

Are penalty shootouts better than a coin toss? Evidence from international club football in Europe

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Abstract

Penalty shootouts play an important role in the knockout stage of major football tournaments, especially since the 2021/22 season, when the Union of European Football Associations (UEFA) scrapped the away goals rule in its club competitions. Inspired by this rule change, our paper examines whether the outcome of a penalty shootout can be predicted in UEFA club competitions. Based on all shootouts between 2000 and 2025, we find no evidence for the effect of the kicking order, the field of the match, or psychological momentum. In contrast to previous results, stronger teams, defined first by Elo ratings, do not perform better than their weaker opponents. Consequently, penalty shootouts seem to be close to a coin toss in top European club football.

Keywords: Elo rating; fairness; football; momentum; penalty shootout

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1 Introduction

The penalty shootout is the ultimate tie-breaking rule in (association) football and several other sports to decide which team qualifies in a knockout match. Penalty shootouts usually take place if the result is tied in both regular and extra time. Penalty shootouts can directly follow regular time, too: in the 2025 Leagues Cup, teams were awarded three points for a win in regular time, two points for a win by a penalty shootout, and one point for a loss by a penalty shootout (Leagues Cup, 2025).

Penalty shootouts are the subject of serious academic interest since Apesteguia and Palacios-Huerta (2010) has appeared in a leading economic journal, the *American Economic Review*, one and a half decades ago (see Section 2). In particular, the authors found a systematic first-mover advantage; the team kicking the first penalty has a significantly higher probability of winning the penalty shootout than its opponent.

The present paper contributes to this discussion by investigating four research questions:

1. Does the shooting order affect the outcome of a penalty shootout?
2. Does the field of the match affect the outcome of a penalty shootout?
3. Does psychological momentum affect the outcome of a penalty shootout?
4. Does the strength of the teams affect the outcome of a penalty shootout?

All of these issues have partially been investigated in the existing literature, as revealed by Section 2. However, our research has three innovative aspects. First, we analyse a relatively homogeneous sample provided by matches played in UEFA club competitions without any matches from national cups, where the strengths of the opponents can vary widely. Second, psychological momentum enjoyed by the comeback team is identified in a novel way, according to which team scored the last goal. Third, team strength is measured by Football Club Elo Ratings, a well-established statistical method to create ratings based on past performance (Aldous, 2017; Gomes de Pinho Zanco et al., 2024; van Eetvelde and Ley, 2019). Previous studies used either the division of the team (Arrondel et al., 2019; Krumer, 2020), or betting odds (Wunderlich et al., 2020; Pipke, 2025) for this purpose.

As we show, the outcomes of the 268 penalty shootouts played in UEFA club competitions between 2000 and 2025 seem to be entirely unpredictable. This contradicts the results of some previous works, which uncover a first-mover advantage (Apesteguia and Palacios-Huerta, 2010; Palacios-Huerta, 2014; Da Silva et al., 2018; Rudi et al., 2020) and the positive impact of psychological momentum (Krumer, 2021). Furthermore, according to our knowledge, *all* existing studies agree that stronger teams are more likely to win in a shootout (Arrondel et al., 2019; Krumer, 2020; Wunderlich et al., 2020; Pipke, 2025), which cannot be observed in UEFA club competitions.

Our findings could be especially important for the Union of European Football Associations (UEFA) when they decide on rule changes in the future. In 2021, UEFA abolished the so-called away goals rule, which awarded the prize (qualification for the next round) in a two-legged match to the team that scored more away goals. This change has increased the probability of reaching a penalty shootout by approximately ten percentage points, from below 5% to nearly 15% (Forrest et al., 2025). In addition, UEFA has recently given serious consideration to removing extra time in order to ease the burden of the best players (Ames, 2025). Since the outcome of a penalty shootout approximates a coin toss in UEFA club competitions with respect to these observables, such a measure would favour weaker

teams and teams playing away, level the playing field, and decrease the dominance of the top clubs.

The paper is structured as follows. An overview of related studies is given in Section 2. The data and the methodology are described in Sections 3 and 4, respectively. Section 5 presents and discusses the results, while Section 6 concludes.

2 Related literature

The issue of first-mover advantage in football penalty shootouts has received serious attention since the pioneering work of [Apesteguia and Palacios-Huerta \(2010\)](#). Some studies find evidence for a significant advantage enjoyed by the team kicking the first penalty in each round ([Apesteguia and Palacios-Huerta, 2010](#); [Palacios-Huerta, 2014](#); [Da Silva et al., 2018](#); [Rudi et al., 2020](#)). These results have inspired formal modelling of the first-mover advantage, as well as several proposals for alternative mechanisms to mitigate or even eliminate this source of unfairness ([Palacios-Huerta, 2012](#); [Echenique, 2017](#); [Brams and Ismail, 2018](#); [Vandebroek et al., 2018](#); [Del Giudice, 2019](#); [Anbarcı et al., 2021](#); [Csató, 2021a,b](#); [Csató and Petróczy, 2022](#); [Brams et al., 2024](#)). The alternating (or ABBA) order was even tried in various tournaments between 2017 and 2018 ([Palacios-Huerta, 2020](#); [Csató, 2021a](#)), albeit the IFAB (International Football Association Board), the rule-making body of football, stopped the experiments in 2018 ([FIFA, 2018](#)). It is worth noting that the first-mover advantage seems to be non-existent in tennis tiebreaks, which use the ABBA sequence ([Cohen-Zada et al., 2018](#); [Da Silva et al., 2018](#)).

On the other hand, several papers report no significant difference between the winning probability of the first-mover and the second-mover ([Kocher et al., 2012](#); [Arrondel et al., 2019](#); [Santos, 2023](#)). According to [Kassis et al. \(2021\)](#), teams whose captains win the coin toss and can choose the shooting order enjoy the advantage. The conflicting results can probably be attributed to small sample sizes ([Vandebroek et al., 2018](#)). Two recent studies ([Vollmer et al., 2024](#); [Pipke, 2025](#)) analysing the highest number of penalty shootouts with respect to first-mover advantage—1759 and 7116, respectively—do not find evidence for the effect of the shooting sequence. However, while the dataset of [Pipke \(2025\)](#) includes all available shootouts up to the 2023/24 season, this does not mean that first-mover advantage cannot emerge in a more homogeneous subset of matches.

Regarding the existence of a penalty-specific home advantage, [Apesteguia and Palacios-Huerta \(2010\)](#) show no difference in the chances of home and away teams for 129 shootouts between 1976 and 2003. [Kocher et al. \(2012\)](#) reinforce this based on 540 shootouts between 1970 and 2003. Analogously, playing at home does not influence the probability of winning in 252 shootouts from French cup competitions ([Arrondel et al., 2019](#)). The results of [Wunderlich et al. \(2020\)](#) suggest no home advantage in 1067 penalty shootouts that took place between 2004 and 2018. The logistic regression of [Bahamonde-Birke and Bahamonde-Birke \(2023\)](#) based on a sample of 471 shootouts demonstrates the absence of such an effect, too. Even though [van Ours and van Tuijl \(2024\)](#) state that a penalty shootout does not seem to be a lottery in the Dutch domestic cup, the 20 home wins out of the 33 shootouts (61%) are not significantly different from 50%.

