The effect of playoff series length on the outcome
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1 Introduction

North American major professional sport leagues generally utilize a best-of-4 playoff series to determine their champion. The postseason tournament for Major League Baseball (MLB) consists of a best-of-5 round followed by two best-of-7 rounds; in 2012, it was expanded to include a one-game, wild-card round. The National Basketball Association (NBA) and the National Hockey League (NHL) have four best-of-7 rounds. The Women's National Basketball Association (WNBA) uses two best-of-3 rounds followed by a best-of-5 round for the Finals. An exception is the National Football
League (NFL), which employs a single-elimination tournament (a best-of-one series) for four rounds with the two highest-seeded teams in each division getting a first-round bye.

From a fan—and, consequently, television revenue—perspective, there tends to be relatively little interest in the early games of a long series. Figure 1 shows the Nielsen ratings for the MLB World Series and the NBA Finals (to account for changes from year-to-year, the data are indexed to that year’s Game 1 ratings); as illustrated in the figure, the television ratings tend to increase as the series continues. Arguably, a shorter series might be an appropriate tactic to increase fan interest. When Dreslough (1999) suggested the one-game, wild-card round for MLB, he noted that “it’s like scheduling a couple of Game Sevens right at the beginning of October”.

**Figure 1** Nielsen ratings as a percent of Game 1 rating (see online version for colors)

![Nielsen ratings chart]

Furthermore, the number of teams that make the playoffs in a given year has expanded considerably. Fifty years ago (i.e., the early 1960s), the number of teams in the playoffs for the NBA, NHL, MLB, and NFL were 6, 4, 2, and 2, respectively. Today, the number of teams that make the playoffs for these four leagues are 16, 16, 10, and 12, respectively. With four best-of-7 rounds, it can take nearly two months to get through the playoff schedule for the NBA and NHL. Again, it might be argued that a shorter series within each round, given the increase in the number of rounds, might be a reasonable approach to maintain fan interest over the course of an extended tournament.

On the other hand, conventional wisdom is that a longer series will increase the likelihood that the superior team will win the series (as we will see in the next section, the current research literature is also consistent with this). This is generally considered to be more “fair” as this team is expected to be given some advantage as a reward for compiling a better regular season. In a short series, luck becomes an important factor, increasing the chance of an upset. The popular press, as well as athletes and coaches, have commented on the fairness of a short series. “A five-game series in the first round is already a crapshoot. A three-game series would be a complete toss-up” (Passan, 2010).

“...A five-game series is probably the most unfair situation in pro sports”, says Milwaukee Bucks Coach George Karl. ‘I have no idea why we have five-game series’ ... Theoretically, a longer series should always reduce the chance of an upset’ (Scanlon, 2001).

So from a revenue-management perspective, we must consider this concept of fairness in addition to the fan interest, ticket sales, and television revenues. Thus, the research question we address is: how does the length of a playoff series affect the probability that the superior team will win the series? Specifically, we will investigate the effect on fairness of the number of games in a series as well as the particular playoff format.

### 1.1 Literature review

If we consider the basic situation in which there is a constant probability, \( p \), that the superior team wins each game, independent from one game to the next, then the probability that this team wins the best-of-\( k \) series, \( P(W | k, p) \), can be expressed as a binomial expansion (see, for example, Boronico, 1999):

\[
P(W | k, p) = \sum_{i=0}^{k} \binom{k}{i} \left( \frac{p^i}{1-p^{k-i}} \right)
\]

where \( w = \frac{k + 1}{2} \) is the number of games a team must win to win a \( k \)-game series (for odd \( k \)). This is consistent with conventional wisdom since, as the number of games in a series increases, the probability that the superior team will win the series increases. For example, if \( p = 0.6 \), then \( P(W | k, p) = 0.600, 0.548, 0.583, \) and \( 0.710 \) for \( k = 1, 3, 5, \) and \( 7 \), respectively. Although Boronico claims this increase to be modest, most teams would likely appreciate increasing the odds of winning a championship from \( 3:2 \) to nearly \( 5:2 \).

