Cooperative Game Analysis of Asian Handicap Big Data Based on Quantitative Difference Model

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Abstract. Purpose: Game theory is mainly divided into cooperative games and non-cooperative games. Most sports game is a non-cooperative game, but football games do not seem to be the case. In order to explore the relationship between football handicap and game rules, a cooperative game model of the interaction between the two sides of the football game is constructed from the perspective of functional internal stability. Method: Select the 875 games of the 7 seasons of the UEFA Champions League from 2012–2013 to 2018–2019 as the research object, and introduce quantitative differences to analyze the absolute value and entropy of the market in the group stage and the knockout stage, as well as the impact of different handicap on the draw time. Result: The absolute value of the Asian handicap in all seasons knockout matches is significantly smaller than that of the group stage; the handicap entropy of all seasons knockout matches is significantly greater than that of the group stage; the larger the absolute value of the handicap, the shorter the draw time of the game progress. Conclusion: The football game is a typical rational cooperative game. Specifically, the smaller the difference in strength between the two sides, the higher the level of sports performance.

Keywords: function-specific homeostasis · football · Asian handicap · cooperative game

1 Introduction

Football is the most popular sport in the world in the past two centuries [1]. The core influencing factors have not yet been finalized. The game occupies a core position in competitive sports competitions, and it has important guiding significance for competition phenomena, competition strategies, winning rules, and competition practices.

Game theory deals with the strategic interactions between players. The ranking preference of each player among multiple possible game outcomes is characterized by

J. Yen et al. (Eds.): ICBIS 2023, AHCS 14, pp. 96–102, 2023.
https://doi.org/10.2991/978-94-6463-198-2_11

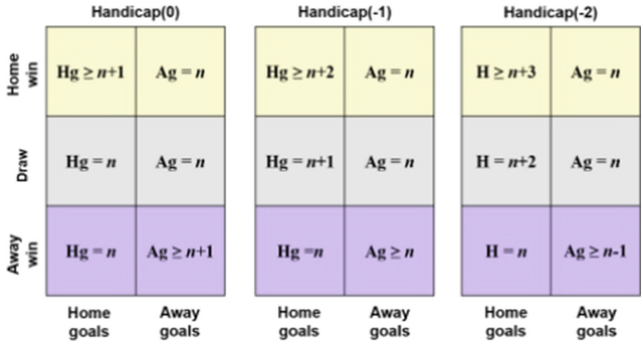

Fig. 1. The game matrix chart of the relationship between home and away goals and win or lose in different handicaps

an objective function, which can try to maximize the objective function (the objective function is a utility function or a benefit function) or minimize the objective function (the objective function is a cost function or a loss function). Game theory is divided into two main categories, namely cooperative game and non-cooperative game. The former can be said to be a strictly (or truly) non-zero-sum game if the sum of the objective functions of the players cannot be reduced to zero with proper positive scaling and/or translation of the decision variables independent of the players. A game is said to be a zero-sum game if the sum of the objective functions of the two players is zero or can be made zero by appropriate positive scaling and/or translation of the decision variable independent of the player [2].

The core idea of solving cooperative games is cooperative equilibrium [3]. In football matches, the Asian handicap (AH) in the odds is a predictive indicator that aims to balance the overall strength of the two teams. It weighs the difference in strength between the home and away teams in the form of handicap, and finally achieves a balance of cooperation in strength. The specific model can be explained by the game matrix diagram (Fig. 1). It can be seen from the above that when the handicap value approaches 0, the difference in strength between the two parties can form an optimal stable solution in an ideally symmetrical environment. But when the handicap value is larger, the difference in strength between the two sides will form a suboptimal stable solution in a non-ideal symmetrical environment (Fig. 1).

2 Method

2.1 Data Source

The research data comes from the UEFA Champions League game progress and results database on the official website of the European Football Associations (www.uefa.com). Football odd data comes from the domestic comprehensive betting information website okooo (www.okooo.com). A total of 875 games in the 2012–2013, 2013–2014, 2014–2015, 2015–2016, 2016–2017, 2017–2018, and 2018–2019 seasons were selected, including 672 games in the group stage and 203 games in the knockout stage. The football

odd AH data sample selects the final odds of each match, among which the bookmaker is William Hill, a global authoritative bookmaker. In addition, the sum of the draw time in each match is collected.

2.2 Data Processing

The entropy of Second Law of Thermodynamics informs us that energy gradients always disperse. The loss of energy gradients is measured as increasing entropy [4]. Any isolated system is either closed (i.e., no interaction of energy or matter with its environment) or includes the system and its environment if there is interaction. The Second Law of Thermodynamics states that the change in entropy of an isolated system is universally positive. According to Shannon's information entropy [5], it is defined as probabilistic distribution law, where higher entropy value means that the system is more stable.