We know only one study on the impact of psychological momentum, although the performance of men is significantly affected by psychological momentum in sports ([Cohen-Zada et al., 2017](#)). [Krumer \(2021\)](#) analyses 214 penalty shootouts from two-legged matches in European cups (European Champion Clubs' Cup/UEFA Champions League, European Cup Winners' Cup/UEFA Cup Winners' Cup, UEFA Cup/UEFA Europa League) between

Table 1: Penalty shootouts in UEFA club competitions from the 2000/01 season to 2025

	Champions League	Europa League	Conference League	Total
Qualification	41 (19)	103 (31)	63 (63)	207 (113)
Knockout stage	14 (5)	27 (9)	9 (9)	50 (23)
Final	6 (0)	5 (3)	0 (0)	11 (3)
Total	61 (24)	135 (43)	72 (72)	268 (139)

UEFA Conference League was called UEFA Europa Conference League until the 2023/24 season.

The row Knockout stage counts only two-legged matches, but not the final, which is played on a neutral field. Numbers in parenthesis show the matches played from the 2020/21 season to 2025.

1970 and 2018. Every additional goal scored by the away team in regular time in the second leg increases its probability of winning the penalty shootout by 12.5 percentage points. However, if the home team wins in regular time, it has only a 50% chance to qualify after a shootout.

[Arrondel et al. \(2019\)](#) reveal that the team playing at a higher level than its opponent wins the penalty shootout with an approximately 20% higher probability. Analogously, a team from a higher division has a significantly higher chance to win according to [Krumer \(2020\)](#): a difference in one league translates to a gap of 8 percentage points in winning probabilities. For instance, a team from the first division defeats its opponent from the second division with a probability of 54%. The author studies 586 shootouts in the cup competitions of the top five European football nations (England, France, Germany, Italy, Spain) between 1979 and 2018.

Stronger football teams have a significantly higher chance of winning a penalty shootout based on 1067 shootouts from the domestic cup competitions of ten European associations (the top five, as well as Belgium, Portugal, Russia, Turkey, Ukraine), the Brazilian cup, the UEFA Champions League, and the UEFA Europa League ([Wunderlich et al., 2020](#)). However, the effect of team strength on success remains rather small; the winning probability does not exceed 60% even against an extremely weak team. The novelty of [Wunderlich et al. \(2020\)](#) resides in the measure of strength difference, determined by winning probabilities based on pre-match betting odds, adjusted for home advantage. The recent analysis of all available penalty shootouts until the 2023/24 season reinforces that the favourites identified by pre-match odds are more likely to win ([Pipke, 2025](#), Table A.5). But the favourite team might not be the stronger team due to home advantage ([Wunderlich et al., 2020](#)).

[Brinkschulte et al. \(2023\)](#) examine the effect of skill on the success of individual penalty kicks. Skill is a composite measure of player market value, goalkeeper market value, and team quality derived from betting odds. Based on 1574 penalties in major international tournaments, the probability that the goalkeeper saves a penalty that is shot on target decreases if a highly skilled player takes the kick.

To summarise, *all* studies considering the strength of teams find at least some bias towards the stronger team in winning penalty shootouts. In other words, penalty shootouts are not equivalent to a pure coin toss; ability is an important success factor even for a mechanical task carried out in a high-pressure environment.

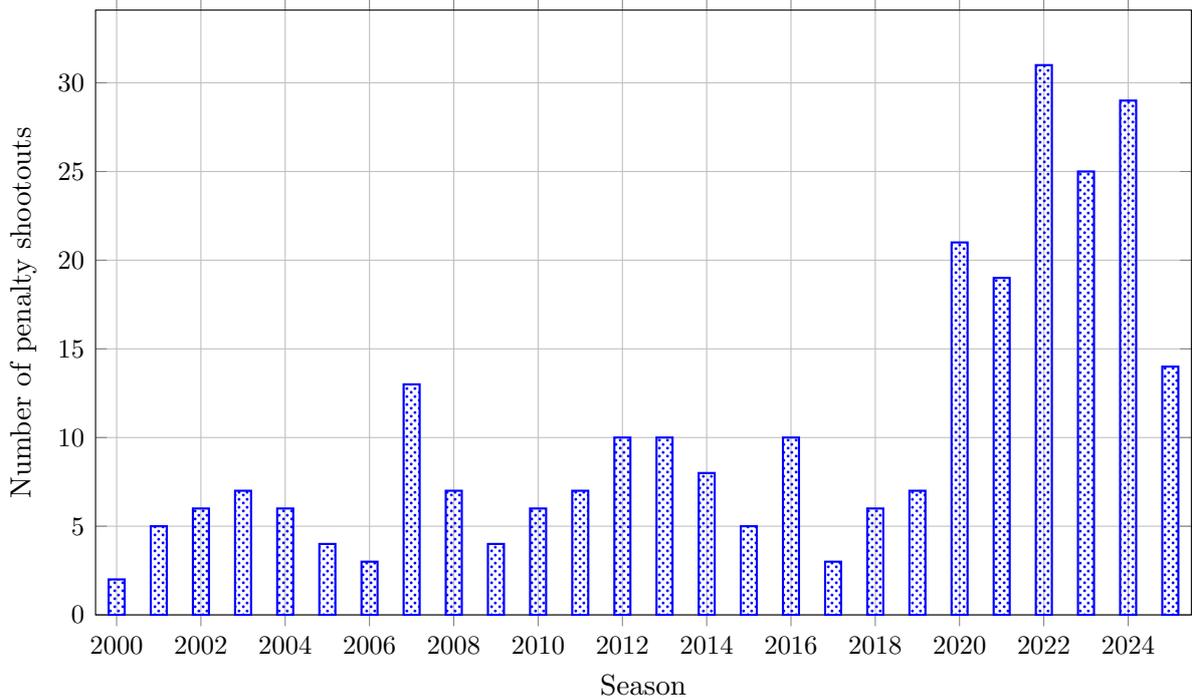


Figure 1: Number of penalty shootouts in UEFA club competitions in each season

Note: Seasons are identified by their starting year.

3 Data

We have collected data from all penalty shootouts that took place in UEFA club competitions, including their qualifiers, from the 2000/01 season until the end of 2025. In the 2025/26 season, only the qualification matches are considered since the knockout stage of this season is played only in 2026. Table 1 summarises the distribution of shootouts across the three tournaments, as well as across their stages. The final is distinguished from other knockout stage matches because it consists of one game played at a neutral venue and is not the usual two-legged match, where one team plays at home in a second leg.

Figure 1 presents the number of penalty shootouts in each season from 2000/01 to 2025/26 (in the latter case, without the spring of 2026). Besides the natural fluctuation, a dramatic increase can be seen from 2020/21, when most qualification matches were played in one leg instead of two due to COVID-19 restrictions, such that the field of the match was decided by a random draw. In addition, the away goals rule was abolished, and a new competition, the UEFA (Europa) Conference League, started in 2021/22. Therefore, our sample is dominated by recent matches over these 25 years: 139 of the 268 penalty shootouts (51.9%) took place in the last six seasons (Table 1).

For all matches decided by a penalty shootout, the dataset contains (a) the time of the match; (b) the round of the game in the tournament; (c) the names of both teams; (d) the location of the match; (e) the number of goals scored by both teams in the match; (f) the name of the team that scored the last goal in regular or extra time (if relevant); (g) the team that kicked the first penalty (first-mover).