Motter (1952) presented alternative methods of estimating the probability of the superior team winning each game and tested the independence assumption made in equation (1); he found that a constant probability was consistent with MLB World Series data and that there was no significant effect of a home-field advantage or of momentum (i.e., serial correlation from game to game). Various authors analyzed properties of the number of games that would be played to win a best-of-\( k \)-series: Maisel (1966) provided expressions for the expected value and variance of the number of games that would be played; Groeneveld and Arnold (1984) considered the limiting properties—for large \( k \)—of the distribution, including the situation in which the probability the superior team wins a game is a beta distribution; Nagaraja and Chakrabarti (1989) investigated the shape of the distribution and provided approximations for its mean, median, and variance; and Lengsfeld (1993) provided a proof of a combinatorial identity. Gibbons et al. (1978) determined the number of games that must be played in a series to obtain a given level of confidence that the superior team will win the series; for example, if the probability that the stronger team wins a particular game is \( p = 0.6 \), it would take a 31-game series to achieve a 90% likelihood of the superior team winning the series.

Other than the NFL’s Super Bowl, the North American major professional sport leagues play their postseason tournaments on the competitors’ venues; thus, authors have incorporated the home-field/advantage into their analyses. Hurley (1993)
assumed equal-strength teams, so only the home-field advantage affects the probability of winning the series; for example, if the probability that the home team wins a game is 0.6, the probability that the team with four home games wins a best-of-seven series is 0.532. Caudill and Mixon (1998), and Bassett and Hurley (1998) extended this analysis to teams of different quality and compared the popular 2-2-1-1-1 and 2-3-2 playoff formats; they found that the expected number of games is greater for the 2-3-2 series with a smaller variance and that there is a higher likelihood of the series going to six games instead of ending in five (although the probability of a seven-game series remains unchanged). Rump (2006) further extended the analysis by considering all seven-game formats with the superior team having four home games including the first and seventh (if necessary) games of the series; be identified four atherocastically different format classes and found the expected length of each (although, again, the probability of the superior team winning the series is the same for all).

1.2 Contribution and overview of paper

The focus of the existing research has been on the number of games in a series since, due to the assumptions made, the probability that the superior team wins the series is the same for any playoff format. However, research has shown that — in addition to relative team quality and the home-field advantage — factors such as momentum (Mizuchi, 1991; Arkes and Martinez, 2011), previous experience in the championship series (Ferrall and Smith, 1999), and a back-to-the-wall effect (Simon, 1977; Swartz et al., 2011) may affect the probability of a team winning a particular game and, therefore, the series. A recent paper (Urban, 2012) incorporated these variables into a logistic-regression model using data from the 1956–2010 NBA Finals to estimate the probability of the superior team winning each game of a playoff series, which can then be combined to determine the outcome of the entire series.

Therefore, the purpose of this research is to investigate the effect of alternative playoff formats — including the number of games, k, as well as the home-away sequence of games — on the issue of fairness (i.e., that the superior team should have a higher likelihood of winning the series). In the next section, we consider the ‘basic’ situation using the data from the 1956–2010 NBA Finals. We then generalise this by considering the effect of various levels of relative team strength as well as the effect of momentum (serial correlation) on the outcome and fairness of the series.

2 Basic analysis

The logistic-regression model of Urban (2012) includes a binary response variable \( Y_i = 1 \) if the superior team wins game \( i \) of the series in year \( t_i = 0 \) (otherwise) and five explanatory variables. Relative team quality is measured as the difference in the regular season win/loss percentage of the two teams:

\[
\text{QUAL} = 100 \times (WP_{sup} - WP_{opp})
\]  

(2)

where \( WP_{sup} \) and \( WP_{opp} \) are the winning percentages of the superior and opposing teams, respectively. The approach of Albright (1993) is used to model momentum, using an exponentially-weighted sum of the lagged response variable:

\[
\text{MTM} = \sum_{m=1}^{\text{lag}} (\rho \times \text{LAG}(m))
\]  

(3)

where \( \text{LAG}(m) \) is the response variable lagged \( m \) periods (i.e., previous games of the series); this allows for positive serial correlation \((0 < \rho < 1)\) or negative serial correlation \((-1 < \rho < 0)\). Finally, indicator variables are used for home-court advantage (HOME), previous finals experience (EXPR), and the back-to-the-wall effect (BACK).

