TI 2025-015/V
Tinbergen Institute Discussion Paper

Non-Transitive Patterns in Sports Match Outcomes: A Profitable Anomaly

Jan van Ours[1]

1 Erasmus University Rotterdam, Tinbergen Institute

Non-Transitive Patterns in Sports Match Outcomes: A Profitable Anomaly

Jan C. van Ours*

February 25, 2025

Abstract

While sports betting markets share similarities with traditional financial markets, they are more accessible for empirical research thanks to availability of high-quality data, straightforward betting procedures, and the finite duration of events. As a result, they are often analyzed for market efficiency and serve as a field laboratory for studying financial markets. This study examines 24 seasons of English Premier League matches, revealing consistent non-transitive patterns in match outcomes among various triads (groups of three clubs). These empirical findings are difficult to rationalize and represent a notable anomaly. Bookmakers ignore the non-transitive patterns when setting odds. Faced with a trade-off between efficiency using historical information and maintaining consistency, they prioritize consistency.

Keywords: Market efficiency, Sports betting, Non-transitivity, Football, English Premier League

JEL-codes: C25, D01, Z2

Declarations of interest: none

The author thanks László Csató for detailed comments on a previous version of the paper.

*Erasmus School of Economics, Tinbergen Institute (Rotterdam) and ECASE (Erasmus Center for Applied Sports Economics), the Netherlands; CEPR (London). Address: Burg. Oudlaan 50, 3062 PA Rotterdam, the Netherlands; email: vanours@ese.eur.nl

1 Introduction

In sports betting markets, individuals can bet on the outcome of a specific sports event, such as predicting who will win a game or match. They can also bet on more specific results, such as the number of goals scored or the goal difference. The potential profit from a bet is determined by the odds set by bookmakers, with higher odds implying a greater payout but with a lower probability. If a bet is incorrect, the money goes to the bookmaker, but if the prediction is correct higher odds can result in a substantial payout.

Bookmakers have a strong incentive to incorporate all available information when setting their odds. If they are better than bettors in predicting match outcomes they can set odds such that on average they will win. However, if the bettors are more skilled the bookmaker may lose. Therefore, in a strict sense, betting on a specific outcome is not purely a gamble. As noted by Levitt (2004), the risk borne by bookmakers in sports betting differs from that of games of pure chance, like roulette. In roulette, the odds are fixed in favor of the casino, ensuring that the casino wins in the long run. However, if bookmakers set incorrect odds for sporting events, they stand to lose significant sums, even over the long term.

Sports betting markets share similarities with traditional financial markets, where participants invest money in assets with the hope of generating positive returns. In both markets, future outcomes are uncertain, there are numerous participants, and historical information about relevant events is widely accessible (Makropoulou and Markellos (2011)). According to Sauer (1998) sports betting markets offer a unique setting for economists to study models of market pricing. Levitt (2004) mentioned three parallels between trading in financial markets and sports betting markets. First, in both settings, investors with heterogeneous beliefs and information seek to profit through trading as uncertainty is resolved over time. Second, sports betting, like trading in financial derivatives, is a zero-sum game with one trader on each side of the transaction. Finally, large amounts of money are potentially at stake.

Some characteristics make sports betting markets more appealing for empirical research than regular financial markets (Kuypers (2000)). According to Shin (1992, 1993) a betting market is like a simplified financial market. The betting market convenes quickly and at the end the outcome is definite and commonly acknowledged. Unlike financial markets, sports betting markets provide detailed price information, with the value of the 'asset' revealed at a predetermined moment in time. While financial assets often have an indefinite duration and no specific point at which their true value is disclosed, the value of bets in sports markets is determined soon after the investment is made. Because in a

sports betting market there is no systematic risk and terminal values are exogenous to betting activity a sports betting market is like a laboratory to test theories of financial markets (Moskowitz (2021)). This does not mean that there are no differences between the two. According to Angelini and De Angelis (2019) unlike in financial markets, in betting markets participants are in general well-informed, motivated and experienced. Furthermore, news in sports is reported quickly and accurately so it is easy for participants to take this information into account when setting their bets. Vandenbruaene et al. (2022) mentioned that sports betting markets have interesting features allowing for clean efficiency tests also because the information set relevant to the pricing of sports bets is small and finally in betting markets agents can be studied in their natural habitat (without being aware that they are observed and with real money at risk).

This paper presents an empirical analysis of football match outcomes across 24 seasons of the English Premier League, revealing non-transitive patterns in the results between various sets of three clubs. Non-transitivity implies that, for example, if team i is likely to win against team j and team j is likely to win against team k, team k is likely to defeat team i. These non-transitive patterns are ignored, creating opportunities for profitable betting strategies. By demonstrating the existence of profitable non-transitive betting opportunities, this paper suggests that football betting markets are not fully efficient. Non-transitivity of match outcomes creates a tension between market efficiency and rationality. In an efficient market, information about past match outcomes should be used to set odds. However, if past match outcomes are inconsistent with each other this is at odds with rationality.

The main contribution of this paper to the literature on market efficiency, particularly the efficiency of sports betting markets, is threefold. First, it demonstrates that persistent non-transitivity existed in match outcomes among various triads of teams over an extended period. Second, it highlights that bookmakers' odds did not account for this non-transitivity because of the tension between efficiency and rationality. Third, the paper illustrates that a simple betting strategy exploiting non-transitivity in match outcomes would have generated consistent profits. According to Thaler and Ziemba (1988), an empirical result that is difficult to rationalize can be classified as an anomaly. In this context, the main finding of this paper constitutes an anomaly.

The paper is organized as follows. Section 2 discusses sports betting markets, emphasizing studies on market efficiency. Section 3 provides an overview of previous research on non-transitivity in match outcomes. Section 4 offers descriptive information about English Premier League football. Section 5 presents a descriptive analysis of non-transitivity

in match outcomes, focusing on surprise wins. Section 6 demonstrates the profitability of non-transitive betting strategies. Section 7 details parameter estimates for non-transitive models. Finally, Section 8 concludes with key findings and implications.

2 Sports Betting Markets

There are several types of sports betting (Sauer (1998)). With points spread betting the payoffs depend on the difference in points scored by two opposing teams. With parimutuel betting the bookmaker takes a predetermined percentage out of the betting pool and the payoff depends on size of the betting pool and the number of bettors who chose a particular outcome. This paper focuses on fixed odds betting in which the payoff to each bet is determined at the time the bet is placed. Fixed odds betting has the peculiarity that when bets are placed the odds are set well before the event and they do not change until the completion of the event.[1] To cover their costs and make a profit, bookmakers use a margin when setting their odds on for example a match outcome. The odds can be transferred into expected probabilities of match outcomes using a simple normalization. With decimal odds, the expected probability of a win of home team i against away team j is equal to:[2]

$$W_{ij}^{e} = \frac{(1/O_{ij}^{h})}{(1/O_{ij}^{h}) + (1/O_{ij}^{d}) + (1/O_{ij}^{a})} = \frac{1}{O_{ij}^{h} \cdot (1 + B_{ij})} \tag{1}$$

where O_{ij}^{h} are the odds for a home win of i against j, O_{ij}^{d} the odds for a draw and O_{ij}^{a} the odds for an away win. B_{ij} is the bookmaker margin, which is equal to the sum of the inverse odds minus one.[3]

In an efficient market, the price fully reflects available information. For financial markets, Fama (1970) distinguished weak-form efficiency implying that all historical information is reflected in the market price, semi-strong-form efficiency that also includes

[1] Whereas in parimutuel betting bettors bet against each other, in fixed odds betting they bet against the bookmaker.

[2] Sometimes odds are given as fractional odds whereby decimal odds = fractional odds + 1. For example, if the fractional odds are quoted as 9/4 this means that the win is 9 for a stake of 4. In decimal odds this is (9/4)+1=3.25. For a stake of 4 the profit will be equal to 4*3.25-4=9.

[3] Shin (1991) proposed an alternative approach to correct for the bookmaker margin taking insider trading into account. This betting market is assumed to have an informed price-setter with better information than the majority of small traders. There are also a few traders who are better informed than the price setter. This approach leads to slightly different expected outcome probabilities. Strumbelj (2014) showed that Shin's model to correct for the bookmaker margin leads to a better predictor of match outcomes than the implied probabilities derived from basic normalization. Strumbelj (2016) mentioned that for forecasting purposes the advantage of Shin's method decreases with an increasing market size. See Koning and Zijm (2023) for a comparison of the traditional method and Shin's approach.

all publicly available information and strong-form efficiency that requires that even privately held information is reflected in the market price. Several studies have explored the efficiency of sports betting markets. Thaler and Ziemba (1988) defined a weak efficient betting market as a market in which no bets have positive expected values. With strong efficiency all bets have the same expected value equal to (1-t) times the amount bet, where t represents the transaction costs. According the Sauer (1998) the most restrictive definition of efficiency is that the expected returns are equal across the betting opportunities. A less strict definition is the absence of profit opportunities. Since profits must be non-negative for the bookmakers, the bettor should not have profitable betting rules. In other words, the expected rate of return to bettors has an upward bound of zero.[4]

Thaler and Ziemba (1988) mentioned the favorite-longshot bias as the most robust violation of the efficiency condition. A longshot is a "wild guess" involving a small chance of winning but with a great reward if successful while betting on a favorite has a high chance of winning a small amount. Low win probabilities are overbet while high win probabilities are underbet. As a result, the expected returns to a bet increase monotonically with the win probability. Favorites win more often and longshots win less often than win probabilities based on bookmaker odds imply. There are various explanations for this. Bets with small probabilities have high payouts and bookmakers may want to avoid large losses if a rare match outcome still materializes. They increase the odds to prevent high payouts. It is also possible that betters are overconfident and they misinterpret probabilities (Snowberg and Wolfers (2010)). Or, bettors are risk-loving seeking high risks (Quandt (1986)). The prospect theory proposed by Kahneman and Tversky (1979) provides another explanation for the longshot bias, suggesting that small probabilities are typically overweighted (Newall and Cortis (2021)). Prospect theory can also explain the favorite bias because high probabilities are treated as if they are certain. If bookmakers offer lower returns on underdogs this could lead to bookmakers generating additional profits. The reverse is possible too, i.e., bettors undervalue underdogs and overvalue favorites. It could also be that bettors favor home teams or teams with a higher sentiment. And, bookmakers can take advantage of fans betting on home teams or their favorite team by setting non-market efficient odds. Furthermore, bettors may be subject to outcome bias where they do not take into account that match outcomes are subject to coincidence.