The first-mover advantage can be analysed on the basis of all (268) penalty shootouts since this information is always available. On the other hand, some matches were played on a neutral field. In order to examine home advantage, we consider two sets of matches, an extended and a restricted set, where the latter is a strict subset of the former. The extended

set does not contain the finals except for the 2011/12 UEFA Champions League final, which was played in München by Bayern München and Chelsea (10 matches are dropped). In addition, one match played by an Israeli and two matches played by Belarusian teams in 2024 and 2025 are disregarded, which leads to 255 matches in the extended set. In the restricted set, 20 matches played behind closed doors in the 2020/21 season, as well as the 2011/12 UEFA Champions League final, are removed.

We identify a comeback team in two different ways. The first adopts the method of [Krumer \(2021\)](#): the team that scored more goals than its opponent (has a positive goal difference) in the match is the comeback team. Consequently, 121 matches where the second leg game is tied should be ignored. The second approach is novel: the team that scored the last equalising goal, which is responsible for reaching the penalty shootout, is the comeback team. Hence, only 37 shootouts could not be examined.

The strengths of teams are quantified by Football Club Elo Ratings (<http://clubelo.com>). [Csató \(2024\)](#) shows that this measure of strength predicts the results of the UEFA Champions League more accurately than the official UEFA club coefficient. Unsurprisingly, Football Club Elo Ratings are widely used in the literature, too ([Bosker and Gürtler, 2024](#); [Csató, 2022](#); [Yildirim and Bilman, 2025a,b](#)). They are available for all penalty shootouts, although we have found a problem in the database of Football Club Elo Ratings (see [Appendix A.1](#) for details). Thus, the impact of the difference in team strength is studied based on 266 penalty shootouts in the baseline, because two Elo ratings are inaccurate. As a robustness check, we also use different thresholds t : a match is retained in the sample only if the difference between the Elo ratings exceeds t .

It may be argued that betting odds could be a better predictor of team strength in penalty shootouts. However, betting odds are known to suffer from several biases ([Braun and Kvasnicka, 2013](#); [Cain et al., 2000](#); [Feddersen et al., 2017](#); [Winkelmann et al., 2021](#)). Furthermore, the betting odds published by bookmakers are usually related to the outcome of one particular match, but our database mostly contains the second legs of knockout ties. Therefore, the favourite team identified by betting odds might not be the stronger team because of home advantage. Even though [Wunderlich et al. \(2020, Section 2.3\)](#) suggests a method to adjust this bias, which allows the classification of a slight favourite as the slightly weaker team, such a procedure is not necessarily reliable in two-legged matches. The reason is the incentives of the teams: one team could be satisfied by a small loss if it still implies its qualification. For instance, if the away team won the first match by two goals, it does not have powerful incentives to attack in the second match even if it has scored one goal less than the other team. The betting odds of a home/away win certainly reflect the effect of these incentives, which have substantially changed from the 2021/22 season due to the abolition of the away goals rule.

Compared to Elo ratings, betting odds can indeed reflect better the current form of the teams by taking, for example, injuries, into account. However, it is far from clear that these factors are relevant to penalty shootouts, where success is based on individual skills, not on collaboration within a team. The use of Elo ratings, given by an “objective” mathematical formula, may also be more persuasive for decision-makers than betting odds driven by market sentiment. Finally, Football Club Elo Ratings have recently been demonstrated to outperform UEFA club coefficients, the official measure of team strength in these competitions, with respect to predictive accuracy ([Csató, 2024](#)). Based on these arguments, we follow the approach of previous papers ([Arrondel et al., 2019](#); [Krumer, 2020](#); [Wunderlich et al., 2020](#); [Pipke, 2025](#)), and do not consider alternative measures of team ability.

4 Methodology

All research questions are first investigated by a two-sided binomial test. The number of penalty shootout wins and losses is calculated for the first-mover, the home team (two cases depending on the definition of neutral field), the comeback team (two cases depending on the type of psychological momentum), and the stronger team (five cases depending on the minimal threshold t).

The connection between the relative strength of teams and the probability of winning the penalty shootout is assessed by logistic regressions, too. The binary dependent variable is the home win/loss. Therefore, matches played on a neutral venue are removed due to the small sample size, similar to (Wunderlich et al., 2020). Denote the Elo rating of the home and the away team by E_h and E_a , respectively. The independent variable Δ_{ha} is either the difference of Elo ratings ($\Delta_{ha}^{(1)} = E_h - E_a$), or the winning probability of the home team implied by the Elo ratings according to the Elo equation of Football Club Elo Ratings (<http://clubelo.com/system>):

$$\Delta_{ha}^{(2)} = \frac{1}{1 + 10^{-(E_h - E_a)/400}}.$$

Note that $\Delta_{ah}^{(1)} = -\Delta_{ha}^{(1)}$ and $\Delta_{ah}^{(2)} = 1 - \Delta_{ha}^{(2)}$.

Figure 2 shows histograms of strength difference Δ : Figure 2.a if the difference is measured directly by Elo ratings ($\Delta^{(1)}$), and Figure 2.b if it is based on the winning probability of the home team ($\Delta^{(2)}$). Although all matches are decided by a penalty shootout, the database is quite heterogeneous, the winning probability of the home team lies between 40% and 60% in less than 30% of the sample.

The first covariate is being the first-mover ($f_h = 1$ if the home team kicks the first penalty). The second covariate is the comeback team ($c_h = 1$ if the home team scores more goals or the last goal). However, including the comeback dummy reduces sample size since no team scores more goal if the final result is 0-0, and no team scores the last goal if the final result is 0-0. There is no need to control for match venue, the possible home (dis)advantage is reflected by the constant.

To summarise, the following equation is estimated:

$$P_h = \frac{1}{1 + e^{\beta_0 + \beta_1 \Delta + \beta_2 f_h + \beta_3 c_h}},$$

where P_h is the probability that the home team wins the penalty shootout, and Δ is the strength difference of the home and the away team. We consider 12 different regressions, depending on the definition of home venue (extended/restricted), the measure of strength difference (Elo rating/winning probability), and the momentum effect (ignored: $\beta_3 = 0$ /more goals scored/last goal scored).

Wunderlich et al. (2020) warn that, although the logistic regression provides information about the connection between team strength and the outcome of the penalty shootout, this is an in-sample approach, which may suffer from overfitting. Since our results are strongly insignificant (see Section 5), we are not worried about this potential bias.

