitz et al. 2021). The technology is intended to reduce error rates, promote fairness in sport and increase spectator confidence. Although the referee ultimately retains the decision-making power, the introduction of the VAR can be seen as a technological innovation to monitor the performance of referees (Holder et al. 2022). The academic literature on the topic of VAR can be categorised into four thematic areas: effect of introduction on the game, attitude measurement, impact on fairness and technology (Chatrath 2022).

Various studies have investigated the effects of the VAR in football, with the results varying from country to country. Lago-Peñas et al. (2019) show a reduction in offside whistles, fouls and yellow cards in the German Bundesliga and Italian Serie A following the introduction of the VAR. The use of the VAR also leads to longer injury time in the first half. A change in the players' incentive structure is cited as the reason for this, as aggression in tackles decreases with awareness of the use of the VAR (Lago-Peñas et al. 2019). Before the introduction of the VAR, strikers were more likely to risk an offside position as the assistant was less likely to recognise them. Similar effects were also observed in the Chinese Super League (Han et al. 2020). Spitz et al. (2021) found an increased number of penalties and red cards as well as a lower number of goals due to the more reliable recognition of offside positions. In the future, players could possibly act more cautiously at the offside line, which could lead to an increase in goals.

Studies on the acceptance of VAR show mixed results. Han et al. (2020) found that the use of a VAR in the Chinese league increases the level of competition and improves the fan experience. In contrast, a study by Märtins et al. (2023) showed that a lack of transparency in VAR decisions can lead to a negative fan experience in the stadium, while TV viewers are less affected. Similar results were confirmed by Scanlon et al. (2022) for the English Premier League. The transparency of VAR decisions is therefore a decisive factor for the acceptance of this technology.

According to Spitz et al. (2021), the introduction of the VAR has led to a significant improvement in the accuracy of referees' decisions. Clear situations were correctly assessed in 92.1 % of the initial assessments, while the VAR increased this rate to 98.3 %. Approximately 6.5 % of the reviewed decisions were defined as grey areas, in which 44 decisions were adjusted following VAR reviews (Spitz et al. 2021). Despite the VAR, 100 % accuracy remains unrealistic as some situations are ambiguous and human decisions can be influenced by bias (Spitz et al. 2021). Holder et al. (2022) found that the use of VAR reduces the home bias in refereeing errors. This is tested in the following empirical chapters.

The technology category examines how technological aids influence decision-making. Spitz et al. (2018) argue that referees judge slow-motion scenes more harshly, while Mather and Breivik (2020) find no influence of replay speed.

2.4.4. Critical View of the VAR

The introduction of the VAR in football was intended to increase fairness, but it has been heavily criticised. Chatrath (2022) describes the use of VAR as a trade-off between fairness and quality of play. The review of match scenes interrupts the flow of the game (Svantesson 2014 and Winand et al. 2021). In addition, Chatrath (2022) found in his study that VAR decisions are not transparent and that correcting offside decisions is often perceived as questionable.

In order to maintain the flow of the game, Lago-Peñas et al. (2020) suggest limiting communication with the VAR and reducing OFR. The actual playing time in football games is only around 52 minutes (Castellano et al. 2011 and Augste/Cordes 2016), as the game is often interrupted by free kicks, throw-ins and other interruptions (Augste/Cordes 2016). However, these interruptions give the impression that play is continuing (Spitz et al. 2021). VAR reviews last a median of 62 seconds for OFR and 15 seconds for VAR-only reviews (Spitz et al. 2021). Although this seems short compared to the total playing time, players have to wait idly

during this time, which reinforces the impression of unnecessary interruption (Errekagorri et al. 2020). Improved communication about the VAR in the stadium and on TV could alleviate this impression.

The introduction of technical aids often raises the expectation that decisions are always objectively correct (Collins 2019). However, the complexity of the situations assessed by the VAR varies. Offside can be clearly and objectively assessed, while red cards usually concern clear fouls. Penalty decisions are more complex as they often involve multiple players in dynamic situations, such as handball, which leads to controversial discussions (Holder et al. 2022).