[4]Note that despite this upper bound of zero betting is very popular worldwide. Presumably, betters derive utility from betting based on the idea that they might win a substantial amount in the near future. Similarly, Thaler and Ziemba (1988) mentioned that buying a lottery ticket is like paying a small amount of money for a fantasy, which is a "pretty good deal". See Stetzka and Winter (2023) for a variety of explanations for the rationality of gambling.

There are quite a few studies on the efficiency of fixed odds betting on professional football matches with a variety of outcomes. Pope and Peel (1989) studying bets at four bookmakers on English Football League matches in season 1982/83 concluded that the betting markets were efficient since there was no trading rule generating abnormal, i.e. excess profits. Cain et al. (2000) studying English Football League matches in 1991/92 found evidence of a favorite-longshot bias. Feddersen et al. (2017) found evidence of bookmakers increasing prices for bets on teams with relatively more Facebook "likes" while Feddersen et al. (2018) showed bookmakers increasing prices on games involving popular home teams. Angelini and De Angelis (2019) studied fixed odds betting in eleven football leagues finding evidence of a favorite-longshot bias in three leagues and efficient betting market in the remaining eight leagues. Elaad et al. (2020) found no evidence of a longshot bias concluding that bookmaker odds tend to be unbiased in general. Vandenbruaene et al. (2022) examined 600 betting strategies over 40 years documenting a number of persistent biases. Feddersen et al. (2023) demonstrated that bookmakers alter betting odds on matches involving clubs in the middle of the domestic league standings that have no chance of qualifying for European football. Hegarty and Whelan (2025) studying efficiencies in betting markets over 11 seasons for 22 European football leagues across 11 countries found evidence of the favorite-longshot bias. Bookmakers making more money on longshot bets suggests a lack of competition since high profits are not competed away by other bookmakers choosing to offer more attractive odds on the longshot bets. Winkelmann et al. (2024) provided an overview of 19 empirical studies on the efficiency of betting markets in the top five European football leagues focusing on home bias, favorite-longshot and sentiment bias. Their main conclusion was that inefficiencies exist but profitable strategies based on these inefficiencies are short-lived and do not occur persistently over time or across leagues. Igan et al. (2015) analyzed points spreads betting on NBA games finding a relationship between betting outcomes and the racial composition of the basketball teams. Using the bias of bettors who think that black teams are better, bookmakers earned extra profits. Igan et al. (2015) showed that by taken this into account betting on teams with fewer black players would have been a simple profitable betting strategy.[5]

Outcome bias may also affect betting markets. Bettors might overestimate the winning probabilities of teams that have recently won, even if some of those wins were coincidental and teams were actually overperforming. Outcome-biased bettors may cause

[5]See Larsen et al. (2008) for similar results showing that sizable profits would have been possible in betting on NBA match outcomes by using a simple betting rule in which the racial mix of players and referees is taking into account.

betting prices to overstate the winning probabilities of overperforming teams and underestimate the winning probabilities of underperforming teams (Flepp et al. (2024)). In an efficient betting market all relevant information should be taken into account. One of questions related to this is how quickly new information is incorporated in betting odds. Some studies used Covid-19 related events as a quasi-natural experiments to analyze how football betting markets were influenced by these events. Covid-19 related playing behind closed doors had a negative effect on home advantage because the lack of crowd support affected team performance or influenced referee behavior (Bryson et al. (2021)). Covid-19 related absences of important football players could also have affected team performance. Winkelmann et al. (2021) studied how betting odds were influenced by the reduced home advantages related to playing behind closed doors. They argued that in an efficient betting market there should be no simple strategy for bettors to make profits. They showed that bookmakers did not take the reduced home advantages in the German Bundesliga into account finding that consistently betting on the away team would have generated profits. Meier et al. (2021) found similar results whereby in the early weeks of the Covid-19 period betting on away wins would have been profitable. Fischer and Schmal (2025) studied how quickly Covid-19 related absence of important players in the top leagues of Germany and Italy affected bookmaker odds finding some inertia in adjustment. Hickman and Metz (2025) showed that in the National Collegiate Athletics Association (NCAA) coaching changes and player turnover were not taken into account in betting markets at the start of seasons. Apparently, bookmakers needed some time to adjust their odds to new information.

A related strand of literature used betting odds to predict match outcomes. If a statistical model is able to provide better predictions of match outcomes than bookmakers through their odds, bettors can make profits. Dixon and Coles (1997) for example showed that one can exploit inefficiencies in the football betting market to make money. They presented an empirical model based on historical data showing that there were opportunities to make better predictions than bookmakers did (see also Dixon and Pope (2004)). Among the papers investigating the usefulness of betting odds for prediction purposes is Strumbelj and Šikonja (2010) who examined the effectiveness of bookmakers odds as forecasts for six major European football leagues concluding that this effectiveness has increased over time.

3 Non-transitivity in Sports Match Outcomes

Non-transitivity in preferences is a common phenomenon. The voting paradox, also known as Condorcet paradox, suggests that if voter preferences for three candidates are non-transitive and voting occurs in pairs, the order in which the pairs are presented determines the outcome. Non-transitivity in games is present in for example the rock-paper-scissors (RPS) game where with simultaneous hand signaling rock beats scissors, scissors beat paper and paper beats rock. Although commonly played by children the game is also analyzed by researchers to understand human behavior (Batzilis et al. (2019)).[6]

In sport matches, it is natural to assume that if team i is likely to beat team j, and team j is likely to beat team k, then team i is also likely to beat team k.[7] Indeed, this transitivity often holds. However, as this paper will demonstrate, there are also persistent non-transitive outcomes among triads—sets of three teams—where team i beats team j, team j beats team k, and team k beats team i. This non-transitivity is intriguing and fascinating. Sometimes it is considered to be a nuisance as the non-transitivity makes it hard to rank teams. After all, if team i beats team j, j beats k and k beats i, how should i, j and k be ranked? Match outcomes have a stochastic component and ranking procedures aim to minimize the effect of this.

Although transitivity seems natural, non-transitivity may occur in pairwise matches between more than two sports teams. In the 2024 UEFA European Football Championship the Netherlands defeated Türkiye, Türkiye defeated Austria and Austria defeated the Netherlands. Non-transitivity in match outcomes is not limited to team sports. Bozóki et al. (2016) found triads of non-transitivity between male tennis players and Temesi et al. (2024) between female tennis players. Van Ours (2024) found non-transitivity in match outcomes over more than three decades between the top three clubs in Dutch professional football where Feyenoord was more likely to triumph over PSV, PSV over Ajax, and Ajax over Feyenoord than the reverse scenarios.

4 English Premier League Football

Professional football is a game played according to the same rules in competitions all over the world. Two teams of eleven players compete against each other in a match that lasts

[6]Non-transitive phenomena are not exclusively present in games and sports. Poddiakov (2025) provided an interesting overview of non-transitive patterns in mathematics, physics and biology.

[7]The literature on pairwise comparisons distinguishes two types of non-transitivity: cardinal and ordinal. Cardinal transitivity requires $a_{ik} = a_{ij}a_{jk}$ for all i, j, k. Ordinal transitivity requires $a_{ik} > 1$ if $a_{ij} > 1$ and $a_{jk} > 1$ for all i, j, k. Clearly, ordinal transitivity is less demanding than cardinal transitivity.

two times 45 minutes with a break of 15 minutes in between. Most league competitions are organized as round-robin tournaments, where each team faces every other team twice. The team scoring most goals in a match wins and earns three points. In the event of a draw, both teams earn one point. The team with the best results at the end of the season wins the league.

Whether a team wins a particular match depends on the relative quality of the teams, the abilities of the coaches, referee decisions, and luck. In the long run, the quality of the team is the primary determinant of success. However, disparities in quality may not be adequate to ensure a clear hierarchy of teams in every game; thus, match outcomes are uncertain. Indeed, without this uncertainty, football would not be as exciting to watch.[8]

In the top tier of English professional football, the English Premier League, twenty teams compete. So, every season, 380 league matches are played. Limited by the availability of bookmaker odds, the period of analysis is 2000/01 to 2023/24. In these 24 seasons 46 clubs played in the English Premier League (EPL).[9] In the empirical analysis in this paper information about match outcomes is included for the ten clubs which over the period of analysis were present in the EPL for at least 21 seasons.