5 Results and discussion

Section 5.1 investigates potential success factors in penalty shootouts by binomial tests, that is, whether teams in a given category win significantly more/less often than 50% compared

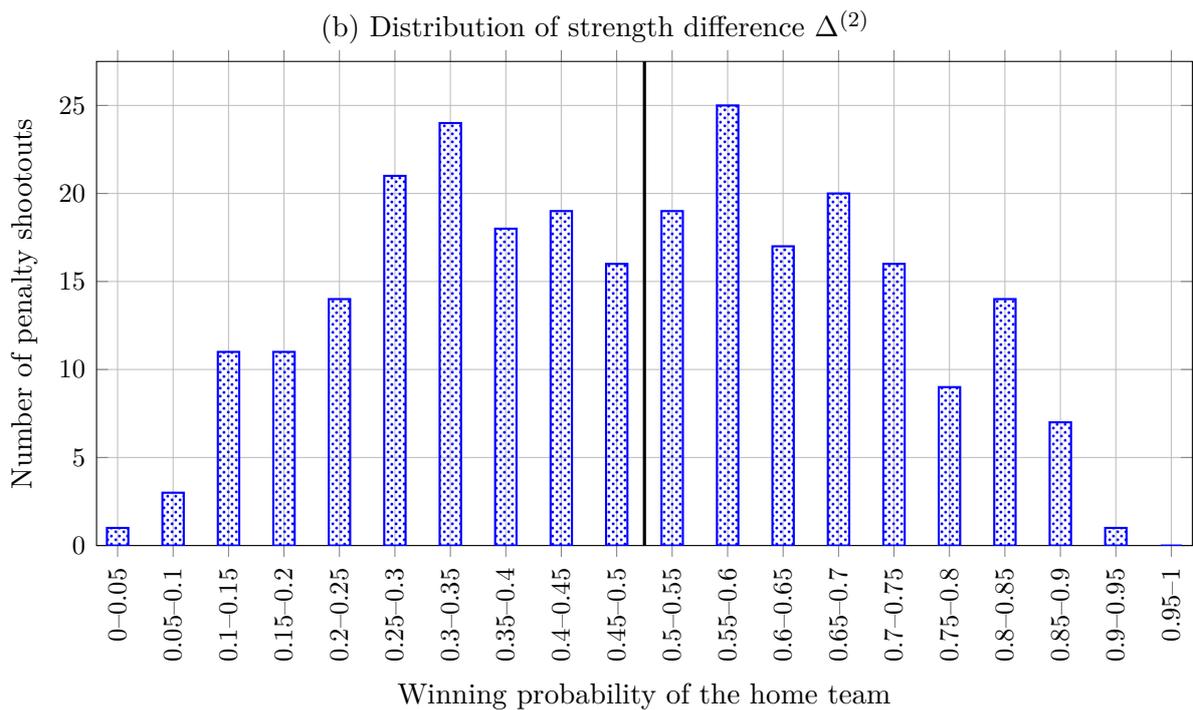
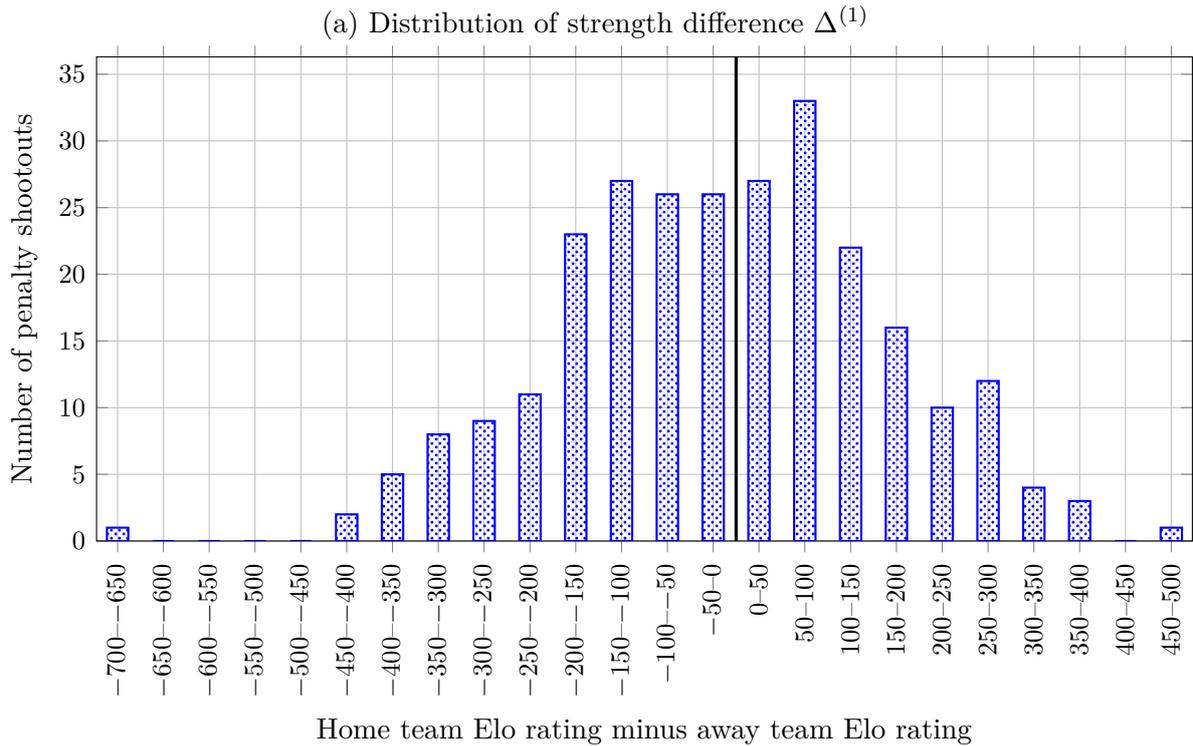


Figure 2: Distribution of the difference between team strengths

to teams in the other category. Section 5.2 considers more dimensions simultaneously via logistic regressions. In both cases, sensitivity analyses are also conducted. Finally, we provide some explanations for the results in Section 5.3.

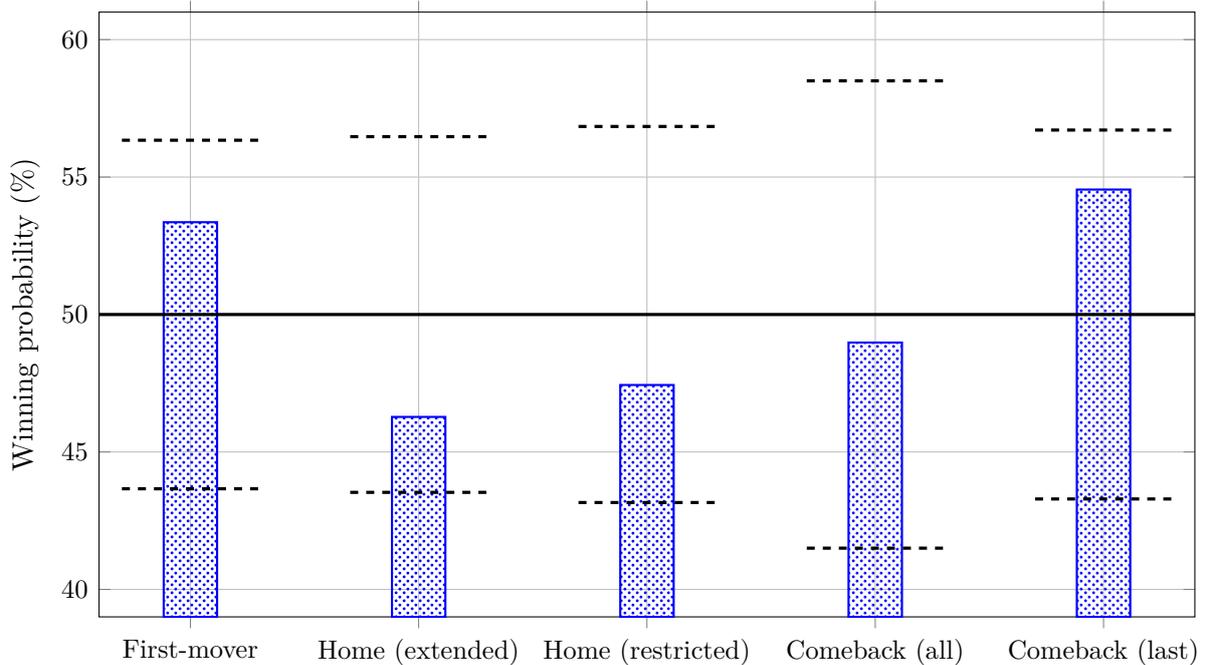


Figure 3: Binomial tests: first-mover advantage, home advantage, momentum

Note: The dashed lines show the bounds of the 95% confidence interval around no advantage of 50% in a two-sided test.

