Measuring team performance and modelling the home advantage effect in cricket

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ABSTRACT

Cricket differs from many team sports in that it is not generally played within easily definable constraints. Thus, it is difficult to compare and contrast team performances. By employing a range of linear and logistic modelling techniques this thesis quantifies the extent to which team quality effects and a range of associated factors such as home advantage have shaped team performance in Test, ODI and domestic cricket. With regards to the latter, the thesis established that, in all forms of cricket, a team's scoring potential and its capacity to win were both significantly amplified when it played at its home ground.

The thesis proposes a method to estimate a projected score for the team batting second in ODI cricket. The method scales up the team's actual winning scores in proportion to its unused run scoring resources. This creates a projected victory margin when it wins with unused run scoring resources at its disposal and provides a more realistic measure of its relative superiority at the point of victory than the current wickets-in-hand method. Accordingly, the thesis recommends a revised scheme for recording victories in ODI cricket which is consistent across innings and provides a mechanism for all victories to be compared and ranked on an equal footing.

The thesis employs linear modelling methods that account for the size of a victory in ODI cricket and the magnitude of the first innings lead in Test and domestic cricket to compute team ratings. The ratings are calculated independently of effects such as home advantage and quantify overall team performance relative to the average rating. They provide a robust measure of team quality and are not sensitive to the extraneous effects that may disproportionately impact on team performance. As a consequence, the thesis recommends that new methods be investigated to officially rate and rank teams in international cricket competitions. The team ratings also form the basis of a proposed outcome prediction model that can be instituted in Test cricket.

The thesis established that a surprising trend has emerged in Test cricket, which confirmed that the team batting second, in general, has enjoyed a distinct winning advantage over its opposition. Accordingly, the thesis ascertained that relative strength during the final rather than penultimate innings significantly affected match outcomes and recommends that

teams, when winning the coin toss, expose their strongest asset, whether this be batting or bowling, in the final innings.

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SIGNED DECLARATION

This thesis:

- Contains no material which has been accepted for the award of any other degree or diploma, except where due reference is made in the text of the thesis
- To the best of my knowledge, this thesis contains no material previously published or written by another person except where due reference is made in the text of the thesis

Signed: ______________________________

Dated: _______________________________

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CHAPTER 1
INTRODUCTION AND LITERATURE REVIEW

1.1 Overview

Cricket generates a wealth of statistics but any rigorous examination of the factors affecting match outcomes and the subsequent attempts by analysts to quantify the extent to which these factors may have impacted on team performance have attracted limited attention. The analysis of team performance in all forms of internationally sanctioned cricket has traditionally been of a cursory nature and the provider of scant information. For example, a team's effectiveness is usually measured by either its win/loss ratio or the extent of its victory margin (in runs). These are important indicators but provide only partial details on how specific factors may have contributed to a team's performance. For example, how valuable is it to bat first after winning the coin toss? Are teams advantaged by playing at home? Is a team's batting strength more important than its bowling strength? How important is it to establish a lead in the first innings of a Test match? How are teams advantaged by the points-based systems utilised in domestic cricket competitions? To effectively answer these questions the thesis will develop a range of statistical techniques in order to

- Formulate alternative ways of defining and measuring team strength in Test, one-day international and domestic cricket
- Quantify the extent to which measurable team performance effects such as home advantage and batting and bowling strength, for example, play a key role in defining a winning match outcome in all forms of cricket and contribute to (a) a team's victory margin in one-day international cricket (b) a team's first innings margin in Test and domestic cricket and (c) a team's innings score in one-day international cricket
- Formulate a new method for recording team victories in one-day international cricket in order that team performance can be compared and contrasted on an equal footing

- Develop a revised method for rating team performance in both one-day international and Test cricket
- Formulate a predictive algorithm that can be used to predict match outcomes in Test cricket

The initial focus of the thesis will be to explore and evaluate the conventional methods that analysts have used to evaluate and compare team performances in cricket at both the international and domestic levels. Secondly, a range of statistical and modelling methodologies will be introduced in order to (a) carefully define and quantify team strength and (b) gauge the extent to which a range of specific performance factors such as home advantage and the order of innings have contributed to match outcomes and the runs differential between competing teams. Note that the runs differential will be represented by either the victory margin, in the case of ODI cricket, or the first innings margin in the case of Test and domestic cricket.

1.2 Structural principles adopted for the thesis

Throughout the analyses, the team batting in the first innings of a match will be designated as Team 1 and the team batting in the second innings of a match will be denoted as Team 2. Consequently, in ODI cricket, Team 1 will be the team batting first and Team 2 will be the team batting second. In both Test cricket and domestic cricket, Team 1 will generally be the team batting in the first and third innings and Team 2 will be the team batting in the second and fourth innings. Note that in the advent of a team being asked to follow on then Team 1 will be the team batting in the first and fourth innings and Team 2 will be the team batting in the second and third innings. Frequent abbreviations used from hereon in are HA for home advantage, ODI for one-day international cricket and D/L for Duckworth and Lewis.

The thesis has been divided into ten chapters. These are summarised as follows:

- Chapter 1 introduces the thesis and provides an overview of previous related work
- Chapter 2 includes an analysis of the domestic competitions played in Australia and England; namely the Pura Cup and the Frizzell County Championship. The analysis

employs conventional exploratory techniques to gauge the degree to which specific factors such as HA impact on the level of team performance

- Chapter 3 introduces the D/L rain interruption rules methodology and demonstrates how it can be employed to calculate a projected score for Team 2 when it wins with unused run scoring resources (in the form of overs and wickets) at its disposal. This is used to calculate a projected victory margin as a measure of Team 2's superiority. As a consequence, this chapter advocates a revised method of recording Team 2 victories that are (a) consistent across innings; (b) provide a mechanism for all Team 2 victories to be compared and ranked and (c) allow Team 1 and Team 2 victories to be compared and contrasted on the same footing. This chapter introduces and builds on the work of Duckworth and Lewis (1998); de Silva, Pond and Swartz (2001) and Duckworth and Lewis (2004). It also discusses the dialogue that occurred between Duckworth and Lewis (2002) and Clarke and Allsopp (2002) regarding the use of the D/L methodology to estimate a projected Team 2 score
- Chapter 4 employs conventional exploratory techniques to quantify the extent to which specific factors such as HA impact on the level of team performance in both ODI and Test cricket. The Team 2 scores employed for the analysis of ODI matches are the projected Team 2 scores introduced in Chapter 3
- Chapter 5 applies logistic and linear modelling techniques to quantify the extent to which match outcomes are a function of first innings performance factors and establishes the degree to which these factors are able to explain the observed variation in the innings margins in the Pura Cup and the County Championship. The linear modelling parameter estimates are used as a basis for the establishment of domestic team ratings
- Chapter 6 builds on chapter 4 and employs logistic and linear modelling techniques to quantify the extent to which innings differentials and match outcomes in both ODI and the ICC Cricket World Cup match are sensitive to specific innings effects such as HA, regional factors and winning the coin toss. Also, in order to provide a measure of relative team strength the linear modelling parameter estimates are used as a basis for the rating of the ODI teams. This chapter also includes the work undertaken by Allsopp and Clarke (1999) in their analysis of the 1999 ICC Cricket

World Cup and Allsopp and Clarke (2000) and Clarke and Allsopp (2001) in their analysis of ODI cricket

- Chapter 7 employs logistic and linear modelling techniques to ascertain the degree to which match outcomes and first innings run differentials in Test cricket are sensitive to specific first innings factors such as HA and regional effects and examines the extent to which these factors are able to explain the observed variation in the first innings margins. The resulting linear modelling parameter estimates are used to rate the Test-playing nations. This chapter includes and extends the work undertaken by Allsopp and Clarke (2004) in their analysis of Test cricket
- Chapter 8 introduces a linear attack and defence model to gauge the extent to which the observed variation in the innings scores in ODI cricket is a function of specific first innings factors such as HA and regional effects. The resulting linear modelling parameter estimates are then used to establish ODI team batting and bowling ratings
- Chapter 9 introduces a linear attack and defence model to analyse Test cricket. This chapter builds on Chapter 7 and the work undertaken by Allsopp and Clarke (2004) in their examination of Test cricket. The resulting linear modelling parameter estimates are then used to establish team batting and bowling ratings for the Test-playing nations
- Chapter 10 provides a simple two-stage method incorporating team ratings and exponential smoothing techniques in order to predict match outcomes in Test cricket
- Chapter 11 concludes the thesis and explores avenues for further study

In the processes of statistical inference, significance tests will be conducted at the 0.05 level of significance whereby *p*-values of the order $p < 0.05$ are deemed to infer statistical significance. For *p*-values of the order $p = 0.000$, correct to three decimal places will be recorded as $p < 0.001$. The convention used to record test statistics will be, for example, $\left(F_{10,\,311} = 0.40,\ p = 0.945\right)$. This signifies an *F*-test value of 0.40 with 10 and 311 degrees of freedom at a significance level of 0.945.

The data used throughout the analyses was obtained via the Cricinfo archives at *www.cricinfo.com*.

The statistical analyses have been carried out via Minitab (Version 13.1), SPSS (Student version 9.0) and Microsoft Excel.

1.3 The structure of cricket

The origins of cricket extend back to the 13th century but the first official Test match was not played until 1877. At the international level, Test and ODI cricket is administered by the International Cricket Council (ICC).

Test cricket is played between the ten ICC sanctioned cricket playing nations and a match involves a maximum of two innings per team. A Test match can last up to five days (and occasionally up to six days), with each day allowing approximately six hours of play. The possible outcomes are a win (or loss), draw, or very rarely, a tie. A team wins outright by having a higher aggregate score after dismissing its opponent in the second innings. In the event of an uncommon situation, if both teams complete their second innings with the same aggregate score the match is declared a tie. Otherwise the match ends in a draw. A drawn result occurs when a match ends with neither team able to secure an outright result in the allotted time. In the majority of cases, when there is a winning outcome, Teams 1 and 2 will have batted and bowled twice. Generally, Team 1 will bat first and third and bowl second and fourth. Conversely, Team 2 will bowl first and third and bat second and fourth. Nevertheless, in some instances either Team 1 or 2 can win a Test match by batting only once. Team 1 will bat once if Team 2 is invited to follow-on and is subsequently dismissed a second time with an inferior aggregate score. This situation occurs when Team 2 is dismissed for a first innings score that is at least 200 runs less than Team 1's first innings score and, at the captain's discretion, is invited to bat a second time (or follow-on). In this case Team 1 will only be required to commence a final innings if its first innings score is surpassed by Team 2's aggregate score. Team 2 will only bat once if it amasses a relatively large total and Team 1 is dismissed a second time for a lower aggregate score.

Limited overs cricket began as a domestic level competition between English County teams in the 1960s. At the international level, the first official ODI match was played on January 5 1971 between Australia and England at the Melbourne Cricket Ground, Australia. ODI cricket had a serendipitous start at the international level, with the first match organised in order to appease a local audience starved of cricket after the third Test match between Australia and England ended prematurely due to inclement weather. Australia went on to defeat England in a 40-over per side match. ODI cricket is now played worldwide at all levels and is restricted to one innings per team. However, ODI sanctioned matches are restricted to the ten ICC sanctioned cricket playing nations. Each innings is allocated a maximum of 50 overs, with the possible outcomes in a completed one-day match being a win (or loss), a draw or a tie. The team with the highest score is declared the winner. A match is drawn if detrimental circumstances (such as inclement weather) do not allow a match to be completed to a point whereby the Duckworth and Lewis (D/L) rain interruption rules can be applied. This is usually at least 15 overs. A tie results when both teams achieve the same score after each innings has been completed. One of the unique features of ODI cricket is that many of the matches are now scheduled to be played as a day/night fixture (or colloquially termed 'under lights'). Under these circumstances Team 1 completes its innings in daylight whereas the majority of Team 2's innings is played 'under lights'.

The ICC Cricket World Cup is an ODI cricket competition that is conducted every four years between ICC sanctioned teams. The first attempt at a World Championship of cricket was in 1912, when a three-way series was conducted between Australia, England and South Africa. Unfortunately, the competition was marred by inclement weather and the concept was not revisited until 1975. Since 1975, however, the ICC Cricket World Cup has been contested every four years and has been a resounding success. The ten ICC Test-playing nations, together with an additional select group of ICC-sanctioned nations currently compete for the title. The World Cup is hosted by either a single nation such as England or a group of nations from the same geographical region such as Oceania (Australia and New Zealand).

Domestic or nationally-run cricket competitions are conducted in each of the International Cricket Council (ICC) sanctioned nations and form the basis of national Test team selection. In essence, the structure of cricket played at this level reflects both the long and short forms of the game that are currently played in the international arena i.e. Test cricket and ODI cricket. The longer matches are generally three or four days in length, with playing conditions similar to those adopted for Test cricket. The short matches are one-day matches limited to 50 overs per side, with playing conditions similar to those adopted for ODI cricket. The Australian national competition, which for the majority of its existence was referred to as the Sheffield Shield, is now officially known as the Pura Cup. Some of the other domestic competitions that are currently played worldwide are the Frizzell County Championship in England and the Busta Cup in the West Indies.

The essential difference between Test and domestic cricket is that in a domestic cricket competition match outcomes are defined by the acquisition of points. The team accruing the most points is declared the winner. The scoring systems adopted by each nation vary from region to region but teams are essentially awarded points for winning outright, leading on the first innings and for specific batting and bowling achievements. With regards to the latter, teams can earn points, for example, if they dismiss all batsmen in relatively quick time or compile a high score with the loss of few wickets. An outright result attracts the largest allocation of points. Teams can also be penalised points for not strictly adhering to sanctioned playing conditions. In essence, domestic competitions are structured so that teams are encouraged to play attractive cricket while at the same time focussing on winning outright.

1.4 The general analysis of cricket

Clarke (1998) in Chapter 4 of Test statistics provides an extensive overview of the work undertaken by analysts in their examination of cricket. The statistical analysis of cricket was pioneered by Elderton and Elderton (1909) in their Primer of Statistics in which cricket data is used to illustrate some of the fundamental aspects of statistics. Further early pivotal work was undertaken by both Elderton (1927) who used cricket scores to demonstrate the exponential distribution and Wood (1941, 1945) and who examined both the consistency of performance and the application of the geometrical distribution to model cricket scores. More recently, Pollard, Benjamin and Reep (1977) have tested the efficacy of modelling cricket scores by employing the negative binomial distribution; Pollard (1977) has compared the application of both the geometric and the negative binomial distributions to model cricket scores; Pollard, Benjamin and Reep (1977) has successfully applied the negative binomial distribution to model batting partnerships; Croucher (1979) has applied the negative binomial distribution in an unsuccessful attempt to model partnerships in Australia versus England Test matches; and Clarke (1991) has employed the geometrical distribution to model the number of balls faced in ODI cricket (instead of the customary scores) to establish that there was no evidence of any significant improvement in performance. Kimber and Hansford (1993) have challenged the methodology used to calculate a batsman's batting average and offer an alternative analytical method based on survival analysis techniques. In modelling run scoring consistency, Elderton and Elderton (1909) propose that the standard deviation should be used as a measure of player performance, with low standard deviations suggesting an acceptable level of consistency. Alternatively, Wood (1945) prefers to use the coefficient of variation as a measure of run scoring consistency. Pollard (1977) and Clarke (1994), have similarly investigated the use of the coefficient of variation in the respective contexts of a batsman's playing profile and ball by ball scoring distributions. In examining the strategies employed in cricket, Clarke (1988) and Johnston (1992) have used a dynamic programming model to investigate the relationship between runs scored and wickets lost in ODI cricket and Croucher (1982) has examined dismissals and dismissal rates in Australia versus England Test matches during the period 1946-80. In attempting to develop a sound player-rating system Johnston (1992) and Johnston, Clarke and Noble (1993) have developed methods to rate both team and player performance in ODI cricket.