Logistic regression is well-suited for situations in which the independent variables take on discrete values such as this (probit provides almost identical results, predicting every game in the same manner). Other categorical-response methods, such as discriminant analysis, make the assumption that the independent variables are drawn from a multivariate normal distribution and, consequently, are less appropriate with discrete independent variables. Table 1 presents the results of the logistic-regression analysis.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Estimate</th>
<th>Standard error</th>
<th>Wald ( \chi^2 )</th>
<th>p-value</th>
<th>Odds ratio</th>
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<tr>
<td>QUAL</td>
<td>0.0372</td>
<td>0.0111</td>
<td>11.2792</td>
<td>0.0008</td>
<td>1.038</td>
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<td>MNTM</td>
<td>1.6130</td>
<td>0.3704</td>
<td>18.9674</td>
<td>&lt;0.0001</td>
<td>5.018</td>
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<tr>
<td>HOME</td>
<td>0.5809</td>
<td>0.1295</td>
<td>20.1245</td>
<td>&lt;0.0001</td>
<td>1.788</td>
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<td>EXPR</td>
<td>0.4977</td>
<td>0.2021</td>
<td>5.8706</td>
<td>0.0154</td>
<td>1.622</td>
</tr>
<tr>
<td>BACK</td>
<td>0.6490</td>
<td>0.3066</td>
<td>7.6657</td>
<td>0.0056</td>
<td>2.337</td>
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</table>

<table>
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<tr>
<th>Test</th>
<th>( \chi^2 )</th>
<th>p-value</th>
</tr>
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<tr>
<td>Overall model evaluation</td>
<td>61.0148</td>
<td>&lt;0.0001</td>
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<tr>
<td>Likelihood ratio test</td>
<td>55.7464</td>
<td>&lt;0.0001</td>
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<tr>
<td>Wald test</td>
<td>47.5106</td>
<td>&lt;0.0001</td>
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<tr>
<td>Goodness-of-fit test</td>
<td>10.2522</td>
<td>0.2478</td>
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Table 1 Results of the logistic-regression analysis

We first consider the basic situation, with relative team quality equal to the mean value over the 55-year data collection period (QUAL = 10), which provides the superior team roughly a 60% chance of winning on a neutral court and moderately-negative
momentum ($\phi = -0.36$, so the team that wins a particular game is somewhat less likely to win the next, all else equal) that was observed in the NBA Finals during this period. If the series were played on a neutral venue, ignoring the home-court advantage, the probability that the superior team would win the series would be 59.2, 62.8, 65.7, and 68.2% for the best-of-one, three, five, and seven-game series, respectively, regardless of the format. This is consistent with previous research in that a longer series results in a higher likelihood of the superior team winning the series. But we now turn our attention to the effect of a home-court advantage on the outcome of various playoff formats.

Table 2 illustrates the probability that the superior team wins the series, from a one-game series – which is played at the superior team’s venue – to various formats for best-of-three, five, and seven-game series (note, each of these formats provides the superior team with $(k+1)/2$ home games including the first and final games of the series). Also shown is the expected number of games played in the series as well as the variance. If we consider the alternating home-away sequences (1, 1-1-1, 1-1-1-1-1, 1-1-1-1-1-1-1), we see that a longer series does, as expected, increase the probability that the superior team wins the series, although the increase is only from 72.2% for a single game to 74.0% for a seven-game series. The 2-2-1-1-1 format (the series format that is used in the first two rounds of the NBA playoffs as well as all rounds of the NHL playoffs) also provides a higher probability than a one-game series, but slightly less than the 1-1-1-1-1-1-1 format.

Table 2  Probability of superior team winning a best-of-k series

<table>
<thead>
<tr>
<th>$k$</th>
<th>Format</th>
<th>Probability superior team wins</th>
<th>No. of games in series</th>
<th>Mean</th>
<th>Variance</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>72.17</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>3</td>
<td>1-1-1</td>
<td>72.72</td>
<td>2.46</td>
<td>0.25</td>
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<td>5</td>
<td>1-1-1-1</td>
<td>73.44</td>
<td>4.12</td>
<td>0.56</td>
<td></td>
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<tr>
<td></td>
<td>2-2-1</td>
<td>71.05</td>
<td>4.01</td>
<td>0.56</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1-2-2</td>
<td>68.69</td>
<td>4.11</td>
<td>0.50</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>1-1-1-1-1</td>
<td>72.98</td>
<td>5.83</td>
<td>0.89</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2-2-1-1</td>
<td>73.13</td>
<td>5.74</td>
<td>0.87</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1-2-2-1</td>
<td>72.77</td>
<td>5.76</td>
<td>0.83</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1-1-1-2</td>
<td>70.49</td>
<td>5.82</td>
<td>0.83</td>
<td></td>
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<tr>
<td></td>
<td>2-2-2</td>
<td>69.90</td>
<td>5.78</td>
<td>0.85</td>
<td></td>
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<tr>
<td></td>
<td>1-2-1-2</td>
<td>69.43</td>
<td>5.83</td>
<td>0.82</td>
<td></td>
</tr>
</tbody>
</table>

On the other hand, the series format that is currently used in the NBA Finals and MLB World Series – the 2-3-2 format – actually decreases the likelihood that the superior team wins the series as we go from a one-game series to a seven-game series. Furthermore, the 2-3-2 format has a lower expected value and variance of the number of games in the series than with the 1-1-1-1-1-1-1 format, and it is 4% less likely to go to a lucrative game seven. While it may reduce the travel requirements for the two teams, it appears to be less desirable from a revenue-management perspective.