5.1 Partial analysis

Figure 3 shows the results of five binomial tests that examine the effect of the shooting sequence, the match venue according to two definitions (mild and strict) of home field, as well as psychological momentum according to two assumptions again. None of them is significant even at the 10% level. Thus, our study joins the set of papers that find no impact of the shooting order, and are fully in line with the literature on home advantage in penalty shootouts. In contrast to Krumer (2021, Table 4), comeback teams do not win more than 50% of penalty shootouts. These calculations can be reproduced on the basis of Table A.1 in Appendix A.2, which also reports the associated p -values.

Figure 4 focuses on the winning probability of the stronger team based on Football Club Elo Ratings. Five definitions of the favourite are used by gradually restricting the sample according to the minimal difference in the Elo ratings of the two teams. However, even teams that have at least 100 points more than their opponents fail to win 50% of their penalty shootouts. These calculations can be reproduced on the basis of Table A.2 in Appendix A.2, which also reports the associated p -values. The lack of positive impact is in stark contrast to the findings of the previous literature: all existing papers (Arrondel et al., 2019; Krumer, 2020; Wunderlich et al., 2020; Pipke, 2025) demonstrate a significantly higher winning probability for a “sufficiently” stronger team.

As we have seen in Section 3, the number of penalty shootouts has substantially increased from the 2020/21 season. Thus, all binomial tests have also been conducted for the first 20 and the last six seasons, respectively. According to Tables A.1–A.2 in the Appendix, the conclusions remain unchanged if we focus on the beginning or the end of the dataset. The only significant value at the level of 5% (but not at the level of 1%) appears for home advantage based on the extended dataset: home teams are less likely to win a penalty shootout than their opponents between 2020 and 2025 if the matches

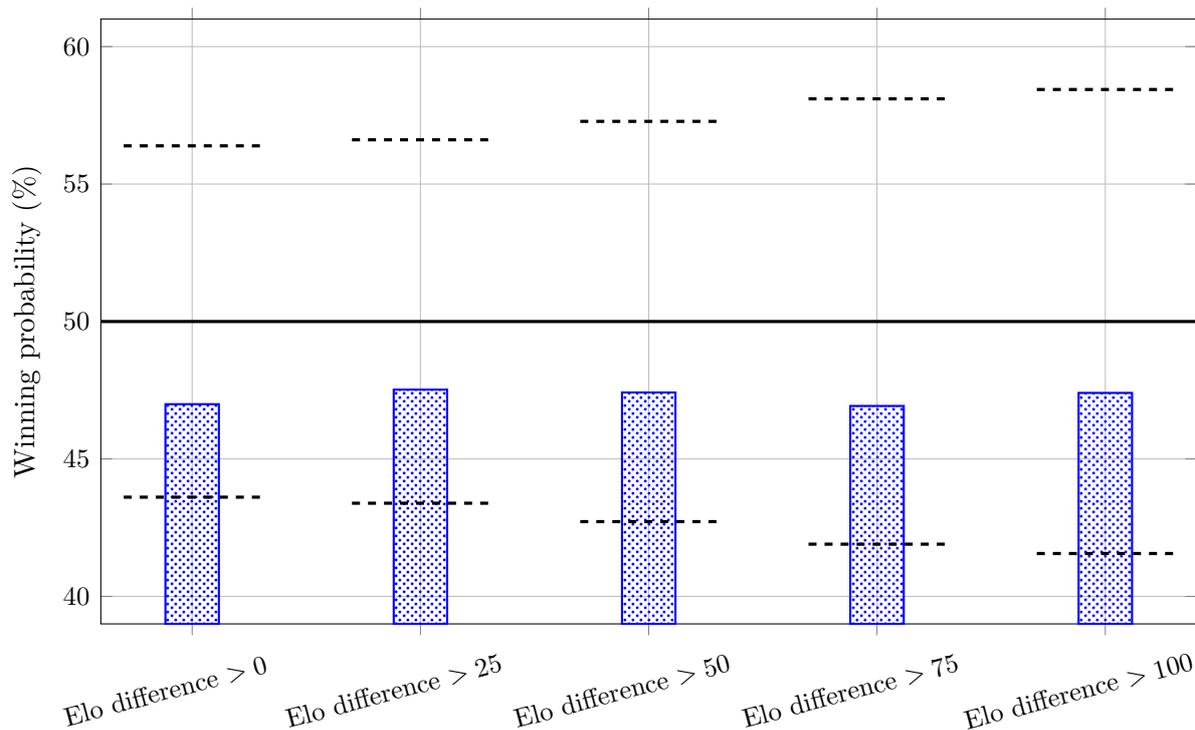


Figure 4: Binomial tests: team strength

Note: The dashed lines show the bounds of the 95% confidence interval around no advantage of 50% in a two-sided test.

played behind closed doors are taken into account (Table A.1). In these 20 one-legged matches, only seven were won by the home team, which is significantly below 50% at a significance level of 10%. This can be explained by choking under pressure (Harb-Wu and Krumer, 2019), which was probably much stronger in these matches than usual, despite the absence of spectators, as, in contrast to the standard rule, the randomly drawn home team should not have played away. The marginally significant effect disappears when only proper two-legged matches are considered under the restricted definition of home venue (Table A.1). Tables A.3 and A.4 reinforce the insignificant impact of all factors considered by distinguishing the penalty shootouts played in the qualification and knockout phases.

Even though the binomial tests do not indicate a significant deviation from the theoretically expected 50%, this might be caused by a small sample size. Furthermore, a failure to reject the null hypothesis rules out only sufficiently large effects. Therefore, it is worth noting that a first-mover advantage can be observed to some extent, especially between 2000 and 2019, when the team kicking the first penalty had a higher probability of winning by more than 10 percentage points. On the other hand, while home teams won more penalty shootouts in the first 19 seasons, they might be disadvantaged recently: since 2020, the winning probability of the home team is lower by about 30% compared to the away team. Last but not least, a slight but consistent comeback team advantage is seen if the comeback team is identified by scoring the last goal, which is a novel definition in the literature. In particular, these teams enjoy an advantage of 9 (based on the whole sample) and 14 (in the last six seasons) percentage points over their opponents, albeit this is still statistically insignificant. Interestingly, the team kicking the first penalty or scoring the last goal is more likely to win—by about five percentage points—in matches played in the knockout stage.