Table 1 gives a summary overview of the match outcomes of these ten clubs when playing against each other. In total 2000 matches were played between these clubs. The clubs are ordered from high to low by average points per match. The range is from Man United obtaining 1.77 points per match to West Ham obtaining 0.88 points per match. The percentage of wins is highly correlated with points per game. Man United won 51% of their matches against the other teams, for West Ham this was 22%.

Table 1 also presents expected match outcomes in terms of expected points and expected wins based on betting odds. Differences between actual and expected match outcomes are named match surprises.[10] On average, the expected match outcomes were

[8]Football is a sport with low-scoring rates and therefore it has a high outcome uncertainty and related to that a high popularity (Scarf et al. (2019)). The high outcome uncertainty may also imply that non-transitive triads in match outcomes are more likely to occur in football than in other sports.

[9]See Appendix A for an overview including information about the data sources. In the presentation club names are shortened: Man City for Manchester City, Man United for Manchester United, Newcastle for Newcastle United, Tottenham for Tottenham Hotspur, West Ham for West Ham United. Note that the period of analysis also includes seasons 2019/20 and 2020/21 during which due to Covid-19 restrictions some matches were played behind closed doors.

[10]An example on how bookmaker odds are transferred into expected wins and expected wins is the following. In season 2022/23 the match Tottenham-Man City had the following odds: home win: 4.4; draw: 4.0; away win: 1.73. This implies that the probability of a home win was equal to $\frac{(1/4.4)}{(1/4.4)+(1/(4.0)+(1/1.73)}$=0.1375. Similarly the probability of a draw was equal to 0.175 and the probability equal to 0.6875. Thus, the expected points for the home team were 0.1375*3+0.175=0.5875 and the expected points for the away team 0.175+0.6875*3=2.2375. The match outcome was 1-0. Therefore, the surprise win for the home team was 1-0.1375= 0.8625 and the surprise win for the away team 0-0.6875 = -0.6875. The surprise points for the home team were 3-0.5875=2.4125 and the surprise points for the

Table 1: **Average Match Outcomes and Elo-rating; 2000/01 - 2023/24**

	Points per game			Wins			Elo-rating		
	Actual	Expected	Surprise	Actual	Expected	Surprise	2000/01	2023/24	N
Man United	1.77	1.66	0.11	0.51	0.47	0.04	106	99	414
Liverpool	1.72	1.64	0.08	0.48	0.46	0.02	109	105	414
Arsenal	1.68	1.62	0.06	0.48	0.45	0.03	105	106	414
Chelsea	1.64	1.69	–0.05	0.46	0.48	–0.02	104	100	414
Man City	1.63	1.61	0.02	0.48	0.46	0.02	93	113	398
Tottenham	1.29	1.32	–0.03	0.35	0.35	–0.00	97	97	414
Everton	1.06	1.09	–0.03	0.26	0.27	–0.01	94	93	414
Newcastle	1.05	1.02	0.03	0.28	0.26	0.02	98	99	384
Aston Villa	0.92	1.02	–0.10	0.22	0.25	–0.03	99	96	368
West Ham	0.88	0.93	–0.05	0.22	0.23	–0.01	95	94	366
Average/total	1.38	1.37	0.01	0.38	0.37	0.01	100	100	4000

Note: Match outcomes from the ten teams playing against each other. Elo-ratings are normalized to an average of 100. The actual average Elo-ratings in 2000/01 and 2023/24 were 1972 and 2133 (source: Elofootball.com); N = number of matches.

very much in line with the actual match outcomes. The difference between actual match outcomes and expected match outcomes ranged from -0.10 to +0.11 points. Similarly, the difference between actual and expected wins ranged from -3% (Aston Villa) to +4% (Man United).

The Elo-rating is an indicator of the strength of a team.[11] Over time, the strength of some teams has changed a lot. Man City for example had an Elo-rating of 1830 in season 2000/01. It then relegated to return to the Premier League the next year. In season 2023/24 their ELO-rating of 2404 was the highest of the EPL. Over time, the average Elo-ratings increased a lot, from 1972 in 2000/01 to 2133 in 2023/24. Therefore, Table 1 shows Elo-ratings normalized to an average of 100 in the first and last season of the sample. Whereas in 2000/01 Man City had the lowest normalized Elo-rating of 93 in 2023/24 it had the highest of 113. Man United had a big drop in the relative Elo-rating from 106 to 99 whereas for the other teams the Elo-rating did not change a lot.

away team 0-2.2375=-2.275.

[11]Elo ratings were used to indicate the relative strength of chess players (Elo (1978)) but nowadays they are used in many sports.

5 Non-transitive Match Outcomes

The analysis of non-transitivity in match outcomes starts with a descriptive analysis of match surprise wins. Panel a of Table 2 shows the balance of expected wins (top right) and the balance of actual wins (bottom left) for every pair of matches played over the period of analysis. Panel b of Table 2 shows the balance of surprise points. The top right of panel a shows, for example, that the expected balance of wins and losses of Arsenal against Aston Villa was 16. The actual match outcomes presented in the bottom left of panel a show that Arsenal actually had a positive win balance of 18 matches against Aston Villa. Thus, as shown in panel b, Arsenal playing Aston Villa had a positive balance of surprise wins of two matches.

The balances of surprise wins were generally not very big. In 24 of the 45 match pairs the balance of surprise wins was less than five. However, there are also big unbalances. There are ten balances of at least seven surprise wins (presented in bold in Table 2b). Man City had a positive balance of 9 surprise wins against Newcastle, the same number as Man United against Tottenham. Man United had a positive balance of 11 surprise wins against Aston Villa and Tottenham even had a positive balance of 13 surprise wins against Man City. Clearly, from the perspective of the surprise wins bookmaker odds were not very helpful in predicting match outcomes. Obviously, there are non-transitive patterns of surprise wins. For example, in the triad Tottenham-Man City-Newcastle: Man City has 9 surprise wins against Newcastle, Newcastle has 8 surprise wins against Tottenham and Tottenham has 13 surprise wins against Man City. The sum of the three suggests that Tottenham, Man City and Newcastle were a non-transitive triad of teams with a total balance of surprise wins of 30. However, not all three teams played in the EPL simultaneously. When considering the 21 seasons that all three teams played in the EPL, the total balance of non-transitive surprise wins equals 27, still a surprisingly large number with more than one surprise win per season.

With 10 teams playing against each other there are $\frac{10!}{7!.3} = 240$ possible triads of which 120 are unique and positive while the other 120 have the same magnitude as the first 120 but with opposite signs.[12] To establish non-transitive surprise match outcomes in triads two restrictions were used. First, each pairwise balance of surprise wins had to be at least equal to one. Second, to rule out small balances that occurred by coincidence, the seasonal sum of the balances of the three match surprises had to be on average

[12]Kendall and Smith (1940) showed that with n teams, the maximum possible number of non-transitive triads (also called 'circular triads') when n is even is equal to $\frac{n^3-4n}{24}$. So with 10 teams there is a maximum of 40 non-transitive triads. The minimum number of non-transitive triads is zero.

Table 2: **Balance of Expected, Actual and Surprise Wins between Pair of Clubs; 2000/01 - 2023/24**

	Arsenal	Aston Villa	Chelsea	Everton	Liverpool	Man City	Man United	Newcastle	Tottenham	West Ham
a. Expected wins (top right) and Actual wins (bottom left)										
Arsenal		16	–3	16	–1	0	–1	17	8	18
Aston Villa	–18		–18	–2	–15	–13	–17	–1	–7	2
Chelsea	1	11		17	1	2	1	17	11	19
Everton	–17	–5	–12		–14	–14	–17	2	–7	4
Liverpool	–1	20	1	20		1	0	16	10	19
Man City	1	20	–6	9	–7		0	15	8	16
Man United	3	28	–1	21	4	–2		18	10	18
Newcastle	–23	6	–13	–4	–19	–24	–20		–8	2
Tottenham	–11	12	–18	13	–14	5	–19	0		11
West Ham	–21	1	–15	–10	–23	–21	–16	–9	–10	
b. Balance of surprise wins										
Arsenal		2	2	1	2			6	3	3
Aston Villa			**7**	**7**						
Chelsea						4	0		**7**	
Everton			5			5		2		6
Liverpool		5	2	6		6		3	4	4
Man City	1	**7**					2	**9**		5
Man United	2	**11**		4	4			2	**9**	
Newcastle		5	4						**8**	**7**
Tottenham		5		6		**13**				
West Ham		3	4				2		1	

Note: in panel b numbers are in bold if the balance of surprise wins is at least seven.

significantly different from zero (at least at a 5%-level).[13]

Imposing these restrictions, there were ten non-transitive triads. The left-hand side of Table 3 provides an overview in which the triads are ordered by the magnitude of the balance of surprise wins. The first row shows that the triad of Tottenham, Man City and Newcastle had an average seasonal balance of surprise wins of 1.31. The tenth triad consists of Man United, Newcastle and West Ham with an average seasonal balance of surprise wins of 0.68.