The perceived transparency of VAR decisions varies between TV viewers and stadium spectators (Mártins et al. 2023). Fans often perceive referee support systems negatively (Winand et al. 2021) and their attitude towards a VAR strongly depends on their emotional interest in the sport (Winand et al. 2021). The low acceptance of the VAR could be due to the conservative nature of the sport and resistance to innovation (Tamir/Bar-eli 2021). Critics of VAR warn of a possible weakening of the referee's authority on the pitch, as referees could potentially rely too much on the technical aid. This could reduce the confidence of players and spectators in the referee's primary decisions and diminish their self-confidence, which could have a negative impact on their decision-making. The introduction of video refereeing also entails additional costs for the league and clubs, which must be weighed against potential benefits in efficiency and fairness (Han et al. 2020).

3. Hypothesis Development

With the help of the conceptual background and our own considerations, three overarching hypotheses are formulated below. The aim is to examine whether the VAR can help to compensate for systematic referee bias.

As has already been shown in various studies, there is an advantage for the home team in professional football, which results from factors such as increased performance, the motivating effect of spectators (Neave/Wolfson 2003) and the influence of the referee (Dohmen 2008) due to the atmosphere and social pressure in the stadium (Nevill et al. 2002). Weaker teams could benefit from refereeing errors because they increase the influence of the element of chance on the outcome of a football match and thus reduce the probability that the stronger team will win a match (Wunderlich et al. 2021). However, according to Lago-Peñas and Gómez-López (2016), referees tend to subconsciously take the playing strength of the teams

into account when making decisions, so that the supposedly stronger team benefits. According to Schewe et al. (2010), there is a clear favouring of the FC Bayern Munich in the German Bundesliga due to incorrect decisions by referees. As the VAR should not be exposed to these psychological factors because he operates away from the game, the first hypothesis follows, which is subdivided into hypotheses 1a and 1b:

H1: The use of the VAR weakens the existing bias of the referees.

H1a: The use of the VAR weakens the existing bias of the favoured team, so that weaker teams benefit from the use of the VAR.

H1b: The use of the VAR attenuates the existing and referee-related home bias, so that away teams benefit from the interventions of the VAR.

According to the principal-agent theory, monitoring is used to counteract information asymmetries and the hidden characteristics problem (Kiener 1990). According to this theory, the VAR should be used as a monitoring tool, especially for inexperienced referees, and correct incorrect decisions. Pollard and Gómez (2009) assume that experienced referees are less susceptible to social pressure situations than inexperienced referees. Pressure situations for referees can arise primarily from spectators, but also from the score, as the decision may have greater sporting consequences if the score is close. Boyko et al. (2007) even demonstrated a positive influence of refereeing experience on the number of fouls whistled in favour of the away team and thus a reduced home bias. With regard to the VAR, the second hypothesis is derived from this, which is again subdivided into hypotheses 2a and 2b:

H2: The difference in experience between the referee and the VAR influences the change rate of the VAR.

H2a: Experienced referees are less often corrected by the VAR than inexperienced referees.

H2b: Experienced VARs correct more often than inexperienced VARs.

4. Data

In order to investigate the effects of the introduction of VAR on fairness in German professional football, the VAR interventions in the first and second Bundesliga from 2019/2020 to 2022/2023 were analysed. Although the VAR has been introduced already in the 2017/2018 season, the reviews have only been fully documented since 2019/2020 and from this season

the VAR is only established in the second Bundesliga. Data was collected from the official Bundesliga website using a Python 3 web scraping programme. Details of the VAR decisions such as situation, review and final decision were recorded. A data frame was created containing match day, match minute, referee, home and away team. A match ID was generated to uniquely identify games. Due to a website error message for certain teams in the 2021/2022 season, the VAR decisions of these teams were collected manually.

In order to evaluate the influence of the VAR, the Python code was adapted to include the subsequent text block of the live ticker in an Excel table in addition to the VAR events. This made it possible to assess whether the home team or the away team benefited from the VAR. Around two thirds of the situations could be clearly interpreted. For the remaining situations, the live tickers were checked manually, if necessary also from other websites such as kicker.de. In addition, data from football-data.co.uk was used to take into account detailed information about the match result, the course of the match and the betting odds. The data sets were linked together. The experience of the referees was collected manually via transfermarkt.de and kicker.de. Performance data on the referees was also obtained from whoscored.com. The data for the times of the goals were taken from the match overview on the DFB.de website.