In order to avoid that the entropy value cannot be calculated due to the occurrence of zero in the handicap, the handicap function exp (*Handicap*) can be calculated first, which is called handicap index. The entropy(X) of a discrete random variable X is defined as:

$$\text{Entropy}(X) = -k \sum_{i=1}^{n} p_i \log p_i \tag{1}$$

where $p_i (0 \leq p_i \leq 1)$ is the probability density function of X and k is a constant. The entropy of each handicap variable i in this study is:

$$\text{Entropy}_i = -\sum_{j=1}^{j=n} p(j) \log(p(j) \tag{2}$$

$$p(j) = \frac{N_j}{N_{sum}} \tag{3}$$

where *p(j)* is the distribution equation of the handicap group, *Nj* is the absolute value of a handicap, and *Nsum* is the sum of the absolute values of the handicap in the group, and the ratio of the two is the proportion of the absolute value of the handicap in the group system. The average entropy value is used to characterize the stability of handicap because the number of games *Mn* in the group stage and the knockout stage is different:

$$\overline{\text{Entropy}} = \frac{1}{M_n} \sum_{i=1}^{M_n} \text{Entropy}_i \tag{4}$$

According to Eq. (2), we can calculate the entropy of the absolute value of handicap in the group match and knockout match in two competitions, and then calculate the average entropy of the group match and knockout match respectively according to Eq. (4).

2.3 Statistical Analysis

The traditional statistical analysis of P-value can only give the qualitative difference of each parameter. In view of this, we introduced the quantitative difference (QD) [6]

method to analyze the quantitative difference of each parameter. The QD takes the logarithm based on the golden ratio constant as the base and is called the golden logarithm. The QD with two values of a parameter is defined as the absolute value of the golden logarithm of its ratio:

$$QD(x_1, x_2) = \left|\log_\tau(x_1/x_2)\right|, \tau = \left(\sqrt{5}-1\right)/2 \approx 0.618 \quad (5)$$

According to the Weber-Fechner Law [7] of psychophysics, we have got three thresholds of QD (α, β, γ), where α is called the Weber threshold. If the QD of any two values is less than α, we called it completely indifferent and this QD is called the biological constant. Amdt-Schulz Law [8] is the dose relationship curve between the classic functions of biomedicine and the influencing factors. β and γ are defined according to the Amdt-Schulz Law. The QD of any two values in the plateau period of the curve is less than β, we called no significant difference, and the QD of any two values in the rising or falling period of the curve is not less than β or γ, it is called the significant or extraordinary significant difference. 11 characteristic constants are calculated according to the self-similarity constant with invariant golden logarithm and the other 11 characteristic constants are calculated according to the following equations:

$$\alpha_{-i} = \log_\tau\left(1 - \tau^{\alpha i}\right) \quad (6)$$

Here, we extend the three thresholds (α, β, γ) of QD to (α, β1, β2). Molecular cell function: (α4, α2, α1, α-1, α-2, …); tissue and organ function: (α5, α3, α2, α1, α-1,…); global body function: (α6, α4, α3, α2, α1,…); advanced global body function: ($\alpha 6 + i$, $\alpha 4 + i$, $\alpha 3 + i$, $\alpha 2 + i$, $\alpha 1 + i$,…), $i = 1,2,\ldots$, in which QD of two values is not less than βi, it is called that two values have βi level significant difference. In this paper, the βi threshold of football match of the research object belongs to the global body function level, and the corresponding significance threshold (0.268, 0.472) should be selected.

3 Results and Discussions

3.1 Result Analysis

The QD test of Fig. 2 shows that in the five seasons of 2013–2014, 2014–2015, 2016–2017, 2017–2018 and 2018–2019, the absolute value of handicap in the group stage is significantly higher than that in the knockout stage (QD ≥ 0.472); In 2012–2013 and 2015–2016, the absolute value of handicap in group stage was also significantly higher than that in knockout stage (QD ≥ 0.268).

The QD test of Fig. 3 shows that the entropy of index handicap in the group stage of all seasons is significantly lower than that in the knockout stage (QD ≥ 0.472).

In the five seasons of 2012–2013, 2014–2015, 2015–2016, 2016–2017 and 2018–2019, the draw time gradually decreases with the increase of the absolute value of the handicap (Fig. 4a). Figure 4b shows that in all competitions, the smaller the handicap, the longer the draw time. Figure 4c shows the percentage of 90-min matches in which the tie time and the winning and losing time are in the absolute value interval of handicap. Among them, the draw time in the absolute value ($0 \le |H| < 1$) interval of handicap is almost the same as the winning and losing time; The draw time in the absolute value ($|H| \ge 2$) interval of the market only accounts for 30%.

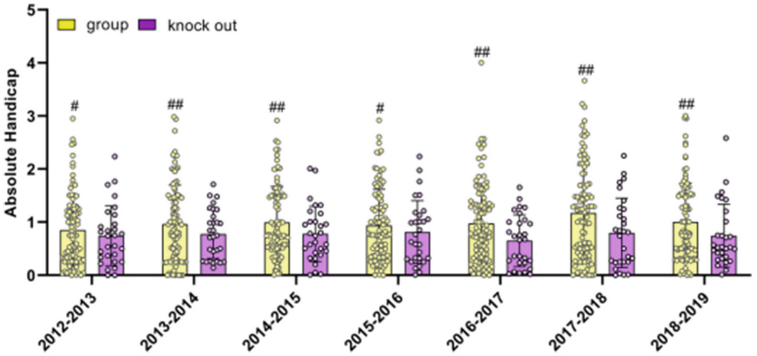

Fig. 2. Comparison of Handicap Absolute Value between Group Match and Knockout Match. Note: # QD is greater than or equal to β (0.268), and ## QD is greater than or equal to γ (0.472), the same as below.