Further dynamic programming methodologies have been undertaken by a number of authors to examine batting strategies, run scoring policies and the assessment of player performance in ODI cricket. Clarke (1988) demonstrated that, in general, teams in ODI cricket could optimise their batting performance by scoring more quickly in the early part of an innings. Preston and Thomas (2000) have also applied these techniques together with survival analysis models to examine batting strategies in ODI cricket. Further work using dynamic programming models have been undertaken by Clarke and Norman (1997, 1999) in their analysis of optimal batting strategies at the end of an innings and by Clarke and

Norman (2003) in their examination of the value of choosing a ‘night watchman’ in Test cricket.

The team batting third in a Test match, if in a strong position, has the option of declaring its innings closed and subsequently inviting the opposing team to bat again. The timing of the decision is crucial and must be made so as to optimise a team’s chances of winning. In essence, before opting to declare, a team must be mindful of the dependence between the time remaining in a match, the strength of its position and the strength of its opponent. For example, a team may have established an unassailable lead but not allowed enough time to dismiss the opposition. Scarf and Shi (2005) have employed logistic regression techniques to model this situation in their analysis of Test cricket. In setting up their model, some of the pivotal factors they take into account are the time remaining in a match, the opponent’s target score, the differential in strength between the teams, the current run rate and the lead (in runs) at the time of the declaration.

1.5 The HA effect and team ratings in organised team sports

In the context of many team sports, the HA effect has been studied extensively and it is well documented that teams, in general, enjoy a significant quantifiable advantage. In essence, HA provides a measure of a team’s capacity to improve its scoring potential when playing on its home ground and provides a gauge of a team’s ability to either maximise its winning potential or minimise its losing potential when playing at home. More precisely, HA represents the advantage a team enjoys over its opponent when playing at home compared with its performance against the same team on a neutral ground. In this context, it would be expected that the average winning and losing margins for the home team would be respectively above and below its average winning and losing margins when playing on a neutral ground. For example, suppose a hypothetical competition consists of only two teams: Team 1 and Team 2, who oppose each other regularly in a sport where goals are scored. During a regular season suppose that Team 2, when competing on a neutral ground, is a 3 goal better side than Team 1. And suppose that Team 1 enjoys an average winning margin of 10 goals at home. This suggests that Team 1 is a $10-3=7$ goals better side than

Team 2 when playing at home. Now suppose that during the ensuing season Team 2 is a 12 goal better side than Team 1 on a neutral ground. If Team 1 still enjoys a HA of 10 goals this suggests that Team 1 now displays a home ground disadvantage of $12 - 10 = 2$ goals. However, even though Team 1 is expected to lose at home its considerable HA has lessened the impact of the dominance of its opponent. This underscores the fact that the average losing margin of an inferior team at home may be substantially smaller than its average losing margin when playing away from home. Citing the example above, even though Team 1 is expected to lose at home its subsequent losing margin is expected to be smaller. This indicates that Team 1 still enjoys a HA for the simple reason that it has restricted the winning margin of its opponent when playing at home. Unfortunately, this will not be reflected in the match outcome of a win, draw or loss. This highlights the misconception often associated with the analysis of HA as purported, for example, by Schwartz and Barsky (1977) in their analysis of baseball, American football and hockey and Courneya and Carron (1992) in their examination of baseball. In this context HA is interpreted as the ability of a team to win more than 50% of its home games in a balanced home and away competition; i.e. in a competition where, during a regular season, teams are opposed to each other in an equal number of home and away matches. This provides an average measure of HA but offers limited information on the effects of HA as it relates to individual teams. In effect, it is surmised that the relative abilities of the opposing teams, together with the associated HA effects, do not act independently of each other since under the systems proposed by Schwartz and Barsky (1977) and Courneya and Carron (1992) the superior teams will ostensibly be the only teams deemed to be displaying a HA. This approach (a) does not take full account of the relative abilities of the competing teams (b) assumes that and team quality and HA effects are dependent on each other and (c) precludes the notion that the capacity of a team to restrict the winning margin of a superior opponent is also a strong indicator of HA.

As a guiding principle, authors such as Edwards (1979), Snyder and Purdy (1985), and Pollard (1986) also define HA in a balanced competition as the ability of a team to win more than 50% of its home games. Essentially, this interpretation assumes that the only effect contributing to the observed differences in team performance is HA. Other effects, such as those associated with the individual strength of competing teams are not taken into account. This suggests that a perennially inferior team could be perceived to have a home ground disadvantage since it is highly likely the team will generally be defeated by more superior teams no matter where the playing environment is located. It is more likely that a HA effect contributes to the relatively inferior teams' average margin of loss being less pronounced at home rather than in their capacity to win at home. Nevill and Holder (1999) in their overview of HA in sport also argue that the quality of the opposition is effectively eliminated by counterbalancing the game location.

Other popular methods adopted by authors to examine the HA effect in team sports are the simple binomial test and the non-parametric χ^2 goodness-of-fit test. Both of these methods compare the number of home wins with the number of away wins in a balanced competition. Subsequently, if the home team performs significantly better than what would be expected by chance alone then this is deemed to be evidence of a HA effect. These methods have been employed by authors such as Edwards (1979) in his examination of American football; Pollard (1986) in his analysis of soccer and Leonard (1998) in his study of the World Series in major league baseball. In order to take account of multiple outcomes such as a win, draw and loss (or in some instances, a tied result) the simple binomial test and the χ^2 goodness-of-fit test can be extended to a multinomial test. The latter analytical method has been suggested by Pollard (1986). However, Nevill and Holder (1999) cautions the use of the χ^2 goodness-of-fit test when comparing home and away performances, indicating that authors have often confused the total points scored with total frequencies. They suggest that this can lead to inflated χ^2 test statistics. They also discuss another analytical error that is often made when tied games are included in the analysis is to assume that, in the absence of a HA effect, the outcomes of a win, draw and loss are equally likely. They contend that this can also lead to inflated χ^2 test statistics. Another aspect of HA that is often overlooked when using match outcomes alone to quantify the HA effect is the size of the victory. For example, this methodology espouses that a one-run victory in an ODI match is rated on par with a 200-run victory. One victory is clearly more decisive than the other. This methodology also disguises the fact that a marginal home loss by a perennially inferior team when opposed to a superior opponent is in effect a stronger display of HA than a marginal home win for the superior team when the match situation is reversed.

Gayton, Mutrie and Hearns (1987), in examining HA in the organised women's sports of American collegiate basketball, field hockey and softball, undertake a different approach to Schwartz and Barsky (1977) *et al*. Instead of assuming that incidence of HA results in more than 50% of games being won at home Schwartz and Barsky (1977) consider the effects associated with team quality by using the extent of the percentage difference in games won at home and away from home as a measure of HA. Schwartz and Barsky (1977) imply that a significantly large percentage difference between home and away wins is evidence of the existence of a HA effect. Gayton and Coombs (1995) adopt a similar approach in their examination of American High School basketball. Gayton and Coombs (1995) use data that spans a 20-year period. The trend in team quality effects may vary considerably over this time period and subsequently impact upon the real extent of HA effects. As a consequence, the inherent variability in team quality may be such that any HA effects could be more influential at some times more than others. For example, it would be expected that in seasons where the variability in team quality is relatively low the subsequent variability in match outcomes would be relatively high and vice versa. Also, the analysis is based on the questionable premise that relatively superior teams display a propensity to winning at home. If Gayton and Coombs (1995) took account of the extent to which the superior team's scoring potential was restricted by relatively inferior teams when playing on the latter's home ground this would offer a more accurate representation of the combined effects associated with team quality and HA.

In their examination of the home versus away performances of American collegiate basketball teams in the Atlantic Coast Conference, Silva and Andrew (1987) also adopt a different approach to authors such as Schwartz and Barsky (1977), Edwards (1979), Snyder and Purdy (1985) and Pollard (1986). Contrary to the notion that HA is primarily quantified as the ability of a team to win more than 50% of its home games in a balanced competition Silva and Andrew (1987) suggest that a team's ability to win at home is not enough to declare that it has a home court advantage. Accordingly, Silva and Andrew (1987) quantify the home court advantage as the ability of the home team to consistently perform at an above average level in a series of identified performance measures such as the field goal percentage, the free throw percentage, turnovers, personal fouls and rebounds. They compare each of these variables to specific subjective performance standards pre-determined by highly qualified coaches. They propose that the home team may perform at an average standard on its home court but is capable of winning regularly because the visitors are possibly playing at a below average level due to an away court disadvantage. They argue that the superior teams generally win because they not only play well at home but are also more adept than their opponents at exploiting their effectiveness in many facets of the game. However, claiming that an above average performance provides evidence of a home court advantage precludes the situation whereby a relatively inferior team may consistently perform above expectations at home in all performance indicators but fail to produce regular winning outcomes. It is also problematic to predetermine overall performance standards at the expense of more idiosyncratic measures such as individual team quality and the vagaries of playing conditions over the period of the study. Another problem raised by the application of subjective judgements to gauge levels of performance is that the experts have used the same standards over the eleven-year period of the study. This may be appropriate but it is founded on the questionable assumption that performance standards have remained consistent over time. A more accurate representation of the home court advantage would also need to take account of the performance of the home team relative to overall trends in team quality standards.

In an examination of the home court advantage in American women's collegiate basketball Madrigal and James (1999) take into account the relative abilities of the opposing teams and, based on winning and losing performances, subsequently categorise the competing teams as being of low or high quality. They established that teams generally had a better home winning percentage and confirmed that the HA was most apparent when strong teams played each other. The HA effect was not as distinct when weaker teams played each other. They also established that high quality teams when opposed to the same opponent generally performed better at home than away from home. In contrast, the low quality teams tended to perform better away from home when competing against the same opponent. Team quality effects were also considered by Acker (1997) in his study of an individual team's HA and location variation factors in American professional football. In determining an individual team's HA he considered three factors: the mean points-margin, a measure of team quality and the overall league mean points-margin. The team quality factor was quantified by the mean points-margin for teams which had posted the same number of regular season victories. He then calculated a regression slope based on these aggregated season victories. The HA was computed by determining the mean points-margin for each team; finding the number of season victories for the team and then plotting the values referenced against the regression slope. If a team's mean points-margin fell above the regression slope it was said to have outperformed the expectations based on team quality, and its distance above the slope was added to the league mean HA. This provided a measure of the HA effect for individual teams. The converse was true if a team's mean points-margin fell below the regression slope. He found a nearly perfect positive linear relationship when comparing team quality and the mean points-margins. He was able to establish that the majority of teams enjoyed a HA of various degrees.

Schwartz and Barsky (1977) compare the HA in a number of indoor and outdoor sports and surmise that HA is more prevalent in the indoor-based sports. Similarly, Pollard (1986) compares the HA effect in a number of sporting competitions and concludes that soccer, on average, generates the largest advantage. These analyses may lead to misinterpretation since the variability and distribution of scores for each of the sports may be substantially different. And since both Schwartz and Barsky (1977) and Pollard (1986) have not conducted any statistical tests throughout their analyses there is no effective way of gauging if there is a significant HA effect or the outcomes are simply caused by random variation effects. A theoretical model that adequately fits the distribution of scores in one sport may be different from the models applied to other sports. Not unexpectedly, if the variability in team quality were relatively low, such as American baseball and ice hockey, any HA effect may be more pronounced than in sports where the variability in team quality is relatively high, such as Australian Rules football and cricket. In sports where there is a high variability in match outcomes, the team quality effect is a weak predictor of match results, making the subsequent outcomes harder to predict. In sports of this nature, aggregate scores are vulnerable to the natural variability inherent in the sports, making it difficult to differentiate between this natural variability and team skill. The converse is true in sports where the variability in match outcomes is low. Not surprisingly, under these circumstances the team quality effect is a strong predictor of match outcomes. Interestingly, in sports such as American baseball and ice hockey it is documented by authors such as Berry (2001) that luck, more so than skill, is often a major factor contributing to a winning match outcome. Berry (2001) suggests that in a one off match, for example, it would not be unreasonable to expect a college baseball team to defeat an American major league team. A case in point is the baseball competition at the Olympic Games, which often surprises with an underdog pulling off an unexpected victory. However, this is not usually the case with sports such as Australian Rules football and cricket because the combined skill level of the players that constitute a team is a key contributing factor in defining match outcomes. Luck plays a far less important role in these sports. Nonetheless, it is important to note that the selection of team squads in many national sports is now centrally controlled by a drafting system and salary cap restrictions. These measures have been introduced in order to balance the overall quality of the opposing teams and to ensure that at the start of a season all teams have a similar chance of winning the competition. Thus, it would be expected that as the relative difference in team quality diminishes, any consequential effects would become less variable. Not surprisingly, match outcomes would become more variable and subsequently harder to predict. The team quality effect in this instance would be a weaker predictor of match outcomes. Under these circumstances it is likely that effects such as HA or possible peripheral pressures may become influential in shaping match outcomes. In light of this, however, the scoring systems adopted by different sports can also contribute markedly to a winning match outcome. In a soccer match, for example, it would not be unexpected for an underdog to snatch a lucky victory because goals come at a premium. Conversely, in an Australian Rules match, with scoring happening continually, a far superior team will be able to score more effectively against much weaker opposition.

Stefani and Clarke (1992) and Berry (2001) have also compared the HA effect across a number of sports that are based on different scoring systems. Stefani and Clarke (1992) compute the quotient of the expected total score and the calculated HA to attain a scale of ratios that can be used to make comparative judgements. Stefani and Clarke (1992) subsequently established that European Cup soccer provided the strongest HA effect. In contrast Berry (2001) proposes that the distribution of scores be ignored and only the match outcomes be considered. Berry (2001) applies conventional binary logistic techniques to model the probability that the home team beats the visiting team, assuming that teams enjoy a common HA that is unique to each sport. Berry (2001) demonstrated that in sports where the team quality effects are less variable such as major league baseball, match outcomes are harder to predict than in sports where team quality effects are highly variable such as American football.

Stefani and Clarke (1992) introduce methods that can be used to predict outcomes in unbalanced competitions such as Australian Rules football. They apply two different schemes to the results; firstly an unweighted least squares approach, which shrinks predictions compared with the differential in team ratings and secondly; a scheme which uses the 0.75 power of error to pre-shrink ratings compared with the least squares approach so that each prediction depends on the actual team rating differential. In applying the first scheme they use linear modelling techniques to ascertain the extent to which the rating differential and a HA effect account for the victory margin. The HA effect is interpreted in two ways; firstly as an effect common to all teams and secondly; as an effect unique to each team. In applying the second scheme they consider two rating systems to predict match outcomes: one based on an unweighted least squares approach and the other based on exponential smoothing using the 0.75 power of error. They assumed that each team displayed a common HA over the period of the study. They established that the respective models correctly predicted match outcomes approximately 68% of the time and concede that the level of accuracy achieved by the models are limited by the available data.