Man City was present in six triads followed by Tottenham present in five triads and Aston Villa and Chelsea who were present in four triads. Man United was present in only two triads, Arsenal and Liverpool were in none of the triads. There are major overlaps in the triads. For example, Man City and Tottenham were together in three triads: with Man United, with Newcastle and with West Ham. Aston Villa and Everton were in two

[13]For every season in which all of the three teams played against each other the average balance of win surprises over the season was calculated. Then, a one-sided t-test was used to establish whether or not the seasonal averages were positive and significantly different from zero over the period of analysis.

Table 3: **Non-transitive Triads; Balance of Surprise Wins and Betting Profits; 2000/01 - 2023/24**

				Surprise wins			Betting profits			
				Average		Cum	Average		Cum	N
1.	Tottenham	Man City	Newcastle	1.31	(0.48)***	27	3.28	(1.27)***	69	21
2.	Tottenham	Man City	Man United	1.00	(0.40)***	23	1.96	(0.97)**	45	23
3.	Aston Villa	Everton	West Ham	0.97	(0.38)**	18	0.34	(0.69)	6	18
4.	Tottenham	Man City	West Ham	0.96	(0.36)***	19	2.17	(0.99)**	43	20
5.	Man City	Aston Villa	Everton	0.95	(0.43)**	19	0.28	(0.65)	6	20
6.	Chelsea	Tottenham	Aston Villa	0.94	(0.40)**	20	0.77	(0.70)	16	21
7.	Chelsea	Man City	Newcastle	0.86	(0.39)**	18	0.92	(0.79)	19	21
8.	Chelsea	Tottenham	Everton	0.81	(0.35)**	19	–0.40	(0.58)	–10	24
9.	Chelsea	Man City	Aston Villa	0.75	(0.42)**	15	0.86	(0.95)	17	20
10.	Man United	Newcastle	West Ham	0.68	(0.35)**	13	0.72	(0.84)	14	19

Note: Standard errors in parentheses; *** (**, *) indicates an average different from zero at a 1% (5%, 10%) level (1-sided test). Cum = cumulative over all seasons. N = number of seasons all teams of the triad were playing. See section 6 for details on betting profits.

triads: with Man City and West Ham. Chelsea and Tottenham were in two triads: with Aston Villa and Everton and Aston Villa and Chelsea were in two triads: with Man City and Tottenham.

If in a triad two teams are much stronger than the third team, it is not likely that non-transitivity will persist for a long time. The weakest team may win against the stronger team every now and then but not too often. Therefore, it is surprising that in some on the non-transitive triads at least one team relegated over the period of analysis while the other two teams did not.

Appendix B Figure B.1 shows the evolution of the balances of cumulative surprises over time, for the triads and the separate pairs of matches. Clearly, the cumulative surprise points were positive at the end of the period of analysis in season 2023/24 but in earlier seasons there were sometimes substantially fluctuations or periods when the cumulative number of surprise points stayed more or less constant or was decreasing.

What is clear from all this is that non-transitivity in match outcomes is a persistent phenomenon in the English Premier League. What is not clear is what the origin is of this non-transitivity. Since it occurred over a period of 24 years it cannot be related to particular managers or particular team compositions.[14]

[14]The non-transitivity could be related to playing style but to the extent that playing styles in matches between two teams are related to fouls, yellow cards and red cards there does not seem to be something systematic. Appendix C Table C1 gives an overview of the differences in fouls, yellow cards and red cards issued in each of the triads of teams and there are no obvious patterns. The seasonal balance of fouls in a triad was positive and significantly different from zero for the triads Aston Villa – Everton – West Ham and Man City – Aston Villa – Everton. However, for other triads the balance of fouls was negative. The same holds for the seasonal balances of yellow cards and red cards.

6 Non-transitive Betting

A key question when examining potential inefficiencies in the football betting market is whether bettors could have achieved profits through non-transitive betting strategies. In other words, can a simple, rule-based approach yield consistent gains? For instance, a strategy of regularly betting on away wins was profitable during the period when the traditional home advantage was diminished because teams played behind closed doors due to Covid-19 restrictions on stadium attendance (Winkelmann et al. (2021), Meier et al. (2021)).

If O_{ij} are the odds for a win of team i playing against team j and W_{ij} indicates the related match outcome (one for a win, zero for a loss or a draw), the betting profits P_{ij} for betting £1 on a win of i against j (ignoring who plays at home) are equal to:

$$P_{ij} = W_{ij} \cdot (O_{ij} - 1) - (1 - W_{ij}) = W_{ij} \cdot O_{ij} - 1 \tag{2}$$

If the match surprise win is defined as $S_{ij} = W_{ij} - W_{ij}^e$ with W_{ij}^e being the expected win probability, the profits are equal to:

$$P_{ij} = S_{ij} \cdot O_{ij} - \frac{B_{ij}}{1 + B_{ij}} \tag{3}$$

If over a series of matches the odds and bookmaker margins are constant ($O_{ij} = O^h$; $B_{ij} = B$), average betting profits over that series of matches are equal to:

$$\overline{P}_{ij} = \overline{S}_{ij} \cdot O^h - \frac{B}{1 + B} \tag{4}$$

If the bookmakers odds are accurate predictors of the match outcomes averaged over this series $\overline{S}_{ij} = 0$.[15] So, with accurate bookmaker predictions the expected bettors profits are negative and the expected bookmaker profits are positive. This would imply that the betting market is efficient. Non-transitivity in match outcomes removes this efficiency.

Betting profits from non-transitive betting on wins of the first teams of pairwise matches in a triad are equal to:

$$P_{ijk} = S_{ij} \cdot O_{ij} + S_{jk} \cdot O_{jk} + S_{ki} \cdot O_{ki} - \frac{B_{ij}}{1 + B_{ij}} - \frac{B_{jk}}{1 + B_{jk}} - \frac{B_{ki}}{1 + B_{ki}} \tag{5}$$

The sign of the profits depends on the surprise wins, the odds and the magnitude of the bookmaker margins.

[15] Note that for every individual match $S_{ij} \neq 0$ as W_{ij} is either equal to 0 or equal to 1 and $0 < W_{ij}^e < 1$.

Columns (4) to (6) of Table 3 provide information about the non-transitive betting profits. If £1 would have been placed non-transitively on a win for each of the six matches within a season, the triad Tottenham – Man City – Newcastle would have generated an average seasonal profit of £3.28 (different from zero at a 1% level of significance).[16] Over the 21 seasons in the period of analysis betting £126 on this triad would have generated total profits of £69. Non-transitive betting in two other triads would have also generated significant positive profits: Tottenham – Man City – Man United and Tottenham – Man City – West Ham with total profits of respectively £45 and £43. Except for the triad Chelsea – Tottenham – Everton that has negative profits (insignificantly different from zero) all other triads would have generated positive profits although on average not significantly different from zero. All in all, it is clear that substantial profits could have been made using a non-sequential betting strategy.

Appendix B Figure B.2 shows the evolution of the cumulative betting profits over the period of analysis. By the end of the period of analysis cumulative betting profits are mostly positive. However, in earlier seasons this is not always the case. In some periods there are negative cumulative betting profits. Comparing Figures B.1 and B.2, it is clear that in periods when surprise wins were absent and thus the cumulative surprise wins were stable cumulative betting profits went down because of the bookmaker margins.

Finally, Appendix D Table D1 gives an overview of parameter estimates if the sample period for the balance of surprise wins is reduced by removing the last five seasons from the analysis, i.e., by removing the Covid-19 and post Covid-19 seasons. This appendix also presents the parameter estimates for betting profits if the analysis is reduced to the last five seasons. Although the point estimates are sometimes affected the main conclusions are not different.

7 Modeling Non-transitivity in Match Outcomes

In previous sections, non-transitivity of match outcomes is identified using simple comparisons of means. Since simple comparisons may not be sufficient to convince critical readers this section presents a formal analysis of the extent to which non-transitivity is present in match outcomes.

In the Bradley-Terry model, the probability that one team beats another team depends on the difference in skills or quality they possess (Bradley and Terry (1952)). The model for three teams i, j, and k can be specified as a logit model. The pairwise win probabilities

[16] So, the strategy would have been to bet on a win of Tottenham against Man City (twice), Man City against Newcastle (twice), and Newcastle against Tottenham (twice).

are determined by the difference in quality Q between the two teams:

$$p_{ij} = \frac{e^{Q_i - Q_j}}{1 + e^{Q_i - Q_j}}, \qquad p_{jk} = \frac{e^{Q_j - Q_k}}{1 + e^{Q_j - Q_k}}, \qquad p_{ik} = \frac{e^{Q_i - Q_k}}{1 + e^{Q_i - Q_k}} \tag{6}$$

The Bradley-Terry model has cardinal transitivity since p_{ik} is fully determined by p_{ij} and p_{jk}:

$$p_{ik} = \frac{p_{ij} \cdot p_{jk}}{1 + 2p_{ij} \cdot p_{jk} - p_{ij} - p_{jk}} \tag{7}$$

The model can be adjusted to account for non-transitivity by adding a parameter θ_{ik} to the probability that i beats k (Spearing et al. (2023)):

$$p_{ik} = \frac{1}{1 + e^{Q_k - Q_i + \theta_{ik}}} \tag{8}$$

If $\theta_{ik} = 0$, there is cardinal transitivity. If $\theta_{ik} \neq 0$, p_{ik} is not fully determined by the other two probabilities and strong transitivity is rejected. If θ_{ik} is negative (positive) this increases (decreases) the probability that team i beats team k relative to the effect of the difference in quality.