The data set comprises 2,448 games from the first and second Bundesliga, of which 1,880 VAR reviews were documented. At least one VAR review took place in 1,101 games, while 1,147 games ended without a VAR review. In 716 reviews, the original referee decision was changed, while in 1,164 reviews the decision remained in place. All data operations and statistical analyses were performed in Stata.

5. Results

5.1. Descriptive Statistics

The data set used comprises $N = 2,448$ games from the first and second Bundesliga in the seasons 2019/2020 to 2022/2023. In total, the VAR reviewed 1,880 situations in these games. This results in 0.768 reviews per match. In 716 situations, the intervention of the VAR led to a change in the original refereeing decision, i.e. there were 0.319 corrections per match. Table 1 shows the descriptive statistics for the variables used.

	N	Mean	Std. Dev.	Min.	Max.
ChangebyVAR	1,880	.381	.485	0	1
Profiting_Team	716	.515	.500	0	1
DiffB365	1,880	-1.299	3.976	-27.94	14.86
Playtime_Minute	1,880	49.581	26.283	1	101
Spectator	1,880	19501.84	20524.6	0	81365
Diffgoals	1,880	.080	1.283	-6	7
Goalpressure	1,880	.797	.401	0	1
AgeH	1,880	37.2633	4.922	22	47
H1Appaerences	1,361	12.643	3.233	1	18
H2Appaerences	1,818	6.875	2.160	1	12
H1Foulspg	1,361	24.187	2.248	16	28.8
H2Foulspg	1,818	25.625	3.192	16.89	34.83
H1LigaNote	1,389	3.044	.324	2.24	4
H2LigaNote	1,815	2.943	.461	1.61	4.88
AgeV	1,879	37.498	23.882	22	53
V1Appaerences	979	11.454	3.761	1	18
V2Appaerences	1,466	6.486	2.486	1	12
V1Foulspg	979	24.377	2.487	16	29.71
V2Foulspg	1,466	26.509	3.187	19.25	34.83
V1LigaNote	1,000	3.090	.333	2.24	4
V2LigaNote	1,461	3.020	.443	1.67	4.88

Table 1: Descriptive Statistics for All Used Variables

ChangebyVAR and Profiting_Team are both binary variables. ChangebyVAR is coded with 0 if no change was made by the VAR in the review. With Profiting_Team, the away team benefits from 0 and the home team from 1. DiffB365 is the difference in betting odds between the home and away team in order to identify a favourite. The negative sign in the variable indicates the expected home bias. Playtime_Minute, Spectator and Diffgoals show the minute of the VAR's intervention, the number of spectators and the difference in goals at the time of the VAR's intervention. Goalpressure is again a binary variable that assumes the value 1 for goal differences of -1, 0 and 1. This means that a tight game situation prevails due to the goals. As a frequently used empirical value, we will also include the age of the referee AgeH later on. The variables HAppaerences show the assignments of the main referee in the previous season. The use of the previous season indicates a certain amount of experience, but also preserves topicality and thus takes into account the constant rule changes in football, so that we do not go back further in time here. This is shown for matches in both the 1st and 2nd Bundesliga, as some of the referees are used in both leagues. HFoulspg describes the fouls whistled per

match in the previous season in order to have an indicator of whether the referee whistles frequently or allows more actions to go through. HLigaNote refers to the average grade awarded by kicker.de in the previous season in both leagues. The variables marked with a V show the same key figures for the VAR used. Various review situations were analysed in the live tickers on www.bundesliga.com/de, with offside positions (40.59 %), fouls (22.07 %) and handball (14.95%) being reviewed most frequently, as can be seen in Table 2. These situations also led most frequently to a correction of the original referee decision. Table 2 also shows in the R/A column whether the referee or assistant referee was responsible for the decision and in the 0/1 column whether there was any room for judgement in the decision. The CR indicates how many decisions of all corrected decisions relate to the respective game situation. Of 716 corrected decisions, approximately 37 % were offside decisions. CR% in contrast describes the correction rate per decision. Approximately 35 % of 763 offside decisions were corrected.