Barnett and Hilditch (1993) investigate the effects of artificial pitch surfaces on HA in four divisions of English club soccer. In their preliminary analysis they considered three home and away measures upon which to compare performances (i.e. on both natural and artificial pitches). These included the number of points scored, the number of wins, draws and losses and the number of goals scored (for and against). To account for effects associated with team quality they construct measures of relative home and away performance in terms of points, goals and match outcomes that are independent of the essential comparative superiorities of the teams. In considering the points scored at home and away from home, to quantify the extent to which league table position predicts the difference in points per match they employ standard linear modelling techniques.

In his analysis of winning and losing streaks in the National Basketball Association Wood (1992) demonstrates that there was a clear relationship between the home court variable and game outcomes. He goes on to suggest that a team's ability to maintain a winning streak is positively linked to its home court advantage. In conducting a stepwise multiple regression analysis to gauge the extent to which the outcomes of the previous game, team record and the home court variable predict game outcomes he established that the home court was the only variable that impacted significantly on the outcome of individual games. He also found that the home court predictor explained more of the variance in game outcomes than the other predictors. In a similar analysis involving American baseball He found no evidence to suggest that any of the following variables: home field advantage, the previous record against the current opponent, the outcome of the previous game and the records of the pitchers, consistently predicted the outcome of individual games. By using the binary outcome of win or loss as the dependent variable in both his analyses of basketball and baseball He is assuming that qualities associated with the selected predictor variables are only contributing to a team's ability to win or lose and not to the extent to which a team wins or loses. To use an extreme example, in a game of basketball a relatively inferior team may lose a match by 80 points away from home but lose by only one point on its home court. In each case the outcome of the game is recorded as a loss but the extent of the loss on the team's home court is marginal. Instead of using the win/loss record as the dependent variable it would be more illuminating if the home court victory margin were used. This would have provided a more sensitive evaluation of the extent to which the predictor variables contribute to a team's winning and losing capacities.

In analysing HA in American college basketball, Harville and Smith (1994) fit various linear models to the outcomes of games played in a season where the outcome parameter is defined as the victory margin. They consider three linear models, all of which account for the relative difference in strength of the opposing teams. The second and third models incorporate a home court advantage parameter that is respectively common and unique to each team. For the second model they assume that the expected difference in score between any two teams in a game played on a neutral court is halfway between that in a game played on the first team's home court and that in a game played on the second team's home court. In the third model it is implicit that the expected score differential between any two teams in a game played on a neutral court equals the difference in the expected score differential in games played by them against a common opponent on the opponent's home court. They apply standard linear modelling methods to determine the extent to which team quality and HA effects contribute to the observed variation in the victory margins. They established that there was strong evidence for the existence of the common home court advantage and some evidence for team-to-team differences in the home court advantage. They concede that there are limitations with the application of the second and third models and suggest some possible improvements. Firstly, they propose that the teams be divided into classes with the home court advantage assumed to be the same if opposing teams are from the same class but different if the teams are from different classes. This situation may arise if teams share a home ground. Clarke (1997) considered this variation in his analysis of Australian Rules football. Secondly, they suggest that the home court advantage could be allowed to vary from game to game as a function of the points scored by the opposing teams. Thirdly, they propose that the common HA parameter used in the second model could be replaced by a parameter that averages out random effects associated with each opposing team and has a common unknown mean and common unknown variance. Next, they suggest that the team quality effects be treated as random effects and possibly allowed to vary with time. Finally they propose that either a fixed or random interaction effect be incorporated and lastly, they suggest that assumptions associated with the residual effects could be relaxed.

The modelling techniques proposed by Harville and Smith (1994) are also adopted by Clarke and Norman (1995) in their examination of soccer data in the English Football League. Clarke and Norman (1995) underscore the fact when examining HA it is crucial that the relative abilities of opposing teams be taken into account because the quality of the opposition may overshadow any effects associated with HA. In modelling the extent to which team ability and possible HA effects predict the goal differential for the home team they assume that HA is unique to each team and initially use standard linear modelling techniques to fit a model to the individual match results. They use the goal differential as the dependent variable since it is more sensitive to HA than simply using the match outcomes of a win, draw or loss. They found HA effects to be quite variable from year to year and established that there was a significant year effect. Division effects were found to be not significant and any effects due to differences between the clubs were marginally significant. They also introduce the concept of a paired HA. This asserts that a team's individual HA is the average of its individual HA when paired with all opponents. They found their estimate of the paired HA gave similar findings to their estimate of the common HA effect, however the findings were found to be highly variable. In analysing the effect of distance on HA they established that a clear relationship existed between the distances travelled by teams and the paired HA, with HA and travel distance being positively correlated. Using the win margins instead of goal difference as the dependent variable they found the estimate of the common HA to be similar but with a tendency to produce slightly more significant results. They note that whatever it is that produces HA tends to operate more effectively in determining winners rather than just larger winning margins. They apply similar techniques in a further study of English soccer data. Instead of using the traditional method of computing the percentage of home wins and adopting this as a measure of the average effect of HA they compute a team's individual HA. This provides a more accurate representation of the HA effect since it takes account of the relative strengths of the opposing teams. Since the competition is balanced Clarke (1996) is able to apply simple arithmetic techniques to the final league table that is equivalent to fitting a linear model to the winning margin by least squares as employed by Clarke and Norman (1995). The method is based on fitting expected values to the marginal totals.

In his modelling of paired comparison data in soccer, where there is a propensity for a large number of draws and a large variability of draw percentages among players, Kuk (1995) employs maximum likelihood and the method of moments techniques to examine the extent to which the relative difference in strength of the opposing home and away teams and their tendencies to force a draw predict the probability of a win, draw or loss. Kuk (1995) considers both a common HA model and an individual HA model. In applying the proposed models to one season of the English Premier Soccer League he established that it was more difficult for teams to achieve a winning outcome in away rather than home matches.

Neville, Newell and Gale (1996) have undertaken an analysis of the factors associated with HA in soccer and in particular examine the English and Scottish football leagues. They investigate the impact of crowd size and the behaviour of officials on HA. They employed the match results and mean attendances in one season of the English and Scottish football leagues as the basis for their study. To quantify the impact of officialdom on HA they recorded the frequency of 'sendings-off' and the 'awarding of penalties'. They found strong evidence for the existence of HA. They also established that HA increased with increasing crowd size and that the observed variation in the frequency of ‘sendings-off’ and penalties scored between leagues can be associated with the linear trend based on mean crowd attendance. Where crowd sizes were smaller the HA in penalties scored was found to be negligible and, in the case of ‘sendings-off’, was reversed in favour of the away side where crowd size was smallest. Where crowd sizes were larger, the away sides were found to be penalised consistently more often than were the home side. They also demonstrate that there is a strong negative correlation between the percentage of home wins and the percentage of home ‘sendings-off’ and a strong positive correlation between the percentage of home wins and the percentage of penalties scored.

Holder and Nevill (1997) examine the extent to which players in tennis and golf tournaments perform above or below their expected level of performance, based on their world rank, when playing at home. They found some evidence of a HA effect in the Wimbledon tennis tournament but concede that this is most likely an anomaly of the data collection. Nevill, Holder, Bardsley, Calvert and Jones (1997) have undertaken a similar study of the identification of HA in tennis and golf tournaments. In their analysis of a number of major international tennis and golf tournaments they established that there was some evidence of a HA effect in the Wimbledon tennis tournament and the US Open golf championship but concede that this can be partially explained by the lack of availability of some of the world rankings data for British tennis players competing at Wimbledon and the selective entry of golfers in the US Open. They found no evidence of a significant HA effect in their examination of the other tournaments.

Lee (1999) investigates HA and the offensive and defensive capabilities of opposing teams in the Australian Rugby League competition. He established that the HA effect was significantly positive and that, in general, a teams’ defensive strength was relatively more important than its offensive strength. Nettleton (1998) also examines home court advantage and, in particular, analyses the sensitivity of offensive and defensive plays to game location for one of the competing teams in an American collegiate basketball competition.

1.6 The HA effect in cricket

Organised team sports such as basketball, hockey and soccer are designed to operate within consistent time and structural constraints such as court size and surface type and are complemented by uncomplicated scoring systems. This accessible game format has generally made the quantitative analysis of HA in most sports an achievable objective. Even though cricket is also controlled by a rigid format it is not subject to the same structural constraints evident in most team sports. For example, in some forms of cricket the fortunes of a team may ebb and flow over a four or five-day period, making the isolation of specific effects, such as those associated with HA, a difficult proposition. In his analysis of Test cricket statistics, Clarke (1998) bemoaned the fact that the examination of HA in cricket has not been thoroughly investigated.

Another aspect of cricket which separates it from most team sports is that the attacking and defensive modes of play, in essence, are clearly defined. It can be argued that a team uses its offensive strength to maximise its score when batting and conversely uses its defensive strength to restrict the score of its opponents when bowling. In contrast, in most team sports, these modes of play regularly interchange within the flow of the game. For example, in a basketball game, a team plays offensively when having a shot on goal but is then immediately required to play defensively if its opponents gain possession of the ball.

Efforts to examine and document the effects of HA in cricket have been perfunctory when compared with the analysis of other organised team sports. In one instance, HA implications have been considered by Crowe and Middeldorp (1996) in their study of the rate of 'leg before wicket' (LBW) dismissals between Australians and their visiting teams for Test cricket series played in Australia between 1977 and 1994. They use a logistic regression model to establish the extent to which the location effect has on the rate of LBW dismissals for both the total number of innings and those of the first six batsmen. They verified that the teams playing Australia were significantly more likely to be given out LBW than the Australian team. The odds of being given out LBW for three of the teams (namely England, Sri Lanka and South Africa) were established to be significantly higher than for the Australian team. They infer from this that one of the possible sources for this perceived HA is familiarity of local conditions i.e. the opponents unfamiliarity with local pitch conditions has in effect made them vulnerable to being given out LBW. In further examination of the officialdom of cricket, Chedzoy (1997) studied the effect of umpiring errors in cricket and provided a means of measuring its impact on batting performance.

Davis (2000), in his analysis of HA in all Test cricket matches played between 1877 and 2000 contrasts the positive differential in runs scored per wicket by a team in its home country with that of its overall performance. A larger differential for home country performances is claimed to be evidence of a HA effect. He establishes that the teams that enjoyed the highest HA were those from the subcontinent: India, Pakistan and Sri Lanka. It is important to note, however, that when comparing rates or percentages it is important to gauge whether or not the observed differences in performances are created by a real effect, such as HA or are simply due to the variability in the team quality effect. Just because a team tends to win at home doesn't necessarily mean that it displays a strong HA. It may simply mean that they are a relatively strong team. Thus, when comparing the real effect of HA it is advisable to also factor in the relative abilities of the opposing teams in order to quantify any effects due to team quality. Otherwise, the degree to which home related effects have perceivably advantaged teams cannot be accurately determined. For example, if a strong team regularly plays at home against markedly inferior teams it is highly likely that the extent of the HA will be inflated by the stronger team's propensity to win easily against weaker opposition. Authors such as Silva and Andrew (1987) quantify HA as not only the ability of the home team to consistently perform well at home but its ability to consistently perform at an above average level in a series of identified performance measures. They propose that the home team may perform at an average standard at home but are capable of winning regularly because the visitors are possibly playing at a below average level due to an away team disadvantage. They also argue that the superior teams display a tendency to win because they not only play well at home but are also more adept than their opponents at exploiting their effectiveness in many facets of the game.

Davis (2000) also supplies supplementary evidence suggesting that the majority of the Test playing nations enjoyed a home umpiring bias with regards to favourable LBW decisions. These findings, to an extent, support the hypothesis proposed by Crowe and Middeldorp

(1996). However, the inferences drawn are markedly different. However, where as Davis (2000) suggests that umpires consciously favoured the home team Crowe and Middeldorp (1996) argue that, because of Australian umpires being more familiar with the local playing conditions, Australia attracted its fair share of favourable LBW decisions when playing at home.

de Silva and Swartz (1997) have examined the HA effect in ODI cricket matches. They initially use exploratory analytical techniques to establish that there is strong evidence supporting a HA effect. They apply a logistic model to evaluate the degree to which the relative abilities of the opposing teams and a common HA effect has on the winning percentage of the home team. They establish that if two teams of equal ability play on the home ground of one of the teams, the winning probability for the home team will increase substantially. They have made some adjustments to their model to account for perceived individual team effects but the computed results are comparable apart from a marginally smaller standard error.

1.7 Team ratings in cricket

At present, at the completion of ICC sanctioned international cricket matches teams are awarded rating points. Points are allocated at the completion of all ODI and Test matches and are subsequently used to calculate a team rating. Team ratings for ODI cricket were officially introduced in August 2003 whereas team ratings for Test cricket were instituted in August 2002. This scheme been introduced so that team performances can be compared and contrasted on the international stage. Test teams compete for the LG ICC Test Championship and ODI teams compete for the LG ICC ODI Championship.

As outlined by the International Cricket Council (2005b), a team rating in a Test match is obtained by dividing a team's total points by its match/series total (to the nearest whole number). The match/series total combines the number of Test matches played and the number of series played. Both the points earned and the match/series totals are weighted so that the match/series total for all Test series played prior to August 2003 are halved. The number of points earned by a team for a given Test match or series depends on the result (win, draw, loss or tie) and the rating of its opponent. The higher the rating of the opponent the more points earned for defeating them. Rating points are calculated at the conclusion of a series and consist of two steps. Firstly, the points earned during the series are calculated and then a rating-points formula is applied in order to determine the number of rating points earned by each team. These points are then added to a team's existing rating points total and used to generate its updated ratings. In earning series points, teams earn one point for a series win and half a point for a draw. If the series comprises two or more matches there is a bonus point available for the series winner or half a point for both teams if the series is tied. In applying the rating-points formula, the points earned depends on the rating gap between the two teams. If the gap is less than 40 points, the number of rating points scored by each team at the end of a series equals

- The (series points scored) multiplied by (50 points more than the opponent's rating) plus the (series points conceded) multiplied by (50 points less than the opponent's rating)

If the rating gap between the teams is 40 points or more, the number of rating points scored by the stronger team equals

- The (series points scored) multiplied by (10 points more than its own rating) plus (the number of rating points conceded) multiplied by (90 points less than its own rating).

If the rating gap between the teams is 40 points or more, the number of rating points scored by the weaker team equals

- The (series points scored) multiplied by (90 points more than its own rating) plus (the number of rating points conceded) multiplied by (10 points less than its own rating).

These figures are then added to a team's existing points. This result is then divided by the new match/series total to produce the updated rating.