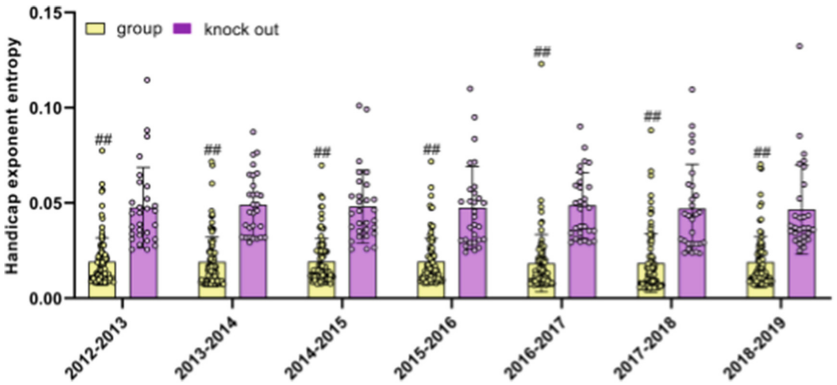

Fig. 3. Comparison of Index Handicap Entropy between Group Match and Knockout Match

3.2 Discussion Analysis

The above research results show that handicap can represent the strength difference between the two teams in a football match. By dividing the Champions League into group matches and knockout matches, it can be found that the absolute value of handicap in group matches is significantly higher than that in knockout matches, which indicates that handicap can explain the strength difference between the two sides and the level of their sports performance. However, the entropy value of the group stage is significantly lower than that of the knockout stage, which indicates that the stability of the two teams in the group stage is far lower than that in the knockout stage, which proves that the two teams in the knockout stage are in high competence.

The cooperative game has a premise, which requires a binding collective agreement and distribution scheme [3]. It is almost impossible to complete this condition in sports competitions. However, football matches are different. Couceiro et al.[9] put forward the conjecture that there will be an equilibrium point in the sports performances of both sides

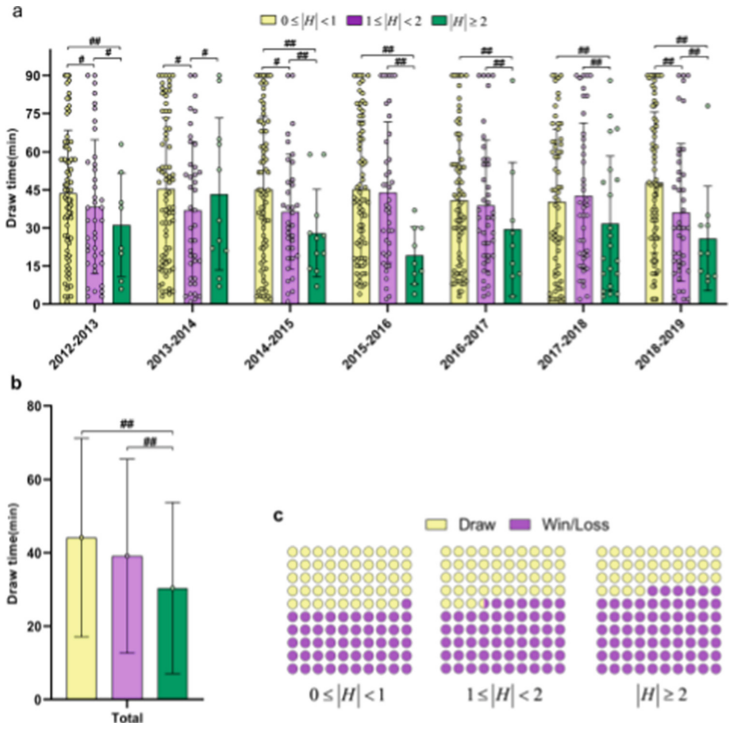

Fig. 4. The draw time of the actual match process corresponding to different handicap

in high-level football matches, and the equilibrium point will gradually aggregate the sports performances of both sides in the matches so that both sides can keep a balanced mode during the matches. In this paper, the odds not only prove that the handicap has predicted the binding equilibrium point before the start of the game, but also find the difference in draw time by grading the handicap.

4 Conclusions

It is effective to use football handicap to calculate the game model of football match. The smaller the handicap at a high level can effectively explain the balance of the cooperative game, and the practical significance it brings is to improve the Function-specific homeostasis level of the sports performance of both teams, which quantitatively indicates the importance of sports competition with opponents with the same strength level. We expect to provide a reasonable competitive strategy for professional teams in different competitive environments in the future.

Acknowledgments. This work was supported by Project of Humanities and Social Sciences from Ministry of Education in China (No. 20YJCZH090); Project of Aviation Sports Research Institute of Civil Aviation Flight University of China (No. JG2023-34); Project of Doctor's Innovation Ability Improvement, Civil Aviation Flight University of China (No. XJ2022009001).

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