Table 2: Logistic regression models for predicting success in penalty shootouts

(a) Extended definition of home-away matches

Measure of strength	Elo difference $\Delta^{(1)}$			Home win probability $\Delta^{(2)}$		
Constant (β_0)	-0.269 (0.179)	-0.034 (0.347)	-0.501* (0.250)	-0.265 (0.347)	-0.065 (0.586)	-0.574 (0.425)
Strength difference (β_1)	0.019 (0.071)	0.046 (0.101)	0.043 (0.079)	-0.009 (0.595)	0.095 (0.846)	0.154 (0.659)
First-mover (β_2)	0.243 (0.253)	0.180 (0.342)	0.266 (0.275)	0.237 (0.254)	0.178 (0.342)	0.263 (0.275)
Comeback (all goals, β_3)	—	-0.122 (0.397)	—	—	-0.158 (0.395)	—
Comeback (last goal, β_3)	—	—	0.402 (0.282)	—	—	0.387 (0.281)
Observations	253	145	219	253	145	219

The dependent variable is 1 (0) if the home (away) team won the penalty shootout. Each column represents a separate regression.

Standard errors are in parentheses. Significance: * $p < 5\%$; ** $p < 1\%$; *** $p < 0.1\%$.

Elo difference $\Delta^{(1)}$ is the Elo of the home team minus the Elo of the away team divided by 100.

(b) Restricted definition of home-away matches

Measure of strength	Elo difference $\Delta^{(1)}$			Home win probability $\Delta^{(2)}$		
Constant (β_0)	-0.141 (0.188)	-0.034 (0.347)	-0.407 (0.261)	-0.080 (0.372)	-0.065 (0.586)	-0.399 (0.455)
Strength difference (β_1)	0.005 (0.075)	0.046 (0.101)	0.025 (0.083)	-0.120 (0.628)	0.095 (0.846)	-0.001 (0.695)
First-mover (β_2)	0.075 (0.265)	0.180 (0.342)	0.196 (0.285)	0.066 (0.265)	0.178 (0.342)	0.189 (0.285)
Comeback (all goals, β_3)	—	-0.122 (0.397)	—	—	-0.158 (0.395)	—
Comeback (last goal, β_3)	—	—	0.325 (0.292)	—	—	0.309 (0.291)
Observations	232	145	204	232	145	204

The dependent variable is 1 (0) if the home (away) team won the penalty shootout. Each column represents a separate regression.

Standard errors are in parentheses. Significance: * $p < 5\%$; ** $p < 1\%$; *** $p < 0.1\%$.

Elo difference $\Delta^{(1)}$ is the Elo of the home team minus the Elo of the away team divided by 100.

5.2 Multi-dimensional analysis

Table 2 investigates the effect of strength difference between the teams on the probability of winning a penalty shootout by logistic regressions, similar to Wunderlich et al. (2020). We study only matches with a home and an away team (Table 2.a uses an extended and Table 2.b uses a restricted definition), and control for first-mover advantage. The consideration of the momentum effect reduces the number of observations since drawn matches or matches with a final result of 0-0 are excluded. Note that the model containing

comeback teams identified by scoring more goals does not depend on the definition of home venue, as the 20 matches affected by the Covid-19 pandemic and a particular final are all played in one leg (see Section 3), thus, their final result should be a draw if they are finished by a penalty shootout.

In Table 2, only one significant coefficient can be found. In particular, the constant is negative if the extended definition of home venue is used and the comeback team is the team scoring the last goal. This is in line with Table A.1, which also indicates a home disadvantage since 2020 based on the extended set of matches. However, the p -value remains above 0.1 if the restricted definition of home venue is applied, showing the sensitivity of the finding to the definition of home venue. Albeit insignificant, the coefficient β_1 is always positive, while β_3 is negative/positive when the momentum effect is identified by scoring all goals/the last goal, as expected from the binomial tests in Figure 2. Crucially, the coefficient β_2 of strength difference is robustly insignificant.

Last but not least, we have assessed whether team strength could have a significant effect by focusing on the recent seasons. Hence, 25-25 logistic regressions are estimated by controlling for strength difference and first-mover effect ($\beta_3 = 0$ is assumed in order to maximise the number of observations): the sample begins in the $20x/20x+1$ season and ends in 2025. Figure 5 plots the corresponding p -values for the coefficients β_0 , β_1 , and β_2 . The winning probability becomes different from a coin toss when all seasons before 2023/24 are ignored—but then the sample size is not more than 64. Furthermore, β_1 is significant only if the last one or two season(s) are considered. Even then, both β_1 and β_2 are negative, which indicates rather a statistical anomaly caused by inadequate sample size. Consequently, in contrast to domestic cups, stronger teams are not expected to win more penalty shootouts in UEFA club competitions.

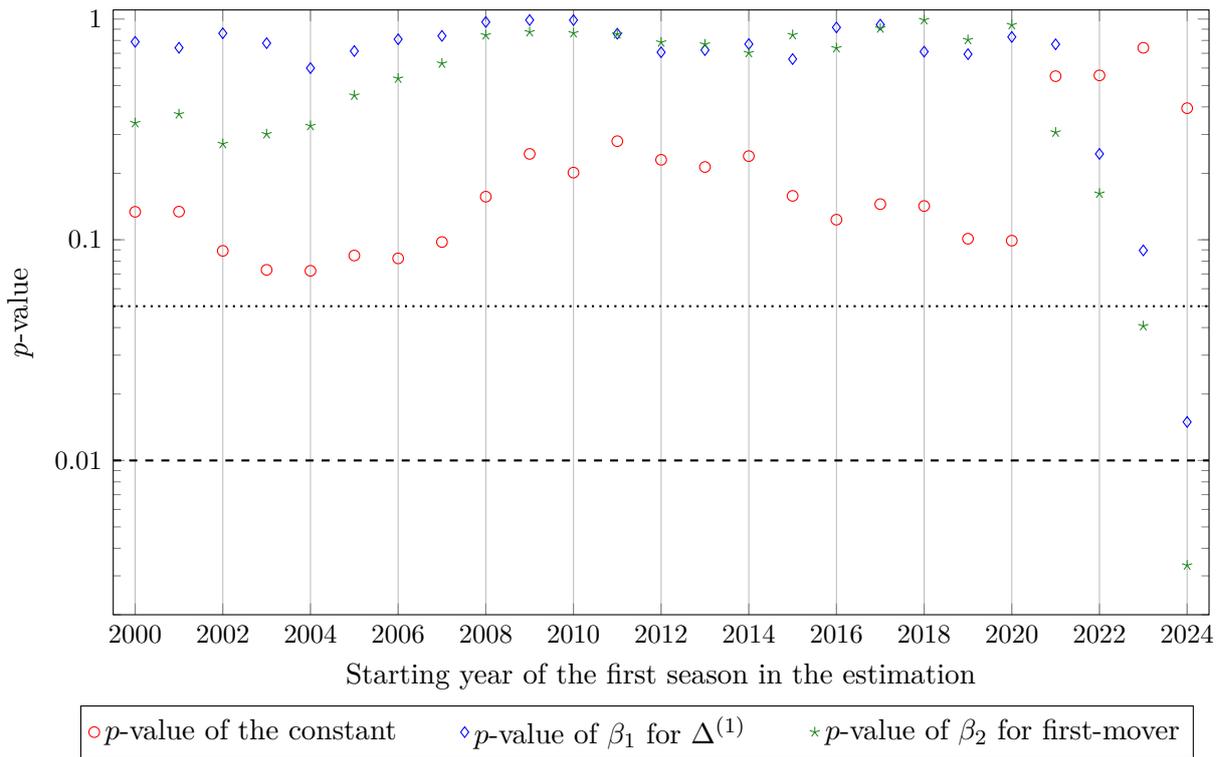
5.3 Discussion

At first sight, our findings may seem to contradict results from the previous literature. The detailed comparison of the estimations by Apesteguia and Palacios-Huerta (2010) and Kocher et al. (2012) uncovers that the discrepancy is often caused by sampling issues, see Kocher et al. (2012). The majority of our sample consists of matches played in the last six seasons, which can explain at least some differences.