As outlined by the International Cricket Council (2005a), a team rating in an ODI match is obtained by dividing the total points earned by the number of matches played, with the answer given to the nearest whole number. The number of points a team can earn depends on two factors: the result (win, tie or loss) and the rating of its opponent. As is the case with Test cricket, the higher an opponent's rating, the more points are earned for defeating them. However, whereas Test cricket ratings cover all matches played since August 2002 the ODI ratings are based on the most recent three years of results. Every August, the first year's results are dropped from the table and so will cover the most recent two years of results. Thus, the ratings automatically change overnight without an ODI match being played. Both matches played and the points earned are weighted, with recent performances weighted more heavily than past performances. First year (Period 1) results attract a one-third weighting; second year (Period 2) results attract a two-thirds weighting and the most recent matches (Period 3) are weighted at one. The rating points a team can score each match are based on the result and the rating gap between the teams. The points are added to a team's existing points total and are used to generate a team's updated ratings. If the gap between the two teams is less than 40 points:

- The winning team scores 50 points more than its opponent's rating
- The losing team scores 50 points less than its opponent's rating
- If the match is tied each team scores its opponent's rating

If the gap between the two teams is 40 points or more:

- If the stronger team wins, it scores 10 points more than its own rating while the weaker team scores 10 points less than its own rating
- If the weaker team wins, it scores 90 points more than its own rating while the stronger team scores 90 points less than its own rating
- If the match is tied, the stronger team scores 40 points less than its own rating whereas the weaker team scores 40 points more than its own rating

Rating systems of this type, though providing a crude measure of a team's relative standing, ultimately fail because they do not take into account aspects that reflect the vagaries and specific characteristics of each match. In a Test match for example, a team winning a five-Test series may have crushed its equally rated opponent, winning each match by a huge margin. In contrast, it may have won each match by the barest of margins. In each of these scenarios, however, under the ICC rules the winning team receives the same number of rating points (i.e. for winning the series) even though in the former case the overall performance was significantly stronger. In a similar vain, the ICC system implies that in a drawn match the competing teams are equally matched. This could be far from the truth. For example, a Test match could be abandoned (due to inclement weather) with one team being on the brink of a decisive victory. Or, similarly, due to enforced breaks in play, the reduction in playing time may mean that one team, though in a superior position, is unable to enforce a deserved victory. ODI cricket raises similar anomalies. For example, in an ODI match between two equally rated teams, a win by one run is ranked on par with a 150 run victory. Clearly, in the latter case, the winning team was considerably more dominant. In both situations the rating system clearly fails to reflect the extent of a team's victory. Surely, it makes better sense to update a team's rating after each innings, with earned rating points commensurate with the final runs differential between the competing teams. The ICC rating system also fails to distinguish between batting and bowling strength. Surely, it is important to differentiate between the two, given that they are radically different disciplines. Finally, the rating system does not take the playing conditions into account. For example, how influential is a team's home or regional advantage? Does this advantage a team's batting or bowling stocks? Should an away win attract more points than a win at home? Notably, the latter has been recognised in the qualifying rounds of the World Cup of Soccer, with an away goal worth more than a home goal.

1.8 Application of the Duckworth and Lewis method

With the inherent time restrictions associated with ODI cricket administrators are often confronted with delays caused by inclement weather. To avoid the abandonment of matches a number of systems, designed to adjust team performances with respect to the time lost, were introduced. The most popular methods were the 'Average run rate method', the 'Most productive overs' method, the 'Discounted most productive overs' method, the 'Parabola method', 'The World Cup 1996' method and the 'Clark curves' method. These systems were met with varying levels of success, but because they did not effectively account for the run scoring resources a team had at its disposal at the time of a stoppage, one of the teams was often disadvantaged. In response to a universal call for a system that was undeniably fair to both teams Duckworth and Lewis (1998) developed their rain interruption rules. This reaction was arguably triggered by a well documented 1992 World Cup semi-final match between South Africa and England. In a closely fought encounter South Africa was on target to surpass England's score. However, at the concluding stages of the match rain interrupted play with South Africa still needing 22 runs to win with 13 balls to face. At the time, this was seen as a difficult but achievable task. However, application of the 'Most productive overs' method of managing interrupted matches was applied whereby the same number of highest scoring overs of Team 1 are used to set Team 2's target score. This ultimately meant that South Africa had to score 21 runs off only one ball-a patently unachievable task. South Africa was understandably devastated and lost the chance to play Pakistan in the final. The D/L method is designed to set a revised target score for Team 2 when a match has been delayed. The method takes into account the residual run scoring resources (in the form of the number of wickets lost and the number of overs remaining) a team has at its disposal at the time of the stoppage. It is based on an exponential decay model that calculates the expected number of runs to be scored in the remainder of an innings as a function of the number of overs remaining and the number of wickets lost. From a D/L viewpoint, a team that has lost only two wickets at the time of a stoppage is potentially much better off than a team that has lost nine wickets. In the England versus South Africa match cited above the D/L methodology would have given a revised target for South Africa of 234 runs, which was the much more realistic expectation of scoring three runs off one ball. Duckworth and Lewis (2004) have since revised their model parameters in order to correct an inherent limitation that arose when Team 1's score was significantly above average. In this instance, the original D/L rules tended to overestimate Team 2's revised target after a stoppage had intervened. The updated parameters in the revised model ensure that any revised target set for Team 2 is not unrealistic, even under extreme circumstances.

Authors such as Preston and Thomas (2002) and Carter and Guthrie (2004) have also recently addressed the situation that arises in interrupted ODI matches and subsequently propose alternative adjustment rules. The former recommend a rule that keeps the probability of winning across stoppages constant whereas under a comparable system proposed by Carter and Guthrie (2004) the probabilities of winning before and after the stoppage are preserved. Both Preston and Thomas (2002) and Carter and Guthrie (2004) contend that under the widely used D/L scheme the probabilities of winning before and after a stoppage are not in a one-to-one correspondence, which, they claim, encourages teams to unfairly orchestrate favourable outcomes. Both Preston and Thomas (2002) and Carter and Guthrie (2004) suggest that their methods are both fair and free of the incentive effects inherent in schemes such as the ones introduced by Duckworth and Lewis (1998, 2004). However, these alternative methodologies have as yet not been trialled by the sanctioning bodies.

de Silva, Pond and Swartz (2001) have employed the D/L rain interruption rules methodology to estimate the magnitude of victory in ODI cricket matches, which is characterized by the effective run differential between opposing teams. When comparing the distributions of the actual and effective run differentials they discerned that the distribution of the effective run differentials had a longer tail than the actual run differentials. They conjecture that this discrepancy arises because the D/L methodology tends to overestimate a team's potential when they have a large number of unused run scoring resources available to them and underestimates a team's potential when they have a limited number of run scoring resources available to them. Accordingly, they propose a modification to the D/L procedure to account for this discrepancy. They suggest that application of their methods would be effective in determining a potential winner in tied matches. In modelling team strength they quantify the degree to which the relative difference in the abilities of the opposing teams and the common HA effect explain the observed variation in the effective run differentials. To emphasise the effect of a team's more recent performances and to facilitate punters intending to bet on the outcomes of future matches they model the data using a weighted least squares model, with recent matches weighted more heavily than those from earlier matches. They established that the HA (in runs) was statistically significant. To avoid the arbitrariness in the choice of weights they also propose a method based on Bayesian principles. Under this scheme a match played in 2000 was weighted about four times as heavily as a match played in 1995.

CHAPTER 2
EXPLORATORY ANALYSIS OF DOMESTIC CRICKET

2.1 Introduction

In examining domestic cricket, two nationally organised competitions will be analysed, namely the Pura Cup competition in Australia and the Frizzell County Championship in England. As is the case with Test cricket, the conventional outcomes of a match are an outright win or loss, a draw or very rarely a tie. However, both competitions are points-based, with the official winner of a match defined as the team who acquires the most points regardless of the traditional match outcome. The protocols for awarding points in both competitions are considerably different. The analysis will utilise conventional statistical techniques in order to gauge team performance over a relatively long period of time. This will provide some information on how effects such as location impact on match outcomes.

2.2 The Pura Cup competition

The Pura Cup is the nationally run cricket competition currently played between the six States of Australia, namely Victoria, New South Wales, Tasmania, South Australia, Western Australia and Queensland. The competition is balanced so that throughout the regular home and away season each team plays each other twice; i.e. once on each other's home ground. Matches are completed within four days except for the final, which can last up to five days. During the regular season the only possible points-based outcomes are a win, loss or very rarely a tie. The allocation of points occurs at two stages; i.e. at the completion of the first innings and at the completion of the match. The protocol for the allocation of points is summarised in Table 2.1. At the end of the regular season the two teams with the highest points-aggregate play off in the final. And since points are not allocated in the final, the traditional match outcomes come into play. The final is usually played over a longer time period in order to allow more time for an outright result. However, if the final ends in a draw, the team that finished on top of the points-table is declared the winner. The structure of the final is designed so that the team who finishes on top of the points-table is rewarded with a distinct advantage over its opponent. This advantage occurs on two fronts: firstly the top team is granted the right to host the final on its home ground and secondly, it need only draw the match in order to be declared the competition winner. The visiting team, as well as having to play away from home, must win outright in order to win the Pura Cup. History suggests that this is a very difficult undertaking. Notably, over the period of the study the visiting team was able to win the final (i.e. an outright result) only twice. On all other occasions, the home team was able to either win outright (on seven occasions) or play out a draw (on only two occasions).

Eleven seasons of results from the 1990/91 to 2000/01 Australasian season have been included in the study, which accounts for 322 Pura Cup matches. In all matches there was a designated home-state team and there were no first innings ties or tied matches. Thus in all matches the total points distributed across both teams were two points if a match was drawn; six points if there was an outright result and the winning team led on the first innings; or eight points if there was an outright result and the winning team trailed on the first innings.

Table 2.1. The allocation of points in the Pura Cup competition

Result	*Match points*
Outright win after leading on the first innings	6
Outright win after a tie in the first innings	6
Outright win after trailing on the first innings	6
Tied result where both teams have completed two innings (irrespective of the first innings results)	3 each
Outright loss after leading on the first innings	2
Tie on the first innings (and no outright result)	1 each
For an outright loss after a tie in the first innings	1
For a loss on the first innings	0
For an outright loss after trailing on the first innings	0
Abandoned or drawn matches with no first innings result	0
Abandoned matches due to negligence	0

In a Pura Cup match the team objective is to maximise its margin of victory (in points) by winning outright after having led on the first innings. Because winning is solely dependent on the allocation of points the psychology of risk associated with a Pura Cup match differs from that of a Test match. For example, in a Pura Cup match, a team may take the safety option and play for a draw in order to preserve a two-point first innings advantage rather than risk losing outright and thus handing a six-point advantage to its opposition. However, in Test match cricket, since a team's primary objective is to win outright there is a tendency for teams to take more calculated risks in order to set up an outright result.

Of the 322 matches included in the study, 167 produced an outright result after the winning team had led on the first innings whereas only 42 matches produced an outright result after the winning team had trailed on the first innings. In the former case, the average first innings lead was a substantial 149 runs whereas in the latter case the average deficit was only 65 runs. In both the cases the winning team secured the maximum allocation of six points. The results suggest that over the period of the study it was almost four times more likely for the team leading on the first innings to win outright than it was for the trailing team to win outright. This underscores the difficulty in attaining an outright result after trailing on the first innings. Not surprisingly, the average deficit for the winning trailing team was considerably less than the average lead for the winning leading team. The remaining 113 matches ended in a draw, with the team leading on the first innings securing two points. Tables 2.2, 2.3 and 2.4 provide a summary of results for the home and away teams over the period of the study. Note that the total number of matches played in Table 2.4 sum to 644 and not 322 because each match is contested by two teams, producing a single outcome. A χ^2 test confirms that the home team won significantly more matches than the away team $\left(\chi_1^2 = 17.0,\ p < 0.001\right)$, with the home team winning substantially more often than the away team. The proportion of matches won by the home and away teams were 61% and 39% respectively. If we focus our attention on the allocation of points we cannot apply a χ^2 test since the point allocations do not represent frequencies. Similarly, we cannot apply a one-sample *Z*-test because the point differentials are not normally distributed. Alternatively, with a median points advantage for the home team being two points per match, the non-parametric Wilcoxon Signed Rank test confirms that this advantage was significantly greater than zero points $\left(W_{321} = 33503,\ p < 0.001\right)$. This confirms that the allocation of points was highly dependent on location, with the home team securing a considerable 70% more points than its opposition. Note that the standard deviation of 4.6 points is relatively high because the point margins are restricted to two, four and six points.

It is evident throughout the period of the study that all teams tended to perform better at home than away from home. As is suggested by Table 2.4, the designated home team, in all cases, was able to win more matches and be awarded more points than its opposition. Queensland, South Australia and Victoria, in particular, performed significantly better at home than away from home. Table 2.5 provides a summary of team performance over the period of the study. Queensland, Victoria and Western Australia were the dominant teams in respect to the number of overall wins and the acquisition of points. Table 2.6 provides the home team points advantage by year, which demonstrates that the home team enjoyed a points advantage during each year of the study. The respective maximum and minimum points advantages were 1.93 (1993) and 0.34 (1998). Figure 2.1 represents the mean home points-advantages by year as a line plot. A one-way analysis of variance test confirms that there was no evidence of a seasonal effect $\left(F_{10,\,311} = 0.40,\ p = 0.945\right)$. This suggests that the advantage for the home team has been consistent throughout the period of the study. The overall strength of the home team is confirmed by the fact that it was able to secure an outright result and thus be awarded the maximum points on 137 occasions. This compares with only 72 outright results being achieved by the away team. Accordingly, the home team was a considerable 90% more likely than the away team to win outright and thus secure the maximum point allocation. Table 2.7 provides a summary of the winning capacity of teams at the various home-state venues, together with the relevant χ^2 values. A drawn result was more likely to occur in Tasmania than in any other State. At all venues, apart from Victoria and Tasmania, an outright result (and thus the obtaining of maximum points) was the significantly more likely event. Notably, it was 31% less likely for an outright result to occur in Tasmania than in the other States; i.e. teams essentially play for fewer points when playing in Tasmania. Given that during a regular season all teams play more matches at their home venue than any other venue these findings suggest that Tasmania, in particular, was disadvantaged by the points system. The disadvantage could be attributed to climatic conditions or the Tasmanian pitch being batter-friendly and thus producing a high number of draws. Table 2.8 explores this situation further, which suggests that the Competition has produced some inequitable outcomes, especially when teams played in both Western Australia and Queensland. At these venues a substantial proportion of matches produced outright results, which suggests that teams were essentially playing for more points. Western Australia and Queensland played were advantaged by the system. Queensland, in particular, has capitalised on this situation by obtaining a high 64% of the points available. The mean points available on Tasmania's home ground were not only relatively very low but Tasmania itself was able to obtain only 53% of them. South Australia has been disadvantaged by the system as it was able to obtain a high 73% of the very limited number of points available on its home ground. Clarke (1986) highlighted a similar situation in the 1985/86 Sheffield Shield competition, whereby Victoria was disadvantaged by having its home venue at the Melbourne Cricket Ground (MCG). The MCG at the time displayed a tendency to produce a disproportionate number of draws, which meant that matches played at the MCG during this season were worth less than in the other States. This also highlights the implicit HA enjoyed by teams who predominantly play at venues that are more conducive to producing results and underscores the need for administrators to take these inequities into account when implementing playing conditions.