To analyze potential non-transitivity of match outcomes in triads, the first two equations of (6) and equation (8) are used and estimated. The qualities of the first two teams in every triad are estimated normalizing the quality of the third team to zero. Furthermore, a dummy variable is included for matches between the first and the third club in each triad. Panel a of Table 4 shows the parameter estimates of this model.

The first row shows that Tottenham and Man City have a significant higher quality than Newcastle. The interaction term for matches between Tottenham and Newcastle is negative and significantly different from zero suggesting that there is no cardinal transitivity in match outcomes between these three clubs. On average, Tottenham is about as strong as Man City (1.55-1.45=0.10), Man City is much stronger than Newcastle (1.45>0) which would suggest that Tottenham is also much stronger than Newcastle. However, Newcastle is about as strong as Tottenham (1.55-1.45=0.10).

For the remaining nine triads that results are the following. The parameter indicating the quality of the first team in the triad compared to the third team is positive and significantly different from zero. That is often but not always the case for the quality of the second team compared to the third team. The interaction term is always smaller than zero and often significantly so suggesting that there is no cardinal transitivity in match outcomes in any of the triads.

Table 4: **Non-transitive Triads–Parameter Estimates Logit Models of Win Probabilities**

a. Baseline				Q1		Q2		T1-T3		Prob Home Win		Obs.
1.	Tottenham	Man City	Newcastle	1.55	(0.50)***	1.45	(0.39)***	–1.45	(0.59)**			126
2.	Tottenham	Man City	Man United	0.53	(0.42)	0.26	(0.30)	–1.58	(0.54)***			138
3.	Aston Villa	Everton	West Ham	0.95	(0.50)*	0.48	(0.35)	–0.72	(0.61)			108
4.	Tottenham	Man City	West Ham	1.86	(0.53)***	1.55	(0.42)***	–1.45	(0.62)***			120
5.	Man City	Aston Villa	Everton	1.86	(0.53)***	0.41	(0.32)	–1.55	(0.62)**			120
6.	Chelsea	Tottenham	Aston Villa	1.43	(0.47)***	0.61	(0.33)*	–0.72	(0.58)			126
7.	Chelsea	Man City	Newcastle	1.68	(0.51)***	1.48	(0.40)***	–0.97	(0.61)			126
8.	Chelsea	Tottenham	Everton	1.70	(0.45)***	1.00	(0.33)***	–1.44	(0.54)***			144
9.	Chelsea	Man City	Aston Villa	1.75	(0.52)***	1.55	(0.42)***	–1.02	(0.62)			120
10.	Man United	Newcastle	West Ham	1.60	(0.51)***	0.43	(0.33)	–0.70	(0.62)			114
b. Sensitivity analysis												
1.	Tottenham	Man City	Newcastle	1.36	(0.53)***	0.81	(0.44)*	–1.76	(0.64)***	4.59	(1.47)***	126
2.	Tottenham	Man City	Man United	0.84	(0.46)*	0.30	(0.31)	–1.60	(0.55)***	2.89	(1.23)**	138
3.	Aston Villa	Everton	West Ham	0.88	(0.52)*	0.18	(0.38)	–0.83	(0.63)	6.52	(2.61)**	108
4.	Tottenham	Man City	West Ham	1.59	(0.55)***	0.98	(0.51)*	–1.60	(0.64)**	2.96	(1.63)*	120
5.	Man City	Aston Villa	Everton	1.51	(0.55)***	0.60	(0.34)*	–1.77	(0.66)***	5.33	(1.72)***	120
6.	Chelsea	Tottenham	Aston Villa	0.21	(0.66)	0.12	(0.38)	–0.85	(0.60)	6.17	(2.40)***	126
7.	Chelsea	Man City	Newcastle	0.82	(0.58)	0.70	(0.45)	–1.36	(0.69)	6.38	(1.50)***	126
8.	Chelsea	Tottenham	Everton	1.22	(0.62)**	0.81	(0.37)**	–1.46	(0.54)***	2.61	(2.39)	144
9.	Chelsea	Man City	Aston Villa	1.01	(0.59)*	1.00	(0.45)**	–1.26	(0.66)*	4.32	(1.51)***	120
10.	Man United	Newcastle	West Ham	0.37	(0.73)	0.32	(0.34)	–0.66	(0.64)	5.51	(2.39)**	114

Note: *** (**, *) indicates whether the parameter estimates are significantly different from zero at a 1% (5%, 10%) level.

To investigate the robustness of the findings in panel a of Table 4 some sensitivity analyses were done. First, expected wins – based on bookmaker data – were included as additional explanatory variable. Note that these expected win probabilities are determined shortly before the actual match takes place. If all available information is included in the odds no other variable should contribute to the explanation of the actual win probabilities. The results for this specification are shown in panel b. The probability of a home win is positively associated with the actual home win probability. Only for the triad Chelsea–Tottenham–Everton the positive association is not significantly different from zero. The effects of the quality of teams are lower than reported in panel a but still in many specifications the effects are significantly different from zero. Apparently bookmaker odds do not capture all available information about quality differences between teams. What is more important is that the interaction term is negative and often significantly different from zero. Clearly, bookmaker odds as they materialize in the expected probability of a home win do not take non-transitive outcomes of the triads into account. Second, in addition to the expected win seasonal fixed effects were included. In both cases, this hardly affected the parameter estimates of the interaction terms. Furthermore, if the quality/strength of the teams was allowed to gradually change over time the interaction terms were not much affected either.

Table 5: **Parameter Estimates Logit Models of Bookmaker-based Expected Win Probabilities**

				Q1		Q2		T1-T3		Obs.
1.	Tottenham	Man City	Newcastle	0.50	(0.18)***	0.94	(0.15)***	–0.03	(0.20)	126
2.	Tottenham	Man City	Man United	-0.43	(0.16)***	-0.02	(0.13)	–0.03	(0.17)	138
3.	Aston Villa	Everton	West Ham	0.08	(0.09)	0.20	(0.06)***	0.04	(0.10)	108
4.	Tottenham	Man City	West Ham	0.61	(0.16)***	1.07	(0.13)***	0.01	(0.17)	120
5.	Man City	Aston Villa	Everton	0.69	(0.15)***	-0.14	(0.06)**	–0.03	(0.19)	120
6.	Chelsea	Tottenham	Aston Villa	0.93	(0.09)***	0.38	(0.07)***	0.10	(0.11)	126
7.	Chelsea	Man City	Newcastle	1.04	(0.20)***	0.94	(0.15)***	–0.09	(0.21)	126
8.	Chelsea	Tottenham	Everton	0.81	(0.07)***	0.31	(0.04)***	0.05	(0.09)	144
9.	Chelsea	Man City	Aston Villa	1.05	(0.19)***	0.83	(0.14)***	0.00	(0.20)	120
10.	Man United	Newcastle	West Ham	1.08	(0.10)***	0.09	(0.06)	–0.07	(0.12)	114

Note: In parenthesis robust standard errors; *** (**, *) indicates whether the parameter estimates are significantly different from zero at a 1% (5%, 10%) level.

The probability of an expected home win as derived from bookmaker odds can also be related to the qualities of the three teams and an interaction term between the first and the third team. Using transformed dependent variables of expected home win probabilities p^e_{ij}, p^e_{jk}, and p^e_{ki} and imposing $Q_k = 0$:

$$\log(\tfrac{p^e_{ij}}{1-p^e_{ij}}) = Q_i - Q_j + \varepsilon_{ij},$$
$$\log(\tfrac{p^e_{jk}}{1-p^e_{jk}}) = Q_j + \varepsilon_{jk},$$
$$\log(\tfrac{p^e_{ki}}{1-p^e_{ki}}) = -Q_i + \gamma_{ik} + \varepsilon_{ki}.$$

The parameter estimates of the interaction terms between the first and third team presented in Table 5 are very different from those in Table 4. All of the interaction terms are very small and insignificantly different from zero. Clearly, in expected match outcomes based on bookmaker odds there is cardinal transitivity.

8 Concluding Remarks

Sports betting markets resemble traditional financial markets but are more accessible for empirical research. Therefore, they are often used as a field-lab example for studying the efficiency of financial markets. The main question is whether all available information is taken into account when bookmakers set their odds. The current paper is about betting on outcomes of football matches in the English Premier League. There are quite a few triads of clubs where often the first club beats the second, the second beats the third and the third club is victorious over the first club. Non-transitivity in match outcomes is a fascinating and recurrent phenomenon and it is clearly not taken into account in the sports betting market.