Regarding first-mover advantage, the results are fully in line with the conclusions of recent studies on large samples (Pipke, 2025; Vollmer et al., 2024). Similar to us, no previous work has found evidence for home advantage. Even though Krumer (2020) reports a momentum effect for away (but not for home) teams, there are two important differences between the two analyses. First, Krumer (2020) measures momentum by the goal difference between the teams in regular time of the second leg; thus, it is not a binary variable as in our case. Second, the sample of Krumer (2020) contains matches played between the 1970/71 and 2017/18 seasons, and there is powerful evidence for a decreasing home advantage in club football over time (Baker and McHale, 2015). Therefore, away teams were more disadvantaged in matches played decades ago, hence, it is logical to assume that they enjoyed a stronger momentum effect if they managed to score more goals against their opponents.

In contrast to all existing studies, stronger teams are found not to win more often, which can be deemed counterintuitive. However, we do not see such a problem after a more detailed analysis. First, Arrondel et al. (2019) and Krumer (2020) find that teams from a higher-ranked division have a higher probability of winning in a penalty shootout.

(a) Strength difference $\Delta^{(1)}$: Elo rating of the home team minus Elo rating of the away team



(b) Strength difference $\Delta^{(2)}$: winning probability of the home team based on Elo ratings

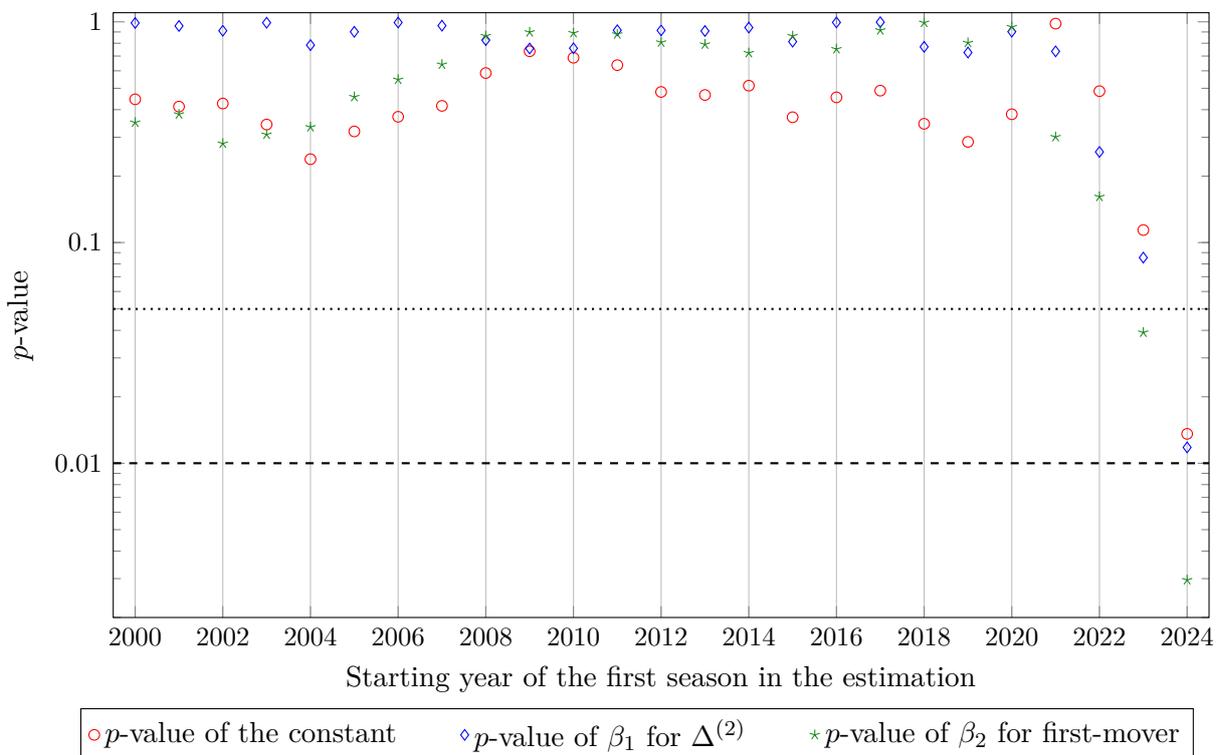


Figure 5: Logistic regressions: Sensitivity of p -values to the first season of the sample
Note: The dotted (dashed) line shows significance at 5% (1%) level.

Our sample is more homogeneous from this perspective: teams from the highest-ranked European leagues do not play in the UEFA Champions League qualification since the 2018/19 season, and at most one team participates in the UEFA Europa League and UEFA (Europa) Conference League qualification. Furthermore, the UEFA Champions League qualification was separated into two paths in the 2009/10 season such that champions from lower-ranked national associations are not allowed to play against non-champions from higher-ranked national associations (Csató, 2022). Even though the knockout stage does not contain analogous constraints, the previous group stage/league phase can effectively remove weak clubs, guaranteeing that teams playing against each other are quite close in abilities. Second, although Wunderlich et al. (2020) report a significant impact for betting odds in domestic cups, its magnitude is relatively small, even extremely weaker teams have a probability of around 40% to win the penalty shootout. UEFA club competitions are more prestigious and lucrative than national clubs, thus strong teams probably field their best squad. Therefore, if the strength difference between the opposing teams is substantial, the match is less likely to be decided by a penalty shootout in UEFA club competitions than in national cups.

Any penalty shootout is clearly a situation with high stakes. In such an environment, choking under pressure can threaten the stronger team, which is expected to win. Indeed, professional biathlon athletes in the top quartile of the ability distribution miss significantly more shots when competing in their home country compared to competing abroad (Harb-Wu and Krumer, 2019). In addition, task-specific practice could contribute to the success of penalty kicks (Navarro et al., 2013). This is especially important because, according to Jordet (2009), players from countries with many international club titles or many internationally decorated players (such as England or Spain), spend less time preparing for their shots and, consequently, are less successful in kicking penalties than players from countries with a lower public status.

6 Concluding remarks

Our paper has aimed to predict success in penalty shootouts in top European football during the last 25 years. We have considered several possible factors, such as the shooting order, the field of the match, and psychological momentum, but none of them affects the probability of winning significantly. First in the literature, team strength is measured by Elo ratings instead of the division of the team or betting odds. This has led to a somewhat surprising finding: even though Elo ratings can forecast results in the UEFA Champions League relatively well, they seem to lose their predictive power if the qualification is decided by penalty shootouts.