Type of Review	R/A	0/1	Review		Correction Rate (CR)		CR %
			Total	%	Total	%	%
Offside	A	0	763	40.59 %	266	37.15 %	34.86 %
Foul play	R	1	415	22.07 %	176	24.58 %	42.41 %
Handball	R	1	281	14.95 %	97	13.55 %	34.52 %
Foul in build-up	R	1	79	4.20 %	40	5.59 %	50.63 %
Handball when scoring goal	R	1	76	4.04 %	26	3.63 %	34.21 %
Handball in build-up	R	1	68	3.62 %	25	3.49 %	36.76 %
Offside in build-up	A	0	43	2.29 %	12	1.68 %	27.91 %
Offence inside	R	0	29	1.54 %	11	1.54 %	37.93 %
Foul when scoring goal	R	1	28	1.49 %	11	1.54 %	39.29 %
Assault	R	1	19	1.01 %	7	0.98 %	36.84 %
Offence outside	R	0	18	0.96 %	13	1.82 %	72.22 %
Ball out of bounds	A	0	16	0.85 %	5	0.70 %	31.25 %
Foul from last player	R	1	12	0.64 %	6	0.84 %	50.00 %
Ball in goal	R	0	10	0.53 %	5	0.70 %	50.00 %
Handball goal prevention	R	1	5	0.27 %	3	0.42 %	60.00 %
Illegality at the 11m	R	1	4	0.21 %	2	0.28 %	50.00 %
Illegality in build-up	R	1	3	0.16 %	1	0.14 %	33.33 %
Prevention of goal opportunity	R	1	3	0.16 %	3	0.42 %	100.00 %
Ball out of bounds in build-up	A	0	3	0.16 %	2	0.28 %	66.67 %
Gross unsportsmanlike action	R	1	2	0.11 %	2	0.28 %	100.00 %
Illegality at the 11m GK	R	1	2	0.11 %	2	0.28 %	100.00 %
Interference by third parties	R	1	1	0.05 %	1	0.14 %	100.00 %
Total			1,880		716		

R/A = Decision Maker: R = Referee & A = Assistant; 0/1 = Margin: 0 = No & 1 = Yes; CR: Correction rate; CR%: Correction rate per decision.

Table 2: Frequency of VAR Checks and Corrections

5.2. Bias of the Referees

Table 3 shows a logistic regression with the dependent variable *ChangebyVAR*. This means that a decision situation actually led to a change due to the intervention of the VAR. In Model 1, the full model is analysed and in Model 2 only the matches that took place under the restrictions of the Covid-19 pandemic are considered in order to filter out what effects an empty or barely filled stadium has on decision-making. In Model 3 and Model 4, the 1st and 2nd division matches are considered separately in order to be able to determine any differentiation in the performance level of the referees and in Model 5 only the decisions that fall within the referee's area of responsibility are taken into account. Model 6 uses the allocation in Table 2 to analyse the decisions that are subject to a certain degree of discretion.

It is noticeable here that both the number of spectators and the difference in goals have a significant influence on the change caused by the intervention of the VAR in the first model. It can be seen that the more spectators there are, the higher the probability of a correction by the VAR and thus of a previously incorrectly assessed situation by the referee. The goal difference has a negative influence on the correction by the VAR and also plays a role in the referee's decision. It is interesting to note that these effects do not occur in Models 3 and 4. In Model 5, the spectators have a significant influence on the decisions of the main referee in isolation. No significant correlations can be found in Model 6. In Model 4, the minute of the game in which the decision is made has an influence. It is also interesting to note that the difference in betting odds does not appear to have a significant influence.

In Table 4, the analysis follows the same scheme as the logistic regression shown in Table 3, but this time the dependent variable is *Profiting_Team*. This binary variable only considers the observations in which the intervention of the VAR actually led to a change in the previously assessed situation. It assumes the value 0 if the visiting team benefits from the change and the value 1 if the home team benefits. It is striking that in all models the difference in odds, the minutes played and the spectators do not appear to have a significant influence on the correction by the VAR. However, the difference in goals has an influence on which team benefits from the correction in Models 1, 5 and 6. It can also be observed that in the situations actually corrected by the VAR, only the decisions with room for judgement remain for the main referee. Models 5 and 6 are therefore identical.