Bookmakers use cardinal transitivity when setting their odds. An obvious question is why bookmakers would allow bettors to make profits through non-transitive betting. Or, if the profits were not made, the question is why bettors did not exploit a simple non-transitive betting strategy. One can only speculate on this. A simple and straightforward explanation is that non-transitive outcomes may have occurred over a long period of time but these outcomes were not written in stone and therefore not recognized. Not by bookmakers and not by bettors. It is only in hindsight that profits could have been made. Indeed, as discussed there were seasons in which the non-transitive outcomes did not materialize and bettors would have lost money. However, it could also be that non-transitive betting is thought to be irrational not only from the perspective of the bookmakers but also from the perspective of the bettors. Returning to the topic of efficient markets, the finding that the non-transitive betting strategy could have been profitable indicates that sports betting markets are not efficient in the sense that not all available information is taken into account by bookmakers when they set their odds.

To have non-transitive outcomes over an extended period cannot simply be a coincidence. It defies logic and introduces an impossible trade-off for bookmakers between the use of recent information and the rational need to set consistent odds. For bookmakers, it may be unimaginable to set odds in a way that leads to internal inconsistency. The same holds for bettors; it is hard to imagine that they would risk their money on outcomes that are inherently inconsistent. The finding that there are non-transitive match outcomes in triads of clubs which bookmakers do not account for constitutes an anomaly.

Persistent non-transitivity in (football) match outcomes is a phenomenon that has not yet been explored systematically—neither as a sports phenomenon nor in relation to the efficiency of sports betting markets. A key question is whether the primary findings on how non-transitivity in match outcomes affects sports betting markets could extend to other markets where similar patterns may emerge.

References

Angelini, G. and L. De Angelis (2019). Efficiency of online football betting markets. *International Journal of Forecasting 35*(2), 712–721.

Batzilis, D., S. Jaffe, S. Levitt, J. A. List, and J. Picel (2019). Behavior in strategic settings: Evidence from a million Rock-Paper-Scissors games. *Games 10*(2), 18.

Bozóki, S., L. Csató, and J. Temesi (2016). An application of incomplete pairwise comparison matrices for ranking top tennis players. *European Journal of Operational Research 248*(1), 211–218.

Bryson, A., P. Dolton, J. J. Reade, D. Schreyer, and C. Singleton (2021). Causal effects of an absent crowd on performances and refereeing decisions during Covid-19. *Economics Letters 198*, 109664.

Cain, M., D. Law, and D. Peel (2000). The favourite-longshot bias and market efficiency in UK football betting. *Scottish Journal of Political Economy 47*(1), 25–36.

Dixon, M. J. and S. G. Coles (1997). Modelling association football scores and inefficiencies in the football betting market. *Journal of the Royal Statistical Society: Series C (Applied Statistics) 46*(2), 265–280.

Dixon, M. J. and P. F. Pope (2004). The value of statistical forecasts in the UK association football betting market. *International Journal of Forecasting 20*(4), 697–711.

Elaad, G., J. J. Reade, and C. Singleton (2020). Information, prices and efficiency in an online betting market. *Finance Research Letters 35*, 101291.

Elo, A. E. (1978). *The Rating of Chessplayers, Past and Present*. London Batsford.

Fama, E. F. (1970). Efficient capital markets: A review of theory and empirical work. *The Journal of Finance 25*(2), 383–417.

Feddersen, A., B. R. Humphreys, and B. P. Soebbing (2017). Sentiment bias and asset prices: Evidence from sports betting markets and social media. *Economic Inquiry 55*(2), 1119–1129.

Feddersen, A., B. R. Humphreys, and B. P. Soebbing (2018). Sentiment bias in National Basketball Association betting. *Journal of Sports Economics 19*(4), 455–472.

Feddersen, A., B. R. Humphreys, and B. P. Soebbing (2023). Contest incentives, team effort, and betting market outcomes in European football. *European Sport Management Quarterly 23*(3), 605–621.

Fischer, K. and W. B. Schmal (2025). Pricing in response to new information: The case of betting markets. *Economic Inquiry 63*(1), 236–264.

Flepp, R., O. Merz, and E. Franck (2024). When the league table lies: Does outcome bias lead to informationally inefficient markets? *Economic Inquiry 62*(1), 414–429.

Hegarty, T. and K. Whelan (2025). Forecasting soccer matches with betting odds: A tale of two markets. *International Journal of Forecasting 41*, forthcoming.

Hickman, D. and N. Metz (2025). How quickly do markets incorporate new information? Evidence from the NCAA men's basketball betting market. *Applied Economics 0*(0), 1–17.

Igan, D., M. Pinheiro, and J. Smith (2015). A study of a market anomaly: "White men can't jump", but would you bet on it? *Journal of Economic Behavior & Organization 113*, 13–25.

Kahneman, D. and A. Tversky (1979). Prospect theory: An analysis of decision under risk. *Econometrica 47*(2), 263–291.

Kendall, M. G. and B. B. Smith (1940). On the method of paired comparisons. *Biometrika 31*(3/4), 324–345.

Koning, R. H. and R. Zijm (2023). Betting market efficiency and prediction in binary choice models. *Annals of Operations Research 325*, 135–148.

Kuypers, T. (2000). Information and efficiency: An empirical study of a fixed odds betting market. *Applied Economics 32*, 1353–1363.

Larsen, T., J. Price, and J. Wolfers (2008). Racial bias in the NBA: Implications in betting markets. *Journal of Quantitative Analysis in Sports 4*(2).

Levitt, S. D. (2004). Why are gambling markets organised so differently from financial markets? *The Economic Journal 114*(495), 223–246.

Makropoulou, V. and R. N. Markellos (2011). Optimal price setting in fixed-odds betting markets under information uncertainty. *Scottish Journal of Political Economy 58*(4), 519–536.

Meier, P. F., R. Flepp, and E. Franck (2021). Are sports betting markets semi-strong efficient? Evidence from the COVID-19 Pandemic. *International Journal of Sport Finance 16*(3), 111–126.

Moskowitz, T. J. (2021). Asset pricing and sports betting. *Journal of Finance 76*(6), 3153–3209.

Newall, P. W. S. and D. Cortis (2021). Are sports bettors biased toward longshots, favorites, or both? A literature review. *Risks 9*(1), 1–9.

Poddiakov, A. (2025). Are mathematicians, physicists and biologists irrational? Intransitivity studies vs. the transitivity axiom. *Human Arenas*, forthcoming.

Pope, P. F. and D. A. Peel (1989). Information, prices and efficiency in a fixed-odds betting market. *Economica 56*(223), 323–341.

Quandt, R. E. (1986). Betting and equilibrium. *The Quarterly Journal of Economics 101*(1), 201–207.

Sauer, R. D. (1998). The economics of wagering markets. *Journal of Economic Literature 36*(4), 2021–2064.

Scarf, P., R. Parma, and I. McHale (2019). On outcome uncertainty and scoring rates in sport: The case of international rugby union. *European Journal of Operational Research 273*(2), 721–730.

Shin, H. S. (1991). Optimal betting odds against insider traders. *The Economic Journal 101*(408), 1179–1185.

Shin, H. S. (1992). Prices of state contingent claims with insider traders, and the favourite-longshot bias. *The Economic Journal 102*(411), 426–435.

Shin, H. S. (1993). Measuring the incidence of insider trading in a market for state-contingent claims. *The Economic Journal 103*(420), 1141–1153.

Snowberg, E. and J. Wolfers (2010). Explaining the favorite–long shot bias: Is it risk-love or misperceptions? *Journal of Political Economy 118*(4), 723–746.

Stetzka, R. M. and S. Winter (2023). How rational is gambling? *Journal of Economic Surveys 37*(4), 1432–1488.

Strumbelj, E. (2014). On determining probability forecasts from betting odds. *International Journal of Forecasting 30*(4), 934–943.

Strumbelj, E. (2016). A comment on the bias of probabilities derived from betting odds and their use in measuring outcome uncertainty. *Journal of Sports Economics 17*(1), 12–26.

Strumbelj, E. and M. R. Šikonja (2010). Online bookmakers' odds as forecasts: The case of European soccer leagues. *International Journal of Forecasting 26*(3), 482–488. Sports Forecasting.

Temesi, J., Zs. Szádoczki, and S. Bozóki (2024). Incomplete pairwise comparison matrices: Ranking top women tennis players. *Journal of the Operational Research Society 75*(1), 145–157.

Thaler, R. H. and W. T. Ziemba (1988). Parimutuel betting markets: Racetracks and lotteries. *Journal of Economic Perspectives 2*(2), 161–174.

Van Ours, J. C. (2024). Non-transitive patterns in long-term football rivalries. *Journal of Sports Economics 25*(7), 802–826.

Vandenbruaene, J., M. D. Ceuster, and J. Annaert (2022). Efficient spread betting markets: A literature review. *Journal of Sports Economics 23*(7), 907–949.

Winkelmann, D., C. Deutscher, and M. Ötting (2021). Bookmakers' mispricing of the disappeared home advantage in the German Bundesliga after the Covid-19 break. *Applied Economics 53*(26), 3054–3064.

Winkelmann, D., M. Ötting, C. Deutcher, and T. Makarewicz (2024). Are betting markets inefficient? Evidence from simulations and real data. *Journal of Sports Economics 25*(1), 54–97.

Appendix A: Details on the data

From 2000/01 to 2023/24 46 clubs played in the English Premier League. Table A.1 provides an overview. Four clubs played for only one season in the EPL while six clubs were present all 24 seasons. The analysis is based on the ten clubs that were present for at least 21 seasons.