3 Extended analyses

To generalise the analysis and investigate the effect of relative team quality and momentum on the 'fairness' of a playoff format, we will compare the probability of the superior team winning the series with a single home game as well as with the popular 1-1-1-1-1-1, 2-2-1-1-1, and 2-3-2 seven-game series formats.

3.1 Effect of relative team quality

Figure 2 illustrates the probability that the superior team wins the series for various values of relative team strength (QUAL) keeping $\phi$ at -0.36. As shown in the figure, for any given format, the probability that the superior team wins the series monotonically increases as the difference in team strength increases. For the situation in which the superior team is considerably stronger than the opponent (QUAL > 12.7), the results are consistent with conventional wisdom in that the longer, seven-game series will more likely result in the stronger team winning the series, particularly with the 1-1-1-1-1-1-1 and 2-2-1-1-1 formats.

Figure 2  Effect of relative team quality for various playoff formats

On the other hand, the opposite is true for low differences in team quality (QUAL < 7.5). For example, if QUAL = 2.0, the superior team has a 65.8% chance of winning a one-game series, but only a 55.9% probability with the 2-3-2 seven-game series, a decrease of nearly 10% points. As the teams become more evenly matched (i.e., as QUAL approaches 0), the probability of the superior team winning the series approaches 50% as the series length increases. Even for moderate differences in team quality (7.5 < QUAL < 12.7), the 2-3-2 format provides a lower probability than a one-game playoff and, for all values of QUAL, a lower probability than the other two seven-game formats.
An interesting consequence occurs when we evaluate the effect of relative team quality on the outcome for 1-, 3-, 5-, and 7-game series. Figure 3 illustrates this effect for alternating home-away sequences (1, 1-1-1, 1-1-1-1-1, 1-1-1-1-1-1). As shown in the figure, when the superior team is considerably stronger than the opponent (QUAL > 7.5), the results are again consistent with conventional wisdom that longer series will more likely result in the stronger team winning the series. However, for moderate differences in team quality (QUAL = 7.5), the length of the series has no effect on the probability of the stronger team winning the series and, for relatively equal opponents, a longer series will actually reduce this probability. Although these alternating home-away sequences are generally considered to be most conducive to the higher-ranked team, this is only true when there is a large difference in the quality of the two teams.

3.2 Effect of momentum

Much of the research on momentum in sports concludes that there is no significant effect of momentum, that winning/losing streaks are simply random occurrences (Vergin, 2000; Albert, 2004). Recently, however, evidence of positive momentum was found in the NBA (Arkes and Martinez, 2011) and NHL (Leard and Doyle, 2011) regular seasons. Furthermore, Mizutani (1991) and Urban (2012) noted negative momentum exists in the NBA Finals. To evaluate the effect of momentum on the outcome, Figure 4 illustrates the probability that the superior team wins the series for various values of serial correlation (ϕ) while maintaining QUAL = 10.

Figure 3 Effect of relative team quality for various series lengths

![Diagram showing effect of relative team quality for various series lengths](image)

By definition, there is no effect of momentum for a one-game series, which provides a 72.2% chance that the superior team wins the series (i.e., one home game). For the seven-game series, the effect of momentum in conjunction with the home-court advantage results in a diverse set of outcomes. For the 1-1-1-1-1-1-1 format, large negative momentum results in a situation in which it is fairly likely that the home team wins each of the seven games. If the superior team wins the first game at home as expected, the opponent is highly likely to win the second game due to the negative momentum and the home-court advantage, then for similar reasons, the superior team is highly likely to win the next game, etc. For positive momentum, the effects of home-court advantage and momentum are more in conflict, and the probability that the superior team wins the series becomes less than a one-game series. The 2-2-1-1-1 format reacts similarly to the 1-1-1-1-1-1 format, although less severe, except for high positive momentum at which it actually provides a slightly greater probability than a one-game series.