Model	(1) Full Sample	(2) Covid	(3) 1st Liga	(4) 2nd Liga	(5) R	(6) Margin
DiffB365	-0.00398 (0.189)	-0.00289 (0.605)	-0.00258 (0.445)	-0.0149 (0.059)	-0.00241 (0.648)	-0.00540 (0.356)
Playtime_Minute	0.000474 (0.266)	0.000953 (0.237)	-0.000297 (0.633)	0.00130* (0.026)	0.0000190 (0.978)	0.000348 (0.646)
Spectator	0.00000161** (0.005)	-0.00000203 (0.922)	0.00000113 (0.110)	0.00000114 (0.295)	0.00000179* (0.045)	0.00000121 (0.218)
Diffgoals	-0.0203* (0.025)	-0.0158 (0.367)	-0.0217 (0.083)	-0.0187 (0.150)	-0.0225 (0.124)	-0.0270 (0.096)
_cons	0.323*** (0.000)	0.308*** (0.000)	0.407*** (0.000)	0.244*** (0.000)	0.363*** (0.000)	0.421*** (0.000)
N	1,880	545	940	940	790	676
F	4.115	0.600	1.560	3.047	1.730	1.359
R ²	0.00870	0.00442	0.00663	0.0129	0.00874	0.00804

p-values in parentheses * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$; (1) Full Sample; (2) Covid = only Ghost Games and Games under the Covid conditions; (3) 1st Liga; (4) 2nd Liga; (5) R = only decisions of the referee; (6) Margin = only decision with room for judgement

Table 3: Logistic Regression with ChangebyVAR as Dependent Variable

	(1) Full Sample	(2) Covid	(3) 1st Liga	(4) 2nd Liga	(5) R	(6) Margin
DiffB365	0.00308 (0.519)	0.00940 (0.329)	0.00479 (0.357)	-0.00971 (0.502)	-0.0132 (0.090)	-0.0132 (0.090)
Playtime_Minute	0.000156 (0.828)	0.000562 (0.681)	0.000311 (0.749)	-0.000250 (0.816)	-0.000799 (0.459)	-0.000799 (0.459)
Spectator	-0.000000605 (0.500)	0.0000501 (0.151)	-0.000000403 (0.702)	-0.000000049 (0.980)	-0.000000810 (0.550)	-0.000000810 (0.550)
Diffgoals	-0.0389** (0.010)	-0.0349 (0.235)	-0.0376 (0.061)	-0.0396 (0.083)	-0.0726** (0.001)	-0.0726** (0.001)
_cons	0.526*** (0.000)	0.484*** (0.000)	0.490*** (0.000)	0.555*** (0.000)	0.542*** (0.000)	0.542*** (0.000)
N	716	195	396	320	318	318
F	2.615	1.312	1.920	0.839	2.909	2.909
R ²	0.0145	0.0269	0.0193	0.0105	0.0358	0.0358

p-values in parentheses * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$; (1) Full Sample; (2) Covid = only Ghost Games and Games under the Covid conditions; (3) 1. Liga; (4) 2. Liga; (5) R = only decisions of the Referee; (6) Margin = only decision with room for judgement

Table 4: Logistic Regression with Profiting_Team as Dependent Variable

5.3 Refereeing Experience

In Table 5 we use ChangebyVAR to analyse the interaction between the referee and the VAR. For this purpose, we only consider the decisions that fall within the referee's area of responsibility (see Table 2), which reduces the data set compared to previous models.