Table A.1: **English Premier League Clubs by Seasons; 2000/01 - 2023/24**

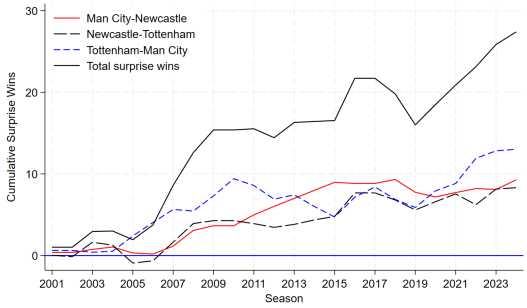
Clubs	Seasons
Blackpool, Bradford City, Coventry City, Luton Town	1
Cardiff City, Huddersfield Town, Ipwich Town, Nottingham Forest	2
Brentford, Derby County, Queens Park Rangers, Reading	3
Sheffield United	4
Hull City	5
Birmingham City, Bournemouth, Brighton & Hove Albion, Charlton Athletic	
Leeds United, Norwich City, Portsmouth, Swansea City, Watford	7
Wigan Athletic	8
Burnley	9
Middlesbrough, Stoke City, Wolverhampton Wanderers	10
Blackburn Rovers, Bolton Wanderers	11
Crystal Palace, Leicester City	12
West Bromwich Albion	13
Sunderland	14
Southampton	16
Fulham	17
Aston Villa, West Ham United	21
Newcastle United	22
Manchester City	23
Arsenal, Chelsea, Everton, Liverpool, Manchester United, Tottenham Hotspur	24

Information about match outcomes and bookmaker odds are from *www.football-data.co.uk*. Bookmaker odds used are closing odds, i.e., last odds before the match starts. All odds are from *William Hill* except for the 29 matches for which these odds were missing. For those 29 matches odds from *Interwetten* are used.

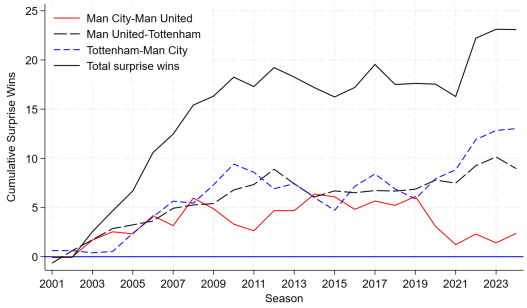
Appendix B: Developments over time

Figure B.1: **Cumulative Surprise Wins; Ten Triads; 2000/01 - 2023/24**

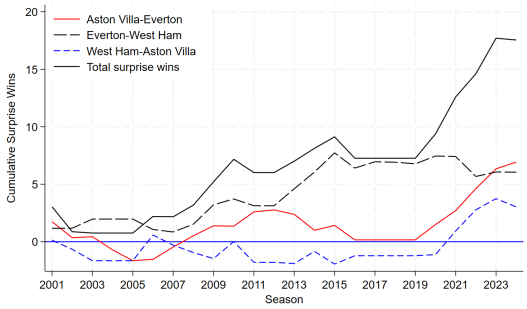
a. Tottenham-Man City-Newcastle



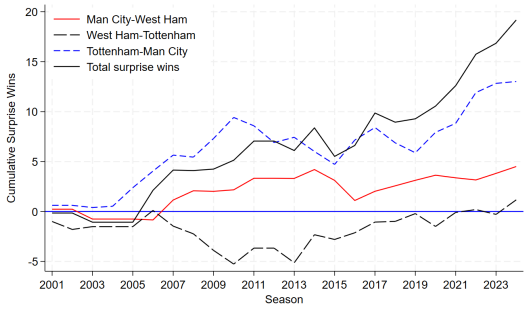
b. Tottenham-Man City-Man Uited



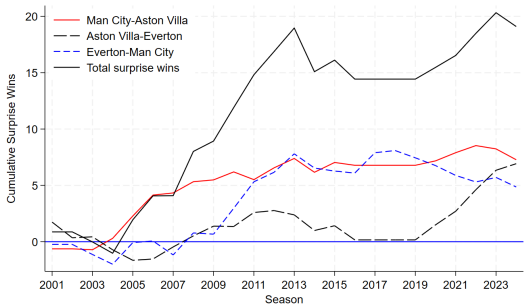
c. Aston Villa-Everton-West Ham



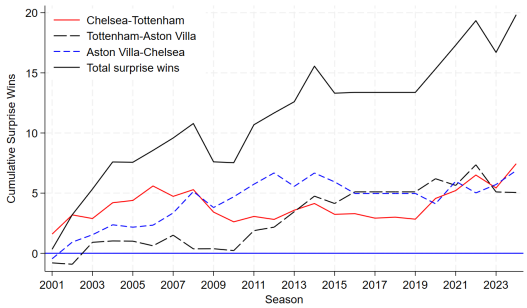
d. Tottenham-Man City-West Ham



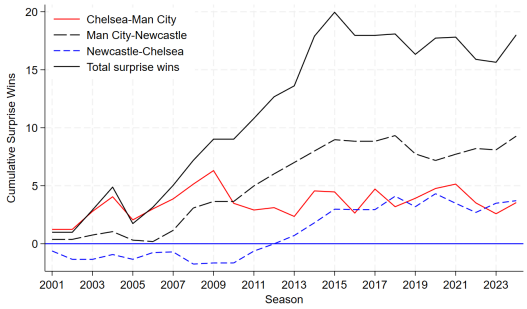
e. Man City-Aston Villa-Everton



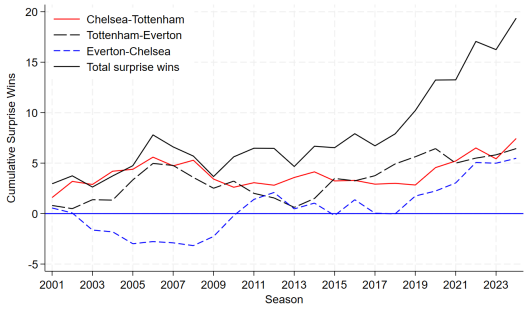
f. Chelsea-Tottenham-Aston Villa



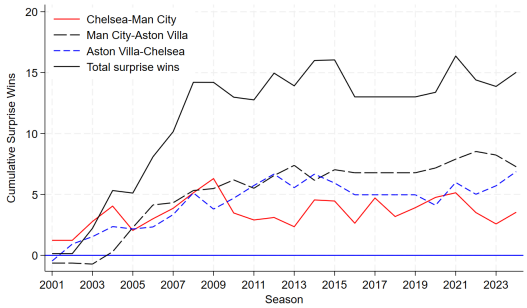
g. Chelsea-Man City-Newcastle



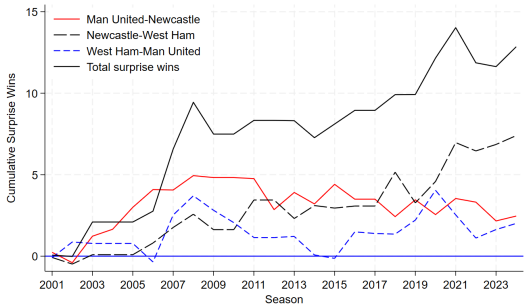
h. Chelsea-Tottenham-Everton



i. Chelsea-Man City-Aston Villa



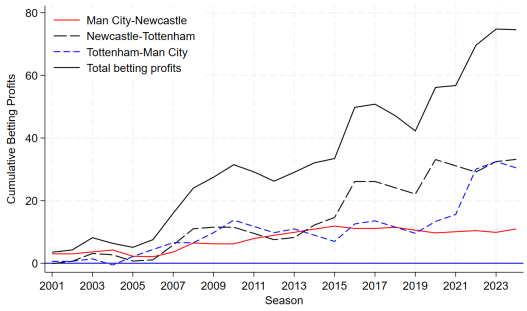
j. Man United-Newcastle-West Ham



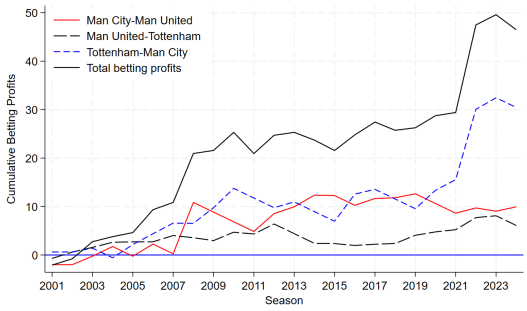
Note: The differences are calculated for the first team of each match pair.