Table 2.2. Overall match results for the home team in the Pura Cup competition for the period 1990-2000

Home wins	198
Home losses	124
Total matches played at home	322

Table 2.3. Point allocation for the home team in the Pura Cup competition for the period 1990-2000

Points For	976
Points Against	588
Total	1564

Table 2.4. Overall match and points results for all teams in the Pura Cup competition for the period 1990-2000

Team	*Number of matches played*	*Number of home wins*	*Number of away wins*	χ_1^2 *value*	*p-value*	*Home points*	*Away points*
NSW	106	31	19	2.88	0.090	152	98
Qld	110	40	23	4.59	0.032	206	114
SA	107	29	14	5.23	0.022	158	56
Tas	104	29	21	1.28	0.258	114	104
Vic	110	37	21	4.41	0.036	180	90
WA	107	32	26	0.62	0.431	166	126
Total		198	124			976	588

Table 2.5. Overall match and points results for all teams in the Pura Cup competition for the period 1990-2000

Team	*Number of overall wins*	*Number of outright wins*	*Number of non-outright wins*	*Total point allocation*
New South Wales	50	35	15	250
Queensland	63	46	17	320
South Australia	43	28	15	214
Tasmania	50	26	24	218
Victoria	58	35	23	270
Western Australia	58	39	19	292
	322	209	113	1564

Table 2.6. Summary statistics for the home points advantage in the Pura Cup competition for the period 1990-2000

Season	*HA (Points)*	*Standard deviation (Points)*
1990/91	1.72	4.27
1991/92	0.55	4.21
1992/93	0.87	4.06
1993/94	1.93	4.22
1994/95	1.07	5.26
1995/96	1.79	4.43
1996/97	1.07	4.81
1997/98	0.87	4.80
1998/99	0.34	4.57
1999/00	1.27	5.19
2000/01	1.79	4.64

Table 2.7. Results for teams at the various home-state venues in the Pura Cup competition for the period 1990-2000

Venue	*Percentage of outright results*	*Percentage of draws*	χ_1^2 *value*	*p-value*
New South Wales	34	17	5.7	0.017
Queensland	39	16	9.7	0.002
South Australia	39	16	9.7	0.002
Tasmania	24	27	0.2	0.674
Victoria	34	21	3.1	0.080
Western Australia	39	16	6.9	0.009

Table 2.8. Points won in the Pura Cup competition for the period 1990-2000

Venue	*Mean points available*	*Mean points won by the home team*	*Mean points won by the away team*	*Percentage of points won by the home team*
New South Wales	4.76	2.98	1.78	63%
Queensland	5.82	3.75	2.07	64%
South Australia	3.95	2.87	1.08	73%
Tasmania	4.20	2.24	1.96	53%
Victoria	4.91	3.27	1.64	67%
Western Australia	5.44	3.02	2.42	55%

Figure 2.1. HA in points by year for the Pura Cup competition for the period 1990-2000

In setting up an outright victory, teams are intent on establishing a substantial first innings lead in order to gain a strong winning edge over its opposition. In a Pura Cup match this offers a two-pronged advantage. Firstly, since the team who has established the lead earns two points, it will win on points if the match ends in a draw and secondly, the leading team is in a strong position to win outright (and consequently earn a further four points), especially if the lead is a substantial one. This suggests that in the Pura Cup competition, a team's ability to establish a first innings lead provides a measure of a team's relative strength since the teams that are more adept at establishing a lead are more likely to secure a win on points. Tables 2.9, 2.10 and 2.11 provide a summary of the first innings performances for both the home and away teams. Table 2.9 suggests that the home team generally scored more runs than the away team and was thus more likely to establish a first innings lead. Consequently, the home team was more likely to win a match on points. Table 2.10 underscores the benefit of establishing a first innings lead, with all teams, on average, displaying a strong winning tendency after leading on the first innings. Conversely, teams showed a strong inclination to lose after surrendering a first innings lead. The home team generally fared much better than the away team from all perspectives: most notably, the home team was more effective at securing a win on points after leading on the first innings and was less likely to lose after trailing on the first innings. It is also evident from Table 2.10 that teams found it extremely difficult to win a match on points after trailing on the first innings or conversely lose a match after leading on the first innings. This exposes one of the inherent difficulties with the structure of the Pura Cup competition since for the trailing team to win a match its only option is to engineer an outright result. This is difficult at the best of times let alone after trailing on the first innings. Table 2.11 provides a break down of the home and away first innings mean scores and the resulting margins (by season). The home team, in general, was more proficient at establishing a first innings lead than the away team. The home team, on average, led on the first innings for ten seasons out of the eleven under review. A one-way analysis of variance test confirms that there was not a seasonal effect $\left(F_{10,\,311} = 0.72,\ p = 0.708\right)$. This suggests that the first innings advantage enjoyed by the home team has been consistent throughout the study period.

Table 2.9. First innings performances for the home and away teams in the Pura Cup competition for the period 1990 to 2000

Outcome	*Home team*		*Away team*	
	Mean	*Standard deviation*	*Mean*	*Standard deviation*
First innings score (in runs)	330	112	300	113
First innings lead (in runs)	31	154	-31	154

Table 2.10. Points results in the Pura Cup competition for the period 1990 to 2000

Outcome	*Overall*	*Home team*	*Away team*
Points win after leading on the first innings	85%	52%	33%
Points loss after leading on the first innings	15%	5%	10%
Points win after trailing on the first innings	15%	10%	5%
Points loss after trailing on the first innings	85%	33%	52%

Table 2.11. Average first innings score for the home and away teams in the Pura Cup competition for the period 1990-2000

Year	*Home score*	*Away score*	*Home margin*
1990	353	306	47
1991	335	318	17
1992	321	317	4
1993	347	337	10
1994	354	284	70
1995	339	272	67
1996	319	288	31
1997	335	314	21
1998	304	308	-4
1999	316	269	47
2000	313	285	28
All years	330	300	30

2.3 The Frizzell County Championship

The Frizzell County Championship is a competition comprising 14 Division 1 Counties, with each County playing each other once. Like the Pura Cup, the competition is balanced and teams are awarded points for the outcome of a match. However, the allocation of points is far more complex than in the Pura Cup. During the period of the study, match points were scored as follows:

- For a win, 14 points were awarded, plus any bonus points scored in the first innings
- In a tied match, each team scored 7 points, plus any bonus points scored in the first innings
- In a drawn match, each team scored 4 points plus any bonus points scored in the first innings
- If scores were equal in a drawn match, the team batting in the fourth innings scored 7 points plus any bonus points scored in the first innings. The opposing team scored 4 points plus any bonus points scored in the first innings
- A maximum of 5 batting and 3 bowling bonus points were awarded for the first 130-overs of the match. The allocation of batting and bowling bonus points are summarized in Table 2.12

Table 2.12. Allocation of bonus points in the Frizzell County Championship

Bonus points	Batting (runs)	Bowling (wickets)
1	$[200, 249]$	$[3, 5]$
2	$[250, 299]$	$[6, 8]$
3	$[300, 349]$	$[9, 10]$
4	$[350, 399]$	
5	≥ 400	

In a regular match, the minimum allocation of 0 points was awarded if a team lost outright and received no bonus points. The maximum allocation of 22 points was awarded if a team won outright and scored 400 runs or more and took 9 or 10 opposition wickets within the first 130-overs of the match. In a rare scenario, a team that lost outright could still score a maximum of 8 batting and bowling bonus points. Teams can also be penalized both runs and/or points for specified indiscretions. Unlike the Pura Cup competition there is no final. The team that finishes on top of the points-table at the end of the season is the winner of the championship.

The differences between the structures of the Pura Cup and the Frizzell County Championship are substantial, which suggests that playing strategies and game psychology could also be markedly different. The major structural differences are outlined below.

- The bottom three teams in the County Championship are relegated each season and consigned to play in the Division 2 competition for at least the ensuing season. Similarly, the top three Division 2 teams are elevated to the Division 1 competition. The Pura Cup involves the same six teams each season.
- Since a team can be tied on points in the County Championship there are three possible match outcomes: a win, tie or loss. In contrast, a team cannot be tied on points in the Pura Cup (unless unforeseen circumstances intervene), which means there are only two match outcomes: a win or a loss
- In the Pura Cup a team is rewarded for establishing a first innings lead and can subsequently win (on points) from this position if the match is drawn. In the County Championship, however, a team is not directly rewarded for establishing a lead. Instead, a team can obtain first innings bonus points regardless of whether it has established lead or not
- In the Pura Cup, if a team trails on the first innings it must win outright in order to receive any points. However in the County Championship, if a match is drawn the team trailing on the first innings can still win (on points) by carrying through first innings bonus points
- Ground rationalization issues in both competitions vary. In the Pura Cup, for example, the majority of matches are played at a small number of designated State venues. In essence there is one venue per State. This ensures that each State team has a local venue it plays at regularly. In contrast, teams in the County Championship play at a much broader range of venues. This would suggest that the

designated home team in the Pura Cup competition would be in a stronger position to exploit its knowledge of local conditions.

Three seasons of results from 2000 to 2002 have been included in the study, which accounts for 209 County Championship matches. In all matches there is a designated home team and there were no first innings ties or tied matches. Note that the current playing conditions for the County Championship (and thus the protocol for the allocation of points) are different from those that were used during the period of the study.

Of the 209 matches, 121 produced an outright result and 88 produced draws with the home team securing 75 outright wins, 88 draws and 45 outright losses. The home team overall won 110 matches on points, tied 12 and lost 87. Tables 2.13, 2.14 and 2.15 provide a summary of results for the home and away teams over the period of the study. Note that the numbers of matches played by each team, over the period of the study, are inequitable due to the seasonal relegation/elevation system. If we ignore tied matches, the home team won 26% more matches than it lost, however, a χ^2 test confirms that the number of wins was not significantly more than the number of losses $\left(\chi_1^2 = 2.7,\ p = 0.101\right)$. Nonetheless, the home team was able to secure significantly more outright wins than the away team $\left(\chi_1^2 = 13.9,\ p = 0.001\right)$. Given that an outright win attracts the most points this would contribute to a potential points- advantage. The proportion of matches won on points by the home and away teams were 53% and 41% respectively. The remaining 6% of matches were tied. This equates to a mean points advantage and standard deviation of 1.7 and 10.8 points per match respectively. The median points advantage for the home team was one point per match. The non-parametric Wilcoxon Signed Rank test confirms that this advantage was significantly greater than zero points $\left(W_{207} = 11597,\ p = 0.011\right)$. This confirms that the allocation of points was highly dependent on location, with the home team securing 19% more points than the away team. In comparing the points-margins over the period of the study, a one-way analysis of variance does not provide any evidence that there was a seasonal effect $\left(F_{2,\,206} = 2.3,\ p = 0.108\right)$. This suggests that the HA has remained consistent over the three-season period. Figure 2.2 displays a plot of HA over the period of the study.

To compare the HA effect across both domestic competitions we can calculate the ratio of the HA with the average absolute points-margin. This produces advantages in the Pura Cup and the County Championship of 28% and 21% respectively. In comparing the variability of the points-margins, the respective coefficients of variation are 3.8 and 5.6. On average, the overall HA enjoyed by teams in the Pura Cup was a more substantial advantage. There are possible reasons for this. Firstly, home teams in the County Championship do not necessarily play at a regular venue, whereas in the Pura Cup competition it is far more likely for teams to play at designated home grounds. Secondly, the points-margins in the County Championship, with a wider range of point allocations, are naturally more variable.

Table 2.13. Overall match results for the home team in the Frizzell County Championship for the period 2000-2002

Home wins	110
Home ties	12
Home losses	87
Total matches played at home	209

Table 2.14. Point allocation for the home team in the Frizzell County Championship for the period 2000-2002

Points for	2340
Points against	1962
Total	4302

Table 2.15. Overall match and points results for teams in the Frizzell County Championship for the period 2000-2002

Team	*Matches played*	*Home*			*Away*			*Home points*	*Away points*
		Win	*Loss*	*Tie*	*Win*	*Loss*	*Tie*		
Derbyshire	15	4	2	1	1	6	1	73	40
Durham	16	4	3	1	1	7	0	71	40
Essex	16	2	6	0	2	6	0	49	67
Glamorgan	15	3	5	0	3	4	0	66	63
Hampshire	32	5	10	1	5	9	2	134	124
Kent	45	14	9	1	14	8	0	266	243
Lancashire	44	12	9	0	10	13	0	251	232
Leicestershire	46	11	8	3	10	12	2	249.5	240
Northamptonshire	16	3	4	1	1	7	0	96	52
Somerset	47	14	8	2	9	12	2	261	202.75
Surrey	46	17	7	0	13	7	2	349.3	249
Sussex	16	3	5	0	4	4	0	75	79
Warwickshire	16	5	2	1	2	5	1	120	78
Yorkshire	48	13	9	1	12	10	2	279.25	273
Total		110	87	12	87	110	12	2340	1962.25

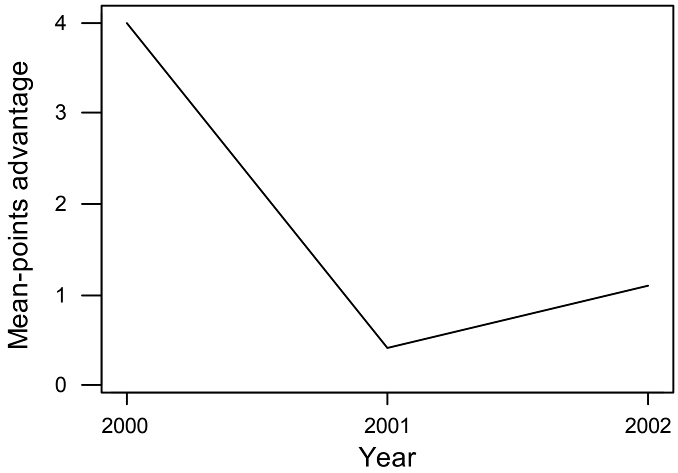

Figure 2.2. HA in points by year for the Frizzell County Championship for the period 2000-2002

2.4 Conclusions

It was established that in the respective Australian and English domestic cricket competitions, namely the Pura Cup and the Frizzell County Championship, the home team, in general, enjoyed a significant winning edge over its opponents. This advantage extended to both match wins and a wins on points. In both competitions, the home team was also able to secure significantly more outright results than the away team. There was no evidence of a seasonal effect, with the overall HA remaining consistent across study periods. The overall HA effect in the Pura Cup and the County Championship were 28% and 21% respectively.

Comparison of the variability of the points-margins across both competitions suggests that the overall HA enjoyed by teams in the Pura Cup was the more substantial. This may have arisen because most home-state teams in the Pura Cup play at a limited number of local venues. Thus, the opportunity exists for local players to become accustomed to local playing conditions. In the Frizzell County Championship, however, the number of venues is far more wide-ranging and so players are not afforded the same opportunity to hone localised skills. It is well documented that vocal home crowd support can be an influential factor in the shaping of a home victory, with the larger the crowd the more influential the support. However, with the crowds for both the Pura Cup and the Frizzell County being very small it can be argued that any advantage gained from a vocal home crowd would be non-existent. This suggests that travel factors in the Frizzell County Championship and familiarity with local conditions in the Pura Cup were possibly more influential in shaping a HA.