Model	(1) Differences R-VAR	(2) Referee	(3) VAR
DiffB365	0.00660 (0.334)	-0.00227 (0.668)	0.00391 (0.540)
Playtime_Minute	-0.000417 (0.716)	-0.000744 (0.387)	0.000244 (0.811)
Utilisation	-0.0566 (0.438)	0.00853 (0.872)	-0.0446 (0.498)
Goalpressure	-0.148 (0.056)	-0.0591 (0.291)	-0.151* (0.025)
ageDiff	0.00251 (0.592)		
AppaerancesDiff	-0.00466 (0.442)		
Appaerances2Diff	-0.000953 (0.932)		
FoulspgDiff	0.00232 (0.797)		
Foulspg2Diff	-0.0103 (0.256)		
LigaNoteDiff	0.0477 (0.508)		
LigaNote2Diff	-0.0239 (0.593)		
ageH		0.00186 (0.723)	
H1Appearances		-0.00901 (0.244)	
H2Appearances		-0.0116 (0.367)	
H1Foulspg		0.00727 (0.509)	
H2Foulspg		0.00394 (0.594)	
H1LigaNote		0.00546 (0.944)	
H2LigaNote		0.0309 (0.505)	
ageV			-0.00340 (0.569)
V1Appearances			-0.00386 (0.629)
V2Appearances			0.00865 (0.524)
V1Foulspg			0.000709 (0.948)
V2Foulspg			0.00460 (0.595)
V1LigaNote			-0.107 (0.210)
V2LigaNote			0.0460 (0.416)
_cons	0.587*** (0.000)	0.230 (0.600)	0.700 (0.116)
N	322	568	392
F	0.681	0.623	0.906
R ²	0.0236	0.0122	0.0256

*p-values in parentheses * p < 0.05, ** p < 0.01, *** p < 0.001; (1) Differences R-VAR = only use of difference variables between referee and VAR as controls; (2) Referee = only use of Referee variables as controls; (3) VAR = only use of VAR variables as controls*

Table 5: Logistic Regression ChangebyVAR with Referee Experience if the Referee is the Decision Maker

We test the same variables as in Models 3 and 4 and only swap the variable Diffgoals for Goalpressure. Goalpressure is a binary variable that takes the value 1 if a team is either ahead or behind by one goal or if the score is a draw in the situation, in short when the score is close. We no longer use the previously used difference variable, as we are now primarily looking at the referees and not what effects this has on the teams involved. In Model 1 we consider difference variables between the referee and the VAR. For example, we look at whether the age difference between the referee and the VAR a role. In Model 2 we only include the variables that affect the referee as control variables and in Model 3 the variables that affect the VAR. Apart from the Goalpressure of the VAR, no other effect is significant in this model.

6. Discussion, Implications, Limitations and Further Research

The VAR was introduced in football with the aim of ensuring a higher level of fairness. Studies show that referees in professional leagues are subconsciously biased and that teams are sometimes systematically favoured (Helsen et al. 2019). The VAR is intended to improve the accuracy of referees' decisions and counteract this favouritism (Frick et al. 2009). The following research question was therefore formulated at the beginning of this study: *To what extent does the use of the VAR change the influence of referee bias on games in the German professional football leagues?* In order to investigate the research question empirically, three main hypotheses were formulated, which are intended to contribute to answering the question based on previous studies.

H1: The use of the VAR weakens the existing bias of the referees.

H1a: The use of the VAR weakens the existing bias of the favoured team, so that weaker teams benefit from the use of the VAR.

H1b: The use of the video assistant attenuates the existing and referee-related home bias, so that away teams benefit from the interventions of the VAR.

In Tables 3 and 4, we have analysed Hypotheses 1, 1a and 1b. Model 1 in Table 3 shows that the VAR intervenes more frequently to correct a decision when the home team is behind and there are more spectators in the stadium. In Table 4, Model 1 shows that the home team benefits from the corrective decision of the VAR when it is behind. This effect can be confirmed in Models 5 and 6. However, this result is not robust in every model in the table, such that the explanatory power is limited. Moreover, we find arguments for not confirming hypothesis 1b

in our data. This result is similar to the study by Dufner et al. (2023), which found no statistically significant impact of the introduction of VAR on home bias in the Bundesliga, and also the results of Holder et al. (2022), who found a reduction in home bias in the Italian Serie A, but not in the German Bundesliga. We cannot find a bias for the favoured team and therefore cannot confirm Hypothesis 1a. This result is in line with the theoretical considerations that favourites or better performing teams benefit from the introduction of VAR due to a reduction in the element of chance, which is more dominant in football than in other sports (Ben-Naim et al. 2006 & Wunderlich et al. 2021).