Figure B.2: **Cumulative Betting Profits; Ten Triads; 2000/01 - 2023/24**

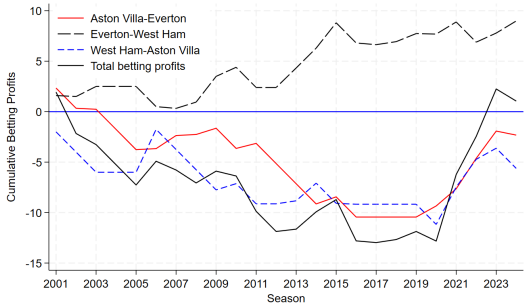
a. Tottenham-Man City-Newcastle



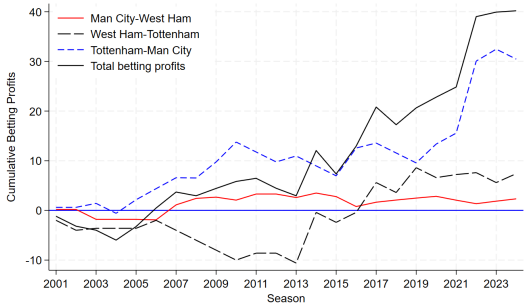
b. Tottenham-Man City-Man Uited



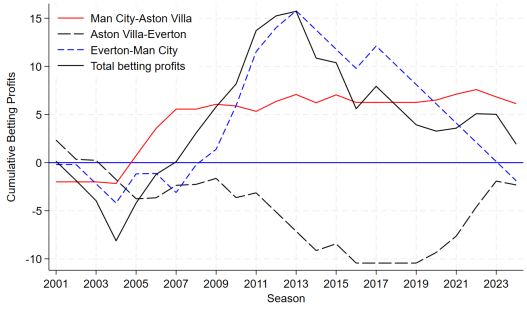
c. Aston Villa-Everton-West Ham



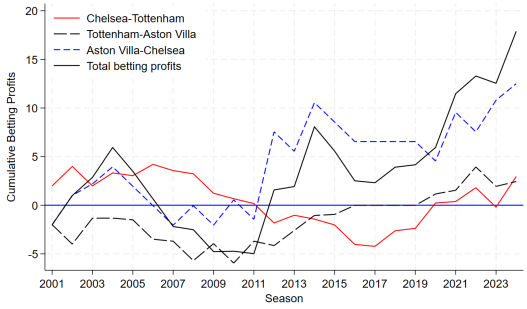
d. Tottenham-Man City-West Ham



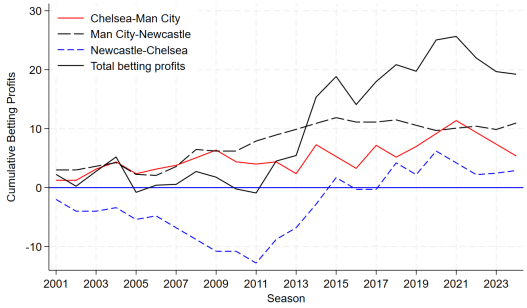
e. Man City-Aston Villa-Everton



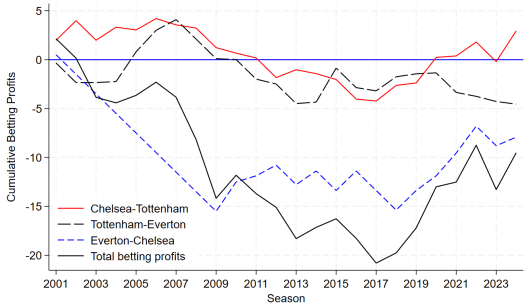
f. Chelsea-Tottenham-Aston Villa



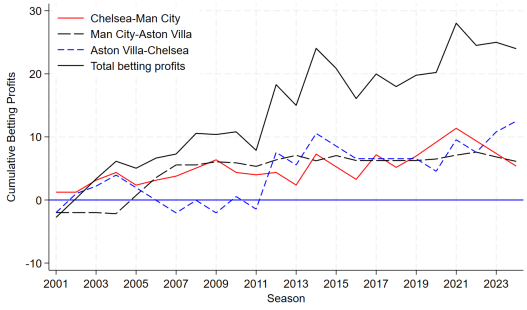
g. Chelsea-Man City-Newcastle



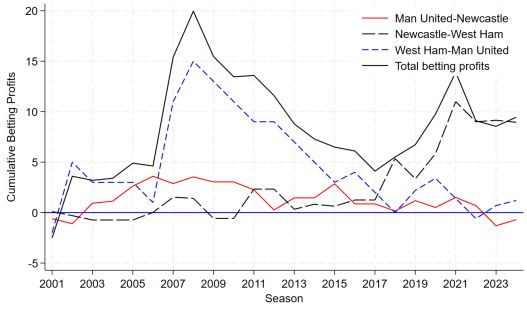
h. Chelsea-Tottenham-Everton



i. Chelsea-Man City-Aston Villa



j. Man United-Newcastle-West Ham



Note: The differences are calculated for the first team of each match pair.

Appendix C: Fouls, Yellow Cards and Red Cards

Table C1: **Non-transitive Triads; Cumulative Balance of Fouls, Yellow Cards and Red Cards; 2000/01 - 2023/24**

				Cumulative			Average					
				Fouls	Yellow	Red	Fouls		Yellow		Red	N
1.	Tottenham	Man City	Newcastle	–60	9	1	–2.9		0.4		0.0	21
2.	Tottenham	Man City	Man United	25	25	–2	1.1		1.1	*	–0.1	23
3.	Aston Villa	Everton	West Ham	118	16	–3	7.4	***	0.9		–0.2	18
4.	Tottenham	Man City	West Ham	26	29	1	1.3		1.5	*	0.1	20
5.	Man City	Aston Villa	Everton	89	1	–1	4.4	**	0.1		–0.1	20
6.	Chelsea	Tottenham	Aston Villa	–64	22	–7	–3.1		1.0		–0.3	21
7.	Chelsea	Man City	Newcastle	–87	4	–5	–4.1		0.2		–0.2	21
8.	Chelsea	Tottenham	Everton	–18	–14	2	–0.8		–0.6		0.1	24
9.	Chelsea	Man City	Aston Villa	–25	16	–5	–1.2		0.8		–0.3	20
10.	Man United	Newcastle	West Ham	9	–1	–3	0.5		–0.1		–0.2	19

Note: *** (**, *) indicates estimate different from zero at a 1% (5%, 10%) level. Cum=cumulative over all seasons. N = number of seasons all teams of the triad were playing.

Table C1 provides an overview of the balance of fouls, yellow cards and red cards for each of the non-transitive triads. For the triad Tottenham - Man City - Newcastle the overall balance of fouls was -60. So, the finding that in terms of match outcomes Tottenham is likely to beat Man City, Man City is likely to beat Newcastle and Newcastle is likely to beat Tottenham is associated with a negative balance of fouls, a positive balance in terms of yellow cards and a positive balance of red cards. However, none of these balances is on average significantly different from zero. Also, for the other nine triads there is no consistent balance in fouls, yellow cards and red cards.

For yellow cards there are significant positive balances for two triads. For fouls there are significant balances for two other triads. This is suggestive of the match wins to coincide with more aggressive behavior on the pitch. However, this is the case only in four out of the ten non-transitive triads. In conclusion, there does not seem to be a clear pattern in the balances of fouls, yellow cards or red cards.

Appendix D: Sensitivity Analysis by Time Period

To investigate the sensitivity of the main findings, the surprise wins analysis for the ten triads has been done over a shorter time period, i.e., 2000/01 - 2018/19. This means that the period of analysis stops five seasons earlier, before the onset of the Covid-19 restrictions on stadium attendance. The results are shown in Table D.1. The magnitude of the point estimates is sometimes reduced but often the results are similar to the baseline estimates presented in Table 3. The precision of the parameter estimates is reduced due to the reduction in the number of seasons in the analysis.

Table D.1: **Non-transitive Triads; Sensitivity Analysis**

				2000/01 - 2018/19				2019/20 - 2023/24			
				Surprise wins		Cum	N	Betting profits		Cum	N
1.	Tottenham	Man City	Newcastle	1.00	(0.61)*	16	16	6.47	(2.97)**	32	5
2.	Tottenham	Man City	Man United	0.98	(0.40)**	18	18	4.05	(3.64)	20	5
3.	Aston Villa	Everton	West Ham	0.56	(0.48)	7	13	2.58	(1.56)*	13	5
4.	Tottenham	Man City	West Ham	0.62	(0.44)*	9	15	3.91	(2.59)	20	5
5.	Man City	Aston Villa	Everton	0.96	(0.55)**	14	15	–0.40	(0.76)	–2	5
6.	Chelsea	Tottenham	Aston Villa	0.84	(0.44)**	13	16	2.75	(1.19)**	14	5
7.	Chelsea	Man City	Newcastle	1.02	(0.47)**	16	16	–0.10	(1.54)	–1	5
8.	Chelsea	Tottenham	Everton	0.54	(0.36)*	10	19	1.54	(1.66)	8	5
9.	Chelsea	Man City	Aston Villa	0.87	(0.50)*	13	15	0.84	(1.89)	4	5
10.	Man United	Newcastle	West Ham	0.71	(0.40)**	10	14	0.54	(1.57)	3	5

Note: Standard errors in parentheses; *** (**, *) indicates an average different from zero at a 1% (5%, 10%) level (1-sided test). Cum = cumulative over all seasons. N = number of seasons all teams of the triad were playing.

Table D.1 also shows the parameter estimates for the betting profits over the period 2019/20 - 2023/24, i.e., the last five seasons in the period of analysis. Again, the point estimates are sometimes different from those presented in Table 3 but also here there are three triads with positive and significant betting profits. Only two triads have negative but insignificant betting profits. The remaining five triads have positive but insignificant betting profits over the last five seasons. In conclusion, also over a much shorter time period it is possible to have many significant balances of surprise wins and have accompanying positive profits in the subsequent period.