Since the match winner in both competitions is entirely dependent upon the allocation of points this exposes an inherent incongruity associated with schemes of this nature. The problem arises because, by default, some matches end up being worth more than others. For example, if a Pura Cup match ends in a draw the match is worth only two points whereas the match is worth six points if the leading team secures an outright result. In light of this, it makes more sense if there is a fixed pool of points which are subsequently distributed in proportion to the result, regardless of the range of outcomes. It was also established that some grounds (or wickets) were more conducive to outright results than others. Thus, teams can be respectively advantaged or disadvantaged if their home ground is prone to producing a high number of outright or drawn results. This is a difficult situation to regulate because the nature of playing surfaces is commensurate with local conditions.

CHAPTER 3
MEASURING AND INTERPRETING VICTORY MARGINS IN ODI CRICKET

3.1 Introduction

In analysing performances in ODI cricket we are consistently faced with a resource inequity problem. Team 1, by batting first, is granted the opportunity to expend its maximum resource quota of fifty overs or ten wickets whether it wins a match or not. Paradoxically, Team 2 is usually only granted the same opportunity if it loses a match since, in losing, it has either (a) exhausted its wicket resource and been dismissed for a score lower than the target score or (b) used up its fifty overs without reaching the target score. Note that the target score is deemed to be a score needed to tie a match. In either case a winning result for Team 1 is documented as the run differential between the two teams. This method of recording a victory for Team 1 provides an accurate measure of the extent of its victory because, in effect, the winning run differential is commensurate with magnitude of the victory. Using this method also ranks the strength of the victory. For example, a win by 150 runs is plainly a more resounding victory than a victory by a single run. In contrast, a Team 2 victory is recorded as the number of wickets it has in hand at the point of victory. For example, if Team 2 wins a match after losing only two wickets this is officially recorded as a $10-2=8$ wicket victory. However, in one-day cricket this method provides very limited details on the extent of Team 2's victory. In losing two wickets, Team 2 could have won the match with 1 ball to spare or with 15 overs to spare. In the former case, Team 2's win is unconvincing whereas in the latter case the win is very decisive and describes an extremely one-sided affair. In each of these cases, both methods clearly fail to satisfactorily describe the extent of Team 2's victory. This example highlights the uninformative manner in which a victory for Team 2 is currently documented. Simply knowing that Team 2 has won by eight wickets easily leads to a misinterpretation of Team 2's level of dominance. This method of recording a Team 2 victory has been handed down from Test cricket where it is used to describe a victory by the team batting last. This is a system which appears to be unique to cricket and makes little sense: In which other team sports are victories for the competing teams documented differently? In summary, a single system is needed that

(a) provides a mechanism for all Team 2 victories to be compared and ranked and (b) allows Team 1 and Team 2 victories to be compared and contrasted on the same footing.

Team 2 can only win an ODI match by passing Team 1's score. This is nearly always achieved with untapped run scoring resources at its disposal; i.e. Team 2, in winning, will generally have either wickets intact or overs at its disposal. The match, in a sense, is truncated at the point of victory with Team 2 restricted from accessing unused run scoring resources. As a consequence, Team 2's winning score will only ever be marginally better than that of Team 1. The resulting victory margin fails to provide a true reflection of the extent of Team 2's victory. The disparity is most pronounced when Team 2 has achieved its target with a large proportion of unused run scoring resources at its disposal. To further highlight this incongruity, a one run victory for Team 2 could have been attained either marginally, off the last ball of the innings with one wicket intact, or substantially, with all ten wickets intact and no overs left. Similarly, a ten wicket victory could have been achieved after relatively few overs have been bowled or off the last ball of the match. Note that the only time Team 2 wins, having expended its available quota of run scoring resources, is when the winning runs are achieved off the last ball of the innings. In this rare and unique occurrence, Team 2 wins the match after having expended the same number of resources as Team 1.

To compensate for the resource inequity problems delineated above, techniques developed by Duckworth and Lewis (1998) to reset targets in interrupted matches will be used to estimate a projected Team 2 score. This will provide an estimate of Team 2's expected score after it has exhausted available quota of run scoring resources. The resulting projected victory margin will (a) provide a more accurate account of Team 2's level of superiority at the point of victory and (b) provide a means for all victories to be compared and contrasted on an equal footing; i.e. after both teams have expended their run scoring resources. As a consequence, the recording of a Team 2 victory will now provide a mechanism for ranking the strength of all victories and will be in step with the more sensible method that is currently used to document a Team 1 victory.

One of the contributions of this thesis is to build on the ideas presented by D/L in order to work towards the development and adoption of a more reliable measure of recording ODI victory margins.

3.2 The Duckworth and Lewis method

The D/L method was developed by Duckworth and Lewis (1998) and was introduced to provide a fair method for resetting targets in one-day matches interrupted by unscheduled breaks in play such as stoppages caused by rain. The method has been ratified by the International Cricket Council (ICC) and is currently utilised in all matches under the ICC's jurisdiction. The application of the D/L method is universal and replaces the various methods authorities have employed in the past to deal with unscheduled interruptions such as the 'average run rate', 'most productive overs' and 'parabola' methods. All previous methods were problematic and invariably failed for a variety of reasons such as not accounting for the overs lost due to the stoppage; not factoring in the number of wickets that had fallen at the time of the stoppage; and not considering the time when the stoppage occurred. Fundamentally, the D/L method attempts to take account of these failings and recognises that teams have two forms of run scoring resources at their disposal, namely the number of overs and wickets in hand. Duckworth and Lewis (1998) in developing their method presuppose that the ability of a team to score runs is essentially a function of its unused run scoring resources. Not surprisingly, one would expect a team with eight overs to face and with all ten wickets intact to be in a potentially much stronger run scoring position than a team with the same number of overs to face but with only one wicket in hand. In the former situation, the team has significantly more unused run scoring resources at its disposal (in the form of wickets) and thus has the potential to score substantially more runs. In the latter case, however, the team has almost exhausted its run scoring resources and would not be expected to score many more runs.

The D/L method sets a revised target for Team 2 when overs in either innings have been lost due to a break in play. The target is revised in accordance with the run scoring resources the two teams have at their disposal at the time of the interruption. Duckworth and Lewis (1998) have prepared a detailed table of values from which the unused run scoring resources (in the form of wickets and overs) are expressed as a single resource percentage, R. A small section of the authors' table is provided in Table 3.1. It is important to note however that the methods used to deal with interruptions in each innings are different and incompatible. When the stoppage occurs during Team 1's innings and the resource available to Team 2 (R_2) is less than what was available to

Team 1 (R_1), Team 2's revised target is Team 1's final score scaled down in accordance with the ratio $R_2 : R_1$. For example, suppose in an ODI match, Team 1 scores 150 for the loss of 9 wickets after 30 overs and rain reduces the match to 30 overs per side. From the D/L tables, $R_1 = 100 - 7.6 = 82.4$ and $R_2 = 77.1$. It follows that Team 2's target score is $150 \times \frac{77.1}{82.4} = 140$ runs. However, if $R_2 > R_1$ then the revised target is Team 1's score increased by an amount that is obtained by applying the excess resource $R_2 - R_1$ to the average Team 1 score. For ODI cricket, D/L deems this to be 225 runs. For example, suppose in an ODI match, Team 1 scores 150 for the loss of no wickets after 30 overs and rain reduces the match to 30 overs per side. From the D/L tables, $R_1 = 100 - 58.9 = 41.1$ and $R_2 = 77.1$. It follows that Team 2's target score is $150 + \frac{225}{100}(77.1 - 41.1) = 231$ runs. Note that if $R_2 = R_1$ then the revised target is simply Team 1's score. Conversely, if Team 2's innings is interrupted, the revised target is Team 1's score scaled down in proportion to R_2. For example, suppose Team 1 makes 250 runs in its 50 overs. Further suppose that Team 2's innings is interrupted after 20 overs have been completed due to rain with its score on 100 for the loss of 3 wickets. If 10 further overs are lost due to rain, leaving 20 overs of play remaining, from the D/L tables, $R_2 = 100.0 - 62.3 + 50.6 = 88.3$ and Team 2' target score becomes $\frac{250}{100} \times 88.3 = 221$ runs.

Table 3.1. Section of the table of 'resource percentage remaining' values adapted by D/L to adjust target scores in 50-over ODI matches

Overs left	*Wickets lost*									
	0	1	2	3	4	5	6	7	8	9
20	58.9	56.7	54.0	50.6	46.1	40.0	33.2	25.2	16.3	7.6
19	56.8	54.8	52.2	49.0	44.8	39.1	32.7	24.9	16.2	7.6
18	54.6	52.7	50.4	47.4	43.5	38.2	32.1	24.7	16.2	7.6

3.3 Calculating a projected score for Team 2

In determining a projected score for Team 2 there are two approaches that can be adopted. Firstly, if we let S_{actual} represent Team 2's actual winning score, the projected score, $S_{\text{projected}}$ is estimated to be

$$\begin{aligned} S_{\text{projected}} &= S_{\text{actual}} + 225 \times \frac{R}{100} \\ &= S_{\text{actual}} + 2.25R \end{aligned} \tag{3.1}$$

where 225 represents the average score for a 50-over one-day innings as defined by Duckworth and Lewis (1998). This will be referred to as method 1.

Alternatively, the actual truncated second innings score can be scaled up in proportion to the unused run scoring resources. This is equivalent to projecting a team's actual second innings score to the target score for which its actual score would have achieved a tied result. Using this method, the projected score is estimated to be

$$S_{\text{projected}} = \frac{100 S_{\text{actual}}}{100 - R} \tag{3.2}$$

This will be referred to as method 2.

In addition, modifications to the D/L resource remaining percentage values, as proposed by de Silva, Pond and Swartz (2001), will be incorporated. As defined by the authors, the adjusted R values are expressed as $R_{\text{mod}} = (1.183 - 0.006R)R$. This adjustment, in effect, accounts for (a) the overestimation of projected 50-over scores when Team 2 uses up very few run scoring resources and (b) the underestimation of projected scores when nearly all available quota of run scoring resources have been expended. One reason why the projected scores are overestimated could be attributed to the rigid fielding restrictions that must be in place during the first 15 overs of a match. This generally encourages the batting side to be adventurous by allowing it to hit more boundaries over and through the congested in-field. It is highly unlikely that this scoring rate will continue, however, because after the completion of the first 15 overs the fielding side is permitted to introduce more defensive fielding restrictions. This invariably provides the fielding team with an improved chance of stopping potential boundary scoring shots. Accordingly, a shot that produced four runs in the early overs may produce only one run in later overs. For the initial scoring rate to continue the batting side may need to become very audacious and play in an unconventional manner. However, taking risks of this nature generally results in poor stroke selection and the loss of valuable wickets. This ultimately restrains the scoring rate since less recognized batsmen are required to take up the cudgels and perform in a manner that is quite often beyond their capabilities. In contrast, it is likely that the underestimation in projected scores occurs when the batting side demonstrates a greater propensity to take risks and thus attempt to score quick runs when it is close to winning but has nearly exhausted available quota of run scoring resources.

Taking account of the changes proposed by de Silva, Pond and Swartz (2001), the adjusted projected score estimated by method 1 is now expressed as

$$\begin{aligned} S_{\text{projected}} &= S_{\text{actual}} + 2.25R_{\text{mod}} \\ &= S_{\text{actual}} + 2.25\left(1.183 - 0.006R\right)R \end{aligned} \tag{3.3}$$

Whereas the adjusted projected score estimated by method 2 is now expressed as

$$S_{\text{projected}} = \frac{100S_{\text{actual}}}{100 - R_{\text{mod}}} \tag{3.4}$$

3.4 Comparison of the first and second innings

To examine the efficacy of methods 1 and 2 we need to consider whether the projected scores for Team 2, as estimated by each method, are statistically equivalent to those actually scored by Team 1. One would expect that if Teams 1 and 2 played until the available quota of run scoring resources for both teams were exhausted the distribution of the actual scores would be essentially the same. Using data provided by the 1999 ICC Cricket World Cup we can examine the distribution of the Team 1 and 2 scores. Table 3.2 details the actual and projected scores, as estimated by methods 1 and 2 in the 1999 ICC Cricket World Cup. Figure 3.1 uses box plots to provide a visual representation of the subsequent distributions of scores. To investigate whether the distribution of the actual Team 1 and 2 scores are equivalent we initially need to conduct a test for normality. The Anderson-Darling test verifies that the scores are normally distributed. A two sample *t*-test (assuming different variances) is then applied to determine whether the distribution of the actual scores for Teams 1 and 2 are statistically equivalent. As expected, the analysis shows that Team 1 has generally scored more runs than Team 2 $\left(T_{80} = 2.5,\ p = 0.008\right)$, with the difference in the mean scores being a substantial 30 runs. This disparity arises because when Team 2 wins a match, its score is truncated at the point of victory. Accordingly, Team 2's winning score will only ever be marginally better than that of Team 1. You would also expect the variability in the resultant victory margins to be relatively low. Under these circumstances you would expect the scores of Teams 1 and 2, in a particular match, to be essentially the same. The only difference being the extent of unused run scoring resources Team 2 has at its disposal. In contrast, if Team 1 wins, the victory margin is highly variable. For example, Team 1 may score 300 runs in its 50 overs and dismiss Team 2 cheaply for 100 runs. Team 1's winning margin is thus a huge 200 runs. Alternatively, Team 1 could win a match marginally after dismissing Team 2 only one run in arrears. Accordingly, large victory margins will only occur when Team 1 wins. The resultant mean score for Team 1 will thus be expected to be much larger than the mean actual score for Team 2.

Estimation of the projected scores (as estimated by methods 1 and 2) suggests that the variability of the method 1 scores is comparatively low. It is notable, however, that the variability of the method 2 scores and the actual Team 1 scores are similar. To test the comparative similarities of the distributions we need to conduct a normality test. The Anderson-Darling test verifies that the projected scores (as estimated by methods 1 and 2) are normally distributed. Subsequent to this an *F*-test for equal variances and a paired *t*-test are used to compare the distributions. The *F*-test confirms that the variability of Team 1's scores and those estimated by method 1 are essentially equivalent $\left(F_{1,\,40} = 1.8,\ p = 0.080\right)$. The two sample *t*-test (with assumed equal variances) verifies that the distribution of scores are effectively the same $\left(T_{80} = -0.1,\ p = 0.901\right)$. Repetition of the tests for method 2 confirms that the variability and distribution of scores are also statistically equivalent with $\left(T_{80} = 0.1,\ p = 0.924\right)$ and $\left(F_{1,\,40} = 1.2,\ p = 0.502\right)$. Thus, when comparing Team 1's score with Team 2's projected scores the distributions of the innings scores are in effect statistically equivalent. Consequently, it can be assumed that relatively large scores for either innings will occur with similar likelihood. This also verifies that in relation to the 1999

ICC Cricket World Cup, method 2 is the slightly more robust method to be adopted for the generation of projected scores. In addition, assuming no bias in the better team batting first, a paired t-test can also be used to compare the actual Team 1 scores with Team 2 projections. For both methods, this confirms that the projected scores are not significantly different to the Team 1 scores. The test statistics are $\left(T_{80}=0.13,\ p=0.897\right)$ and $\left(T_{80}=-0.10,\ p=0.920\right)$ for methods 1 and 2 respectively.