Figure 4 Effect of momentum for various playoff formats

![Diagram showing effect of momentum for various playoff formats](image)

Consider again the 2-3-2 series which is used in the NBA Finals and the MLB World Series. Except for very high positive momentum (ϕ > 0.784), it always results in a lower probability of the superior team winning the series than does a one-home-game playoff. In fact, it can result in a difference of over 4% points (at ϕ = 0.33 and −0.76), even with the moderately large relative team quality (QUAL = 10) that is common in the NBA Finals. Furthermore, it always results in a lower probability than the 2-2-1-1-1 format and, for ϕ < 0.620, it results in a lower probability than the 1-1-1-1-1-1 format. Obviously, this format would not be considered a 'fair' approach if the objective is to reward the superior team for a better regular season.

Figure 5 illustrates the effect of momentum for the alternating 1-, 3-, 5-, and 7-game home-away sequences (1, 1-1-1, 1-1-1-1, 1-1-1-1-1). As shown in the figure, 7-game series tend to be more fair than 5-games series; however, the 3-game series results in a higher probability of the superior team winning the series than does the 5-game series for positive momentum, and even higher than the 7-game series when there is high positive momentum (ϕ > 0.55).
4 Conclusion

Conventional wisdom is such that longer playoff series are more conducive to the superior team winning the series. However, we find that the popular 2-3-2 series actually decreases this likelihood, except for high differences in team quality and very high levels of positive momentum. The 1-1-1-1-1-1 playoff format appears to be most conducive to this issue of 'fairness' although the 2-2-1-1-1 format which is used in previous rounds of the NBA playoffs as well as all rounds of the NHL playoffs is similar in nature. However, depending on the relative team quality and level of momentum, they too can result in a lower probability of the superior team winning with a longer series. Similarly, longer series tend to be more fair, but for relatively small differences in team quality and for high levels of positive momentum, shorter series can actually provide a better chance for the superior team to win the series.

Therefore, league management may wish to consider alternative playoff formats to address the issue of fairness. Since a longer series does not necessarily result in a greater probability that the superior team will win the series, a three- or five-game series might be considered to increase fan interest. If a seven-game series is considered necessary, a 2-2-1-1-1 format would incur more travel for the participants, but would likely provide a better likelihood - relative to the 2-3-2 series - of the superior team winning the series. Finally, it should be noted that this analysis is based on 55 years of data from the NBA Finals; additional research would be appropriate to extend this type of analysis to other sports, to earlier playoff rounds, etc. to ensure these results can be generalized to other situations.

References


Notes

1The 2-3-2 format is such that the first two games and the last two games (if necessary) are played at the venue of the superior (higher-seeded) team, with the middle three games played at the opponent’s venue; for the 2-2-1-1-1 format, games 1, 2, 5, and 7 are played at the venue of the superior team.

2The NBA is appropriate for this analysis since (a) the NFL uses a single-elimination tournament, (b) the momentum effect for MLB is difficult to evaluate due to changes in the lineup from one game to the next (in particular, the pitchers), and (c) although other basketball leagues (e.g., WNBA) and hockey leagues (e.g., NHL) also utilize a best-of-7 playoff format, the NBA’s relative popularity – measured by substantially higher Nielsen ratings – make it an attractive choice from a revenue-management perspective.

**Makeup of UK petrol retail price: a case of income and environmentalism and implication for China’s taxation revenue and control of PM2.5 pollutants**

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Abstract: UK petrol retail prices have been changing owing to different reasons, including changes in any of the four major components – fuel duty, the product (in connection with crude oil prices), VAT and the retailers’ or delivery profit and the weaker pound sterling. However, this does not change the fact that the taxes on fuels, including fuel duties and the VAT’s account for over 50% of the retail price, one of the highest in the EU, which are not only one of the major sources of government revenue but also helps to protect the environment by discouraging drivers from using their cars. Therefore, it may also have a strong implication for the Chinese government, especially in its efforts to tackle traffic congestions, streamline the toll way charge systems and to control the PM2.5 pollutants while still struggling to stabilise its revenue from taxes/fuel duties.

**Keywords**: UK petrol retail price; fuel duties and VATs; government revenue; environment protection; PM2.5; control measures.


Biographical notes: Hui Ding is an Associate Professor at the School of Foreign Languages and a researcher at the Academy of Chinese Energy Strategy of China University of Petroleum. His research interests include international relations, pricing and taxation, and energy economics and policies. He was a visiting scholar/academic visitor to the Center for Translation and Intercultural Studies at the University of Manchester, UK.

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