These results could have important policy implications. First, a drawn match can advance to a penalty shootout where the winner receives two points instead of one in order to increase attendance and prompt players to train more for penalty shootouts, which may be advantageous for the national team (Palacios-Huerta, 2014). This rule was used in the 1988/89 season of the Argentinian League, and is currently applied in the Leagues Cup, an international club competition in North America, since 2023. If the outcome of a penalty shootout does not differ from a coin toss, stronger teams would have more powerful incentives to attack since a draw means half extra points for both teams in expected value. Second, abolishing extra time, an intervention recently contemplated by UEFA, would favour weaker teams and improve competitive balance.

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Appendix

A.1 A mistake in Football Club Elo Ratings data

Two Armenian football clubs, Ararat Yerevan (<http://clubelo.com/Ararat>) and Ararat-Armenia (<http://clubelo.com/Ararat-Armenia>), have similar names. Both teams have played in UEFA club competitions recently.

In the 2021/22 Armenian Premier League, Ararat-Armenia was the runner-up and qualified for the second qualifying round of the 2022/23 UEFA Europa Conference League. Ararat Yerevan was ranked fourth and qualified for the first qualifying round of the 2022/23 UEFA Europa Conference League. Ararat Yerevan lost in the first round against the North Macedonian club Shkëndiye, while Ararat-Armenia lost in the second round—by penalty shootouts—against the Estonian club Paide Linnameeskond. However, Football Club Elo Ratings registered both matches for Ararat Yerevan, see <http://clubelo.com/Ararat/Games/Latest>. Thus, the Elo rating of Ararat-Armenia remains unknown in these matches.

In the 2022/23 Armenian Premier League, Ararat-Armenia was ranked third and qualified for the first qualifying round of the 2023/24 UEFA Europa Conference League. It won in the first round—by penalty shootouts—against the Albanian club Egnatia, and lost in the second round against the Greek club Aris. However, Football Club Elo Ratings registered both matches for Ararat Yerevan, see <http://clubelo.com/Ararat/Games/Latest>. Thus, the Elo rating of Ararat-Armenia remains unknown in these matches.

In the 2023/24 Armenian Premier League, Ararat-Armenia was ranked third and qualified for the second qualifying round of the 2024/25 UEFA Conference League. It won in the second round against the Moldavian club Zimbru Chişinău, and lost in the third round against the Hungarian club Puskás Akadémia. However, Football Club Elo Ratings registered both matches for Ararat Yerevan, see <http://clubelo.com/Ararat/Games/Latest>. Thus, the Elo rating of Ararat-Armenia remains unknown in these matches.

In the 2024/25 Armenian Premier League, Ararat-Armenia was ranked second and qualified for the second qualifying round of the 2025/26 UEFA Conference League. It won in the second round against the Romanian club Universitatea Cluj, and lost in the third round against the Czech club Sparta Praha. However, Football Club Elo Ratings registered both matches for Ararat Yerevan, see <http://clubelo.com/Ararat/Games/Latest>. Thus, the Elo rating of Ararat-Armenia remains unknown in these matches.

Therefore, we could not know the Elo rating of one team, Ararat-Armenia, in two penalty shootouts, which were ignored in the corresponding analyses.

More worryingly, the unreliability of the Elo ratings for Ararat Yerevan spreads to their (supposed) opponents, opponents of opponents, and so on, raising questions about the validity of Football Club Elo Ratings data. Unfortunately, we are not able to correct this error of the underlying database. We have informed the creator of Football Club Elo Ratings, *Lars Schiefler*, about the problem but received no answer.

A.2 Supplementary tables

Table A.1: Results of binomial tests: first-mover advantage, home advantage, momentum

Period Potential success factor	2000/01–2025			2000/01–2019/20			2020/21–2025		
	Total	Ratio	p -value	Total	Ratio	p -value	Total	Ratio	p -value
First-mover	268	53.4%	0.299	129	55.8%	0.218	139	51.1%	0.865
Home (extended data)	255	46.3%	0.260	122	52.5%	0.651	133	40.6%	0.037*
Home (restricted data)	234	47.4%	0.472	121	52.9%	0.586	113	41.6%	0.090
Comeback (all goals)	147	49.0%	0.869	75	53.3%	0.644	72	44.4%	0.410
Comeback (last goal)	231	54.5%	0.188	108	51.9%	0.773	123	56.9%	0.149

Two-sided binomial tests. Significance: * $p < 5\%$; ** $p < 1\%$; *** $p < 0.1\%$.

The column Total (Ratio) shows the number (proportion) of penalty shootouts won by the team indicated in the row.

Table A.2: Results of binomial tests: team strength

Period Scenario	2000/01–2025			2000/01–2019/20			2020/21–2025		
	Total	Ratio	p -value	Total	Ratio	p -value	Total	Ratio	p -value
Elo difference > 0	266	47.0%	0.358	129	46.5%	0.481	137	47.4%	0.608
Elo difference > 25	242	47.5%	0.480	120	46.7%	0.523	122	48.4%	0.786
Elo difference > 50	213	47.4%	0.493	108	46.3%	0.501	105	48.6%	0.845
Elo difference > 75	179	46.9%	0.455	92	45.7%	0.466	87	48.3%	0.830
Elo difference > 100	154	47.4%	0.573	76	47.4%	0.731	78	47.4%	0.734

Two-sided binomial tests. Significance: * $p < 5\%$; ** $p < 1\%$; *** $p < 0.1\%$.

The column Total (Ratio) shows the number (proportion) of penalty shootouts won by the favourite team.

Table A.3: Results of binomial tests in different tournament stages:
first-mover advantage, home advantage, momentum

Tournament phase Potential success factor	Qualification			Knockout		
	Total	Ratio	p -value	Total	Ratio	p -value
First-mover	207	52.2%	0.578	61	57.4%	0.306
Home (extended data)	204	46.1%	0.294	51	47.1%	0.780
Home (restricted data)	184	47.3%	0.507	50	48.0%	0.888
Comeback (all goals)	108	49.1%	0.923	39	48.7%	1.000
Comeback (last goal)	176	53.4%	0.407	55	58.2%	0.281

Two-sided binomial tests. Significance: * $p < 5\%$; ** $p < 1\%$; *** $p < 0.1\%$.

The column Total (Ratio) shows the number (proportion) of penalty shootouts won by the team indicated in the row.

Table A.4: Results of binomial tests in different tournament stages: team strength

Tournament phase Scenario	Qualification			Knockout		
	Total	Ratio	p -value	Total	Ratio	p -value
Elo difference > 0	205	48.3%	0.675	61	42.6%	0.306
Elo difference > 25	188	49.5%	0.942	54	40.7%	0.220
Elo difference > 50	165	49.1%	0.876	48	41.7%	0.312
Elo difference > 75	145	46.9%	0.507	34	47.1%	0.864
Elo difference > 100	134	47.0%	0.546	20	50.0%	1.000

Two-sided binomial tests. Significance: * $p < 5\%$; ** $p < 1\%$; *** $p < 0.1\%$.

The column Total (Ratio) shows the number (proportion) of penalty shootouts won by the favourite team.