Table 3.2. Actual and projected scores estimated by Teams 1 and 2 in the 1999 ICC Cricket World Cup

Team 1	*Team 2*	*Actual Team 1 scores*	*Actual Team 2 scores*	*Method 1 projected scores*	*Method 2 projected scores*
Sri Lanka	England	204	207	236	238
India	South Africa	253	254	277	284
Kenya	Zimbabwe	229	231	290	314
Kenya	England	203	204	283	313
Zimbabwe	India	252	249	249	249
South Africa	Sri Lanka	199	110	110	110
South Africa	England	225	103	103	103
Zimbabwe	Sri Lanka	197	198	230	231
India	Kenya	329	235	235	235
Zimbabwe	England	167	168	245	256
Kenya	South Africa	152	153	219	216
India	Sri Lanka	373	216	216	216
India	England	232	169	169	169
Zimbabwe	South Africa	233	185	185	185
Sri Lanka	Kenya	275	230	230	230
Scotland	Australia	181	182	225	225
Pakistan	West Indies	229	202	202	202
Bangladesh	New Zealand	116	117	205	192
Australia	New Zealand	213	214	252	258
Pakistan	Scotland	261	167	167	167
Bangladesh	West Indies	182	183	215	213
Pakistan	Australia	275	265	265	265
Bangladesh	Scotland	185	163	163	163
New Zealand	West Indies	156	158	205	200
Bangladesh	Australia	178	181	295	365
Scotland	West Indies	68	70	195	158
Pakistan	New Zealand	269	207	207	207
West Indies	Australia	110	111	176	156
Bangladesh	Pakistan	223	161	161	161
Scotland	New Zealand	121	123	230	234
Australia	India	282	205	205	205
Pakistan	South Africa	220	221	231	231
India	Pakistan	227	180	180	180
Australia	Zimbabwe	303	259	259	259
South Africa	New Zealand	287	213	213	213
Pakistan	Zimbabwe	271	123	123	123
India	New Zealand	251	253	269	272
South Africa	Australia	271	272	275	276
New Zealand	Pakistan	241	242	266	271
Australia	South Africa	213	213	213	213
Pakistan	Australia	132	133	252	281
Mean		219	189	218	220
Standard deviation		62	50	47	56

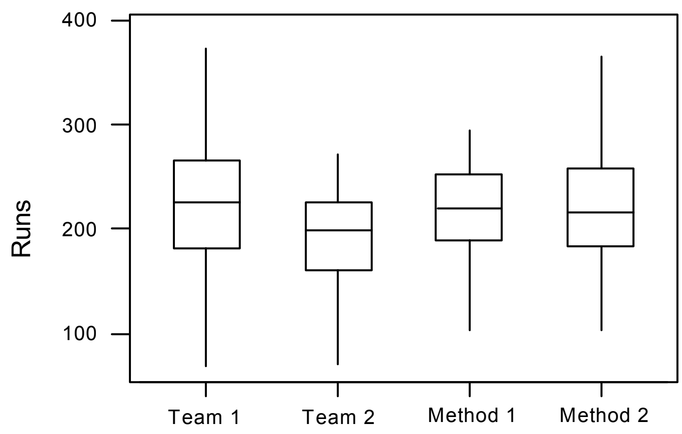

Figure 3.1. Distribution of scores for the 1999 ICC Cricket World Cup

3.5 An examination of methodology

In their analysis of the 1999 ICC Cricket World Cup, Clarke and Allsopp (2001) used (3.1) to estimate projected Team 2 scores, which were subsequently used to estimate projected victory margins. In a technical note Duckworth and Lewis (2002) questioned the validity of using (3.1) to estimate projected victory margins. Instead, Duckworth and Lewis (2002) propose that the victory margin should be expressed as the excess in runs over the par score at the point of victory. Duckworth and Lewis (2002) quantify the par score, P as

$$P = \frac{S_{\text{tie}}\left(100 - R\right)}{100} \tag{3.5}$$

where S_{tie} is Team 1's score or simply the score to be achieved by Team 2 to tie a match. As Duckworth and Lewis (2002) correctly point out, in adopting method 1, we are faced with a discontinuity problem. Citing their example, in a match between Scotland and the West Indies in the 1999 ICC Cricket World Cup, Scotland was dismissed for 68. The West Indies responded with 70 for the loss of only two wickets in 10.1 overs. Duckworth and Lewis (2002) demonstrate that at the point of victory the West Indies, with 77.4% of unused run scoring resources, were 55 runs ahead of the

D/L par score of $\frac{68(100-77.4)}{100}=15$ runs. Thus, using D/L rain interruption rules methodology, the victory margin (or the excess of runs over par) is as expressed as $70-15=55$ runs. Alternatively, if (3.1) were applied, the projected score would be $70+2.25\times 77.4=244$ runs and the subsequent projected victory margin would be $244-68=176$ runs. In a formal response, Clarke and Allsopp (2002) argue that the projected score provides a more accurate measure of the West Indies superiority over Scotland. However, Duckworth and Lewis (2002) contend that if the match was abandoned due to rain only one ball earlier (i.e. after 10 overs), when the West Indies were 68 for the loss of two wickets, application of the D/L rain interruption rules would officially record the victory margin as 53 runs. However, if it didn't rain and the next ball was allowed to be bowled then (3.1) predicts a winning margin for the West Indies of 176 runs. Duckworth and Lewis (2002) suggest that this creates an unacceptable discontinuity. However, Clarke and Allsopp (2002) argue that this situation is unavoidable since different rules are applied to adjacent balls. In response, Clarke and Allsopp (2002) identify that it is irrelevant whether the match was abandoned after 10 overs or run its course after 10.1 overs since in either case the method used to estimate a projected score should be exactly the same. As Clarke and Allsopp (2002) point out, with the West Indies at 68 for 2 after 10 overs, they have 77.6% of run scoring resources at its disposal. This gives a projected score of $70+2.25\times 77.4=243$ runs. The victory margin would now be 175 and in effect the discontinuity disappears. This situation underscores the reason for estimating 50-over projected scores; i.e. calculating a projected victory margin provides a realistic account of the relative superiority of one team over another. Nevertheless, as Duckworth and Lewis (2002) rightly contend, method 1 in some instances breaks down due to inconsistencies. In citing their example to highlight this problem, they suppose that Team 1 scores 300 and Team 2 responds with 220 for the loss of five wickets after 40 overs before the match is abandoned due to rain. With 27.5% of untapped run scoring resources, method 1 estimates Team 2's projected score to be $220+2.25\times 27.5=282$ runs. Team 1 would be 18 runs better off. In contrast (3.5) gives a par score of $\frac{300(100-27.5)}{100}=218$ runs, which has Team 2 duly winning by 2 runs. There is a clear inconsistency here, which is an undesirable circumstance. However, this inconsistency will only arise when Team 1's score exceeds 225 and the match is abandoned at a time when and Team 2's score is less than that of

Team 1. This is illustrated by the following formal argument (without the inclusion of the adjustments proposed by de Silva, Pond and Swartz (2001)). Since $S_{\text{tie}} - \frac{S_{\text{tie}}(100-R)}{100} > 0$ for all $R \in (0, 100)$ then for consistency we require that $S_{\text{actual}} + 2.25R - S_{\text{tie}} > 0$. The inequations can be transposed to establish that an inconsistency arises whenever $S_{\text{tie}} > 225$ and $S_{\text{tie}} > S_{\text{actual}}$. Under normal circumstances the inconsistency will never arise when calculating a projected margin because (3.1) is generally applied when Team 2 wins, thus $S_{\text{actual}} > S_{\text{tie}}$ in all instances. It follows that $S_{\text{actual}} + 2.25R - S_{\text{tie}} > 0$ for all $R \in (0, 100)$ and consistency is preserved.

An alternative solution as suggested by Clarke and Allsopp (2002) is to scale up the actual score in proportion to the unused run scoring resources as described by method 2. From the above example, equation (3.4) estimates Team 2's projected score to be 306 runs. This preserves the positive advantage implicit in the application of (3.5). This can be proven formally by the following line of reasoning. For both methods to be consistent we require that both $S_{\text{actual}} - \frac{S_{\text{tie}}(100-R)}{100} > 0$ and $\frac{100S_{\text{actual}}}{100-R} - S_{\text{tie}} > 0$ or $S_{\text{actual}} - \frac{S_{\text{tie}}(100-R)}{100} < 0$ and $\frac{100S_{\text{actual}}}{100-R} - S_{\text{tie}} < 0$. If we assume that $\frac{100S_{\text{actual}}}{100-R} - S_{\text{tie}} > 0$ then it follows that $S_{\text{actual}} > \frac{S_{\text{tie}}(100-R)}{100}$ or $S_{\text{actual}} - \frac{S_{\text{tie}}(100-R)}{100} > 0$. Similarly, if we assume that $\frac{100S_{\text{actual}}}{100-R} - S_{\text{tie}} < 0$ then $S_{\text{actual}} < \frac{S_{\text{tie}}(100-R)}{100}$ or $S_{\text{actual}} - \frac{S_{\text{tie}}(100-R)}{100} < 0$. Thus, by *reductio ad absurdum*, the consistency is preserved.

In summary, given that the application of method 2 removes the inconsistencies highlighted by Duckworth and Lewis (2002) and the distribution of scores is statistically equivalent to those achieved by Team 1, the projected scores estimated by method 2 (including the adjustment proposed by de Silva, Pond and Swartz (2001)) will be used throughout the analysis of one-day cricket results and adopted for the remainder of the thesis.

3.6 Creating a victory margin

Once a projected score for Team 2 has been estimated the projected victory margin can be calculated. This provides an effective measure of the relative strength of the two teams at the point of victory. A large projected margin would suggest that the relative strength differential is also large, whereas a small projected margin would imply that the teams are more evenly matched. To illustrate how this works, suppose Team 1 and Team 2 play each other twice in a hypothetical competition, with Team 2 being victorious by eight wickets each time. And assume Team 1 is dismissed cheaply for 150 runs in each match. However, in the first match suppose Team 2 scores a solid 151 for the loss of 2 wickets in 35 overs whereas in the second match, struggles over the line to reach 151 for the loss of 2 wickets with only one over to spare. In the first match, Team 2 is a decisive winner, with a substantial 44.4% of untapped run scoring resources still to be expended. However, this resource availability drops markedly to 3.9% in the second match. Clearly, Team 2's victory in the first match was much more considerable than in the second. However, this disparity would not be reflected in the official victory margin of eight wickets. Using (3.4), with R_{mod} for each match being $\left(1.183-0.006\times44.4\right)44.4=40.7\%$ and $\left(1.183-0.006\times3.9\right)3.9=4.5\%$ respectively, the subsequent projected scores are $\dfrac{100\times151}{100-40.7}=255$ and $\dfrac{100\times151}{100-4.5}=158$ runs. It is self-evident that the extent of the victories are significantly different, with Team 2's first victory being a substantial 97 runs better than the second. This denounces the false notion that, in each match, Team 2 had an easy eight wicket victory. In the first match Team 2 is the dominant team. Its superiority is evident, with a large victory margin of $255-150=105$ runs. In the second match, however, the victory margin is only 8 runs. This suggests that both teams were evenly matched, with, possibly, a few lucky breaks going the way of Team 2.

In contrast, Duckworth and Lewis (1998) define the victory margin as the excess in runs over the par score at the point of abandonment of a match. This can also be used to represent how far Team 2 is ahead of its target score at the point of victory. However, in most instances this patently underestimates the relative superiority of one team over another. This is illustrated by the results from the 1999 ICC Cricket World Cup. The victory margins estimated by each method are provided in Table 3.3. The margins estimated by (3.4) are, for the most part, substantially higher and more highly variable than the margins estimated by the par scores. This is not surprising since the latter represent the victory margin at the point of completion of the match whereas the differentials estimated by (3.4) represent the projected margins after both teams have, in effect, expended their available quota of run scoring resources. The largest differences between the methods arise when Team 2 has chased a small total to win after expending relatively few run scoring resources. For comparative purposes, Table 3.4 provides the respective margins when Team 1 was victorious. An F-test confirms that the variability of the Team 2 victory margins estimated by the D/L method and the de Silva *et al* method were essentially different $\left(F_{1,\,39} = 2.9,\; p = 0.020\right)$. There was no evidence to suggest, however, that the variability in the margins estimated by both D/L and de Silva *et al* were different from those estimated by Team 1. A one-way analysis of variance test confirms that the victory margins estimated by all methods were statistically equivalent $\left(F_{1,\,39} = 2.5,\; p = 0.088\right)$. Figure 3.2 displays box plots of the distributions of the respective victory margins for Teams 1 and 2.

To highlight why the victory margins estimated by (3.4) provide a more accurate representation of the relative strength difference between competing teams at the point of victory consider, for example, the Scotland versus New Zealand match. Scotland batted first and scored 121. New Zealand passed the total easily with the loss of 4 wickets and with more than 32 overs to spare. This was a substantial victory for New Zealand. From Table 3.3, the excess in runs over the par score is calculated to be 68 runs; i.e. at the point of victory New Zealand, after 18 overs, was 68 runs ahead of where it needed to be in order to be on target for a win. In contrast, the margin estimated by (3.4) is a high 113 runs; i.e. if run scoring resources were made available, New Zealand would be expected to score a further 113 runs in the remaining 32 overs. Given the high degree of resource availability the latter provides a more accurate measure of the extent of New Zealand's victory.

Table 3.3. Victory margins for Team 2 in the 1999 ICC Cricket World Cup

Team 1	*Team 2*	*Victory margin estimated by method 2*	*Victory margin recorded as the excess over par*
Sri Lanka	England	34	24
India	South Africa	31	23
Kenya	Zimbabwe	85	59
Kenya	England	110	73
Zimbabwe	Sri Lanka	34	26
Zimbabwe	England	89	59
Kenya	South Africa	64	44
Scotland	Australia	44	32
Bangladesh	New Zealand	76	49
Australia	New Zealand	45	33
Bangladesh	West Indies	31	23
New Zealand	West Indies	44	31
Bangladesh	Australia	187	111
Scotland	West Indies	90	53
West Indies	Australia	46	31
Scotland	New Zealand	113	68
Pakistan	South Africa	11	8
India	New Zealand	21	16
South Africa	Australia	5	4
New Zealand	Pakistan	30	23
Pakistan	Australia	149	90
Mean		64	42
Standard deviation		46	27

Table 3.4. Victory margins for Team 1 in the 1999 ICC Cricket World Cup

Team 1	*Team 2*	*Victory margin*
Zimbabwe	India	3
South Africa	Sri Lanka	89
South Africa	England	122
India	Kenya	94
India	Sri Lanka	157
India	England	63
Zimbabwe	South Africa	48
Sri Lanka	Kenya	45
Pakistan	West Indies	27
Pakistan	Scotland	94
Pakistan	Australia	10
Bangladesh	Scotland	22
Pakistan	New Zealand	62
Bangladesh	Pakistan	62
Australia	India	77
India	Pakistan	47
Australia	Zimbabwe	44
South Africa	New Zealand	74
Pakistan	Zimbabwe	148
Mean		68
Standard deviation		43

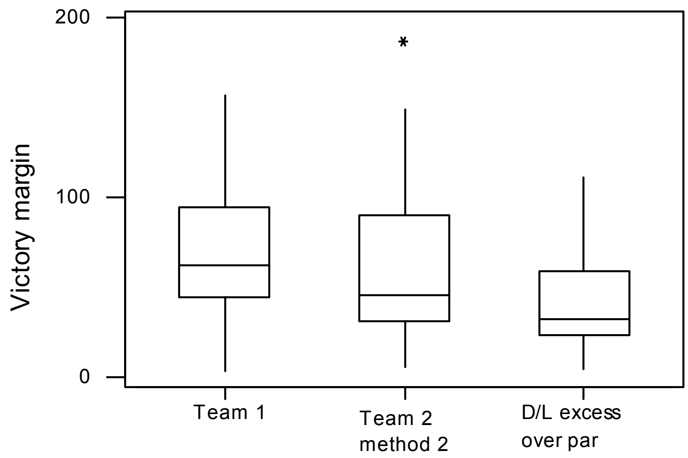

Figure 3.2. Distribution of the victory margins for Team 1 and Team 2 in the 1999 ICC Cricket World Cup

3.7 Recent changes to the D/L method

Duckworth and Lewis (2004) have recently updated their rain interruption rule methodology to reflect the changing nature of ODI cricket. As a result, their model has been modified in order to more accurately account for (a) Team 1's ability to score higher than in the past and (b) the contributions made by the earlier and later batsmen. As a result of the former scenario, the average first innings score in the D/L model has increased from 225 to 235 runs. Updated resource percentage tables that reflect these changes have been produced and came into operation on 1 September 2002. However, in situations where Team 1 scores a well-above-average total has required a complete upgrade of the D/L model. The required calculations can only be undertaken using computer software and is known as the *Professional Edition*.