H2: The difference in experience between the referee and the VAR influences the change rate of the VAR.

H2a: Experienced referees are less often corrected by the VAR than unexperienced referees.

H2b: Experienced VARs correct more often than unexperienced VARs.

In Table 5 we compared different experience values of the referees and the VARs in order to find out whether different experiences change the correction rate in the interaction. With the exception of the close score when looking at the VAR in Model 3, we were unable to find any significant correlations and therefore could not confirm that experience plays a role in decision-making. This is in line with the study conducted by Holder et al. (2022), which also found no systematic differences in VAR use between inexperienced and experienced referees. However, their study only related to the red card and penalty kick situations. Picazo-Tadeo et al. (2016) were also unable to identify any differences between experienced and inexperienced referees in social pressure situations and justified this with the functioning selection of referees by the professional league.

Significant correlations were found for the spectator variable, meaning that the stadium atmosphere generally has an influence on the referees' decision-making. In contrast to the studies by Holder et. al (2022), the stadium occupancy rate was not selected as an independent variable in this study, but rather the total number of spectators in order to take into account the difference between a sold-out stadium with 10,000 spectators and a fully utilised stadium with over 50,000 spectators. A study taking into account stadium capacity utilisation was also carried out, but this did not lead to any significant results, similar to Holder et. al (2022). Our main result supports the idea that a higher error rate can be explained by the greater social pressure in stadiums with many spectators (Nevill et al. 2002).

The analyses within the framework of the principal-agent theory offer insights into the effects of monitoring, particularly in the context of the Bundesliga and the VAR as a monitoring tool. It is shown that there is no information asymmetry between referees and their principals that leads to a problem with hidden characteristics. The study found that there are no systematic differences in the review or correction of decisions between experienced and less experienced referees. As all referees observed are qualified at top national level, this suggests that the selection process of the associations is largely mature (Picazo-Tadeo et al. 2016). The cooperation between referees and football associations seems to minimise the problem of hidden characteristics and calls into question the need for a VAR as a monitoring tool for referee performance. However, the VAR has only a limited influence on hidden behavioural problems and referee bias because he can have similar information asymmetries as the referee, as he is part of the same group of people. With regard to the principal-agent theory, it must be examined whether the increased agency costs resulting from the use of an additional VAR team and the technical infrastructure align the interests of principal and agent and whether this financial expenditure is economically justified.

Stakeholder theory shows that a VAR helps to reduce inefficiencies and improve referee decisions, which is in line with the interests of stakeholders who are interested in maximising objective compliance with the rules. The results indicate that the error rate of referee decisions increases with the number of spectators and the match result. The VAR is therefore particularly important in the highest leagues in order to protect the interests of stakeholders and ensure maximum fairness in sport.

According to the technology acceptance model by Davis (1989), the willingness to use technologies depends mainly on perceived usefulness and user-friendliness (Davis et al. 1989). This study focusses on perceived usefulness. Märtins et al. (2023) found that transparency in VAR use plays an important role in the subjective perception of fans, although this is more negative than expected (Märtins et al. 2023). Objectively, VAR compensates for systematic refereeing errors, which leads to improved output quality and confirms its objective usefulness. This explains the more positive attitude of referees compared to fans and other stakeholders (Zeit.de 2023).

From a sports economics perspective, the analyses conducted extend the existing research on the influence of VAR on fairness. The results of Holder et al. (2022) and Dufner et al. (2023) are partially confirmed. In addition, other referee biases identified in the past by sports econ-

omists such as Nevill (2002) and Lago-Peñas & Gómez-López (2016) were transferred to the research field of VAR and empirically tested.

Although the use of the VAR is often criticised in the general discussion (Chatrath 2022), the empirical studies conducted show that the criticism is only partially justified. The analyses confirm that the VAR as an additional referee cannot eliminate all existing systematic problems or subconscious biases of referees. However, his very existence offers a benefit. The majority of corrections are made for offside positions and there are already fewer corrections here, as attackers change their movements in the knowledge that the VAR is correcting them (Han et al. 2020). From a practical point of view, consideration could be given to adapting or expanding the VAR so that not only clear mistakes are corrected, but also the objectively comprehensible correct decision is made in as many match-deciding situations as possible (goals, penalties and red cards). However, this change to the rules would have a negative impact on the flow of a match (de Dios Crespo 2020), which is why alternative utilisations should also be considered. The DFB and DFL should focus on managing expectations in connection with the VAR. From the point of view of the referees themselves, but also from the perspective of the fans and other stakeholders, it is essential to realistically clarify unjustified expectations and clearly define the remit of the VAR. The analyses carried out help to realistically assess the effect that a VAR can have on the fairness of sport. As a result, the stakeholders' trust in the decisions of the VAR and ultimately the acceptance of the VAR in football can be increased.

This work is subject to several limiting factors. The VAR was introduced in the German first Bundesliga the 2017/2018 season and in the second Bundesliga in the 2019/2020 season. However, the reviews and corrections by the VAR in the 2017/2018 and 2018/2019 seasons were not fully and transparently documented on the Bundesliga website, meaning that these two seasons could not be included in the analysis. In order to optimally analyse developments in the use of the VAR, data collection would also have been useful for the period immediately following the introduction of the VAR. The analysis carried out from the 2019/2020 season onwards is based on the VAR reviews documented on bundesliga.com. It cannot be ruled out that further reviews took place during the observation period, but these were not documented. The study is based on the assumption that a decision corrected by the VAR is actually correct. In reality, however, even corrected decisions are often controversial. In order to be able to identify a decision as correct or incorrect beyond doubt and objectively, a different research design is conceivable, for example the evaluation of scenes by a panel of experts. This work

poses the question of whether the VAR succeeds in correcting bias and the resulting systematic problems of referee decisions. It must be taken into account that the referee retains the decision-making authority on the pitch and the VAR only intervenes in an advisory capacity. Further research is required because the VAR himself may be subject to the same or possibly other systematic problems or influences. The data used is only based on the two professional football leagues in Germany while, as Holder et al. (2022) showed, problems such as home advantage do not appear to occur equally across all leagues. It would therefore make sense to extend the analysis to other top European leagues and compare possible influences.

7. Conclusion

The aim of this study was to empirically analyse to which extent the use of the VAR changes the influence of referee bias on matches in the German professional football leagues. Therefore, the theoretical section described the systemic referee biases identified by sports economists that impair fairness in football. With the empirical analysis of 2,448 first and second division matches from the 2019/2020 to 2022/2023 seasons, the current state of research on the introduction of the VAR in football is extended by a database covering four seasons and an analysis of various referee biases that have so far only been partially considered in the academic literature.

The data analysis made it clear that the use of VAR can only partially counteract the referee bias and can therefore only change the influence of referee decisions on matches in the German professional football leagues to a limited extent. A reduction in home bias through the introduction of VAR and a significant influence of the referees' experience on cooperation with the VAR could not be shown. These results confirm the findings of previous studies. However, with regard to the error rate of referee decisions under social pressure, the VAR was identified as a suitable instrument for improving fairness in football and reducing the influence of the referee on the outcome of a match. Expanding the database to include future seasons or other European top leagues and examining whether other psychological factors affect the performance of VAR would therefore appear reasonable in the future.

A high level of transparency in decision-making by the VAR and expectation management are essential in order to involve stakeholder groups and promote the acceptance of assistive technology in a conservative and rather change-resistant industry such as professional sport. The results of the empirical evaluation provide a basis for discussion in order to realistically

assess and communicate the extent to which a VAR can counteract the systematic bias of the referee or is subject to a similar bias as the referee on the pitch.

It is apparent that the VAR can only partially counteract existing referee bias because a systematic favouring of one of the two teams by the referee's bias is not only recognisable in clear wrong decisions but also in controversial situations. However, the current rules of football limit VAR interventions to certain situations and only clear erroneous decisions. Instead of questioning whether the use of a VAR can be justified, alternative applications should be discussed in order to utilise the advantages of video reviews even more efficiently and to effectively counteract referee bias in professional football.

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