To analyse the effect of the changes suppose that in an ODI match Team 2 reaches its target score of 200 runs after 45 overs have been completed with the loss of 7 wickets. Using the original D/L tables, Team 2's projected score is estimated to be $\frac{100 \times 200}{100 - 14.0} = 233$ runs. With the application of the modifications proposed by de Silva *et al*, the modified resource percentage value, R_{mod} is calculated to be

$(1.183-0.006\times14.0)14.0=15.4\%$. The subsequent estimate for the projected score is $\frac{100\times200}{100-15.4}=236$ runs. Application of the new D/L tables estimates the projected score to be $\frac{100\times200}{100-12.5}=229$ runs. Further suppose that the same target score is reached in only 30 overs with 8 wickets in hand. Using the original D/L tables, Team 2's projected score is estimated to be a very high $\frac{100\times200}{100-54.0}=435$ runs. The modified resource percentage value, R_{mod} is calculated to be $(1.183-0.006\times54.0)54.0=46.4\%$. This substantially reduces the projected score estimate to $\frac{100\times200}{100-46.4}=373$ runs. Application of the new D/L tables estimates the projected score to be a considerably high $\frac{100\times200}{100-52.4}=420$ runs. In summary, it appears that application of the new D/L tables produces slightly more conservative estimates when Team 2 wins with relatively few run scoring resources at its disposal but produce inflated projected scores when Team 2 wins easily with a high proportion of unused run scoring resources at its disposal. Under normal circumstances scores of this magnitude would be highly unlikely. The de Silva, Pond and Swartz (2001) modified resource percentage values (as applied to the original D/L resource percentage values) for the most part appear to provide much more realistic projection estimates.

To analyse the situation in more depth, assume Team 2 has reached its target score with 20 overs remaining and with 0, 2, 5, 7 and 9 wickets at its disposal. Table 3.5 provides the resource percentage values for each of the three methods as outlined above. The corresponding projected scores are provided in Table 3.6. Figures 3.3 and 3.4 provide a plot of the projected scores based on 0, 2, 5, 7 and 9 wickets and with 10 and 20 overs remaining. The methods are comparable when Team 2 has relatively few run scoring resources at its disposal. The methods are least comparable when Team 2 has a substantial number of run scoring resources at its disposal. Under this circumstance, applications of both forms of the D/L method (without the de Silva *et al* modification) display a tendency to grossly overestimate the projected scores. It is highly unlikely that a team will score in excess of 400 runs no matter how many run scoring resources it has at its disposal. The psychology of the game together with relaxed fielding restrictions beyond 15 overs suggests that teams experience considerable difficulty sustaining a high level of batting intensity. Scores in the vicinity of 380 have proven to be achievable but seldom occur. There is a rider, however. In what appears to be one of the most one-sided matches in ODI history, Sri Lanka dismissed Zimbabwe for 38 runs and passed the target in only 4.2 overs. In doing so, Sri Lanka scored 39 for the loss of 1 wicket. With 89.3% of unused run scoring resources remaining, the projected score for Sri Lanka is an obtainable 364 runs using the D/L methodology but only 92 runs using the adjustment proposed by de Silva *et al*. Application of the latter method clearly underestimates Sri Lanka's expected score. It appears that the de Silva *et al* method severely breaks down when estimating a projected score in situations when a high proportion of run scoring resources have not been expended.

To further demonstrate the efficacy of all the above methods, especially when a team is able to respectively maintain a high scoring rate throughout its innings with the expending of (a) few run scoring resources and (b) a wealth of run scoring resources, assume that a hypothetical team in one match maintains a rate of 10 runs per over but has lost 8 wickets within the first 4 overs and in another match loses only 2 wickets for the entire match. Figures 3.5 and 3.6 each display the expected 50-over scores upon completion of overs 5 through to 50. The results clearly suggest that if Team 2 has exhausted a wealth of run scoring resources the projected scores for all methods are comparable. However, if Team 2 has a large number of unused run scoring resources at its disposal both D/L methods grossly overestimate the projected score. On the other hand, the de Silva *et al* method underestimates the projected score when relatively few overs have been bowled. Nonetheless, in the majority of cases (say, innings that last in excess of 10 overs), the de Silva *et al* method produces the more realistic estimates. Note that the projected scores for all methods are comparable when a team has relatively few overs are at its disposal.

Duckworth and Lewis (2004) accept that a better method of recording ODI victory margins needs to be developed. However, they challenge the use of the D/L methodology to estimate a projected score, especially in short matches where the victory has been one-sided. Conversely, they propose that a suitable division of 100 points between competing teams would more usefully represent the victory margin. They suggest that the division of points should use the team's relative runs per percentage of resource consumed at the point of victory. This is a practical suggestion, however, it is somewhat removed from the established culture of using the language of runs and wickets to document victories. In their dismissal of the projected score concept as a mechanism for creating a victory margin, Duckworth and Lewis (2004) are to some extent misguided in their criticism because what constitutes a one-sided match is ambiguous. To illustrate this point; in the abovementioned one-sided Sri Lanka versus Zimbabwe match, the one-sidedness and shortness of the match arises because of Sri Lanka's bowling performance; not its batting prowess. Under these circumstances, with so many overs available to make few runs, Sri Lanka could afford to take its time when batting regardless of how proficient it was in dismissing Zimbabwe for a low score. A one-sided batting performance would invariably arise in a match where a team reaches a relatively high score with the expending of few run scoring resources.

Table 3.5. Resource percentage values for a truncated score of 200 with 10 and 20 overs remaining

Number of wickets lost	*Original D/L method*		*de Silva et al modification applied to the original D/L method*		*New D/L method*	
	10 overs	20 overs	10 overs	20 overs	10 overs	20 overs
0	34.1	58.9	33.4	48.9	32.1	56.6
2	32.5	54.0	32.1	46.4	30.8	52.4
5	27.5	40.0	28.0	37.7	26.1	38.6
7	20.6	25.2	21.8	26.0	17.9	21.2
9	7.5	7.6	8.5	8.6	4.7	4.7

Table 3.6. Team 2 projected scores based on a truncated score of 200 with 10 and 20 overs remaining

Number of wickets lost	*Original D/L method*		*de Silva et al modification applied to the original D/L method*		*New D/L method*	
	10 overs	20 overs	10 overs	20 overs	10 overs	20 overs
0	303	487	300	391	295	461
2	296	435	295	373	289	420
5	276	333	278	321	271	326
7	252	267	256	270	244	254
9	216	216	219	219	210	210

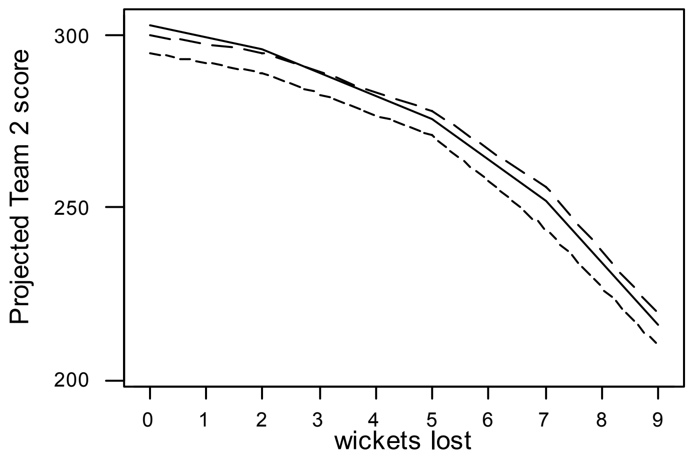

Figure 3.3. Projected Team 2 scores based on a truncated score of 200 with 10 overs remaining as estimated by the D/L method (——); the de Silva *et al* method (— —) and the new D/L method (- - -)

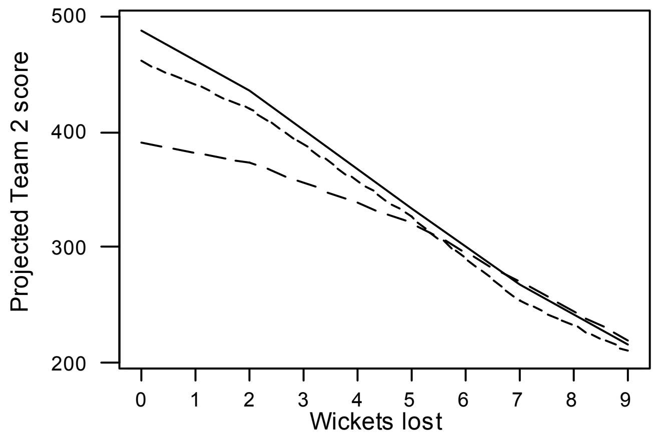

Figure 3.4. Projected Team 2 scores based on a truncated score of 200 with 20 overs remaining as estimated by the D/L method (——); the de Silva *et al* method (— —) and the new D/L method (- - -)

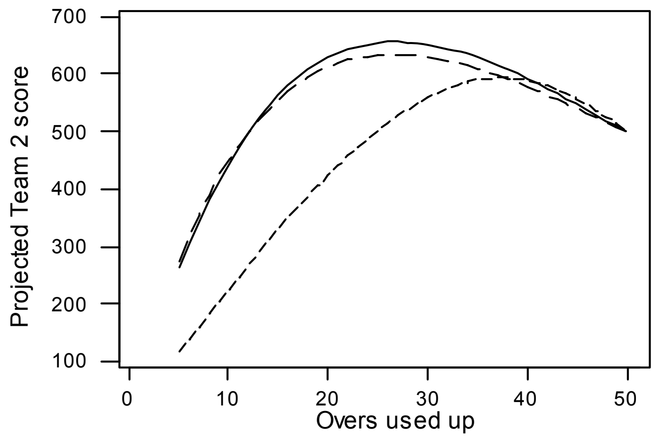

Figure 3.5. Projected Team 2 scores as estimated by the original D/L method (——); the new D/L method (— —) and the de Silva *et al* method (- - -) when a team maintains a scoring rate of 10 runs per over, with the loss of 2 wickets

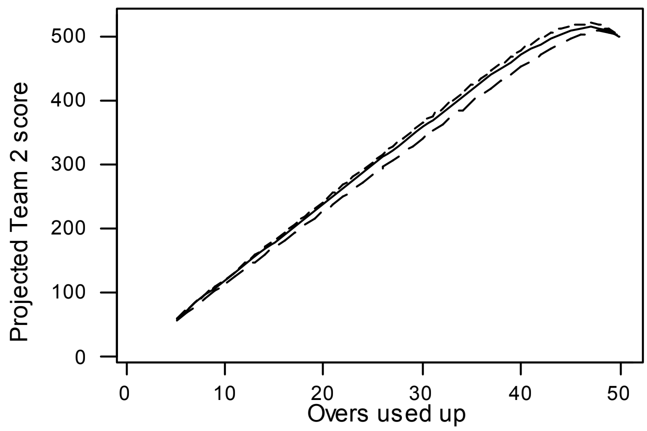

Figure 3.6. Projected Team 2 scores as estimated by the original D/L method (——); the new D/L method (— —) and the de Silva *et al* method (- - -) when a team maintains a scoring rate of 10 runs per over, with the loss of 8 wickets

3.8 Conclusions

It is evident that the method currently employed by cricket authorities to record a Team 2 victory in ODI cricket is not consistent with the methods used to record a Team 1 victory. This can be a little misleading because it provides limited information on the extent of a Team 2 victory. For example, a Team 1 victory of 100 runs is patently more substantial that a victory by one run. In contrast, a ten wicket victory for Team 2 could have been achieved with one ball to spare or 15 overs to spare. A revised system needs to be introduced which (a) is consistent across innings; (b) provides a mechanism for all Team 2 victories to be compared and ranked and (c) allows Team 1 and Team 2 victories to be compared and contrasted on the same footing. The current method used to record a Team 1 victory makes sense because the level of dominance exercised by the winning team in effect is commensurate with the margin of victory. For example, a 150 run victory is clearly more decisive than a victory by 10 runs. There is a call for a similar method to document a Team 2 victory. At present, the method used to record a Team 2 victory sheds little light on the strength of the win. For example, a 10 wicket victory could have been achieved on the last ball of the day or with 20 overs to spare.

It was established that the D/L rain interruption rules methodology can be used to scale up the actual winning Team 2 scores in proportion to its unused run scoring resources to estimate a projected score. The inclusion of the modifications to the resource percentage values suggested by de Silva, Pond and Swartz (2001) ensure that the projected scores for Team 2, in the main, are not overestimated when it wins with a relatively large number of run scoring resources at its disposal and are not underestimated when it wins with relatively few unused run scoring resources available to it. It was also established that the application of the recently updated D/L resource percentage values did not improve on the projected estimates that included the de Silva *et al* resource percentage adjustments. Once the projected score is estimated, this essentially creates a projected victory margin for Team 2 when it wins with unused run scoring resources at its disposal. It was posited that this provides a more realistic measure of Team 2's relative superiority at the point of victory than the current wickets-in-hand method and ensures that all victories, across innings, are measured on a consistent scale (in runs) and are ultimately compared and contrasted on the same footing: for example, after both teams have theoretically expended their available quota of run scoring resources. Under the present system, the only situation that produces a result, with both teams having exhausted available quota of run scoring resources, is when Team 2 wins (or loses) off the last ball of its innings.

CHAPTER 4

EXPLORATORY ANALYSIS OF ODI AND TEST CRICKET

4.1 Introduction

In the examination of ODI and Test cricket traditional exploratory techniques will be used to analyse ten years of data in five-year periods. For ODI cricket, the analysis will be conducted from the beginning of the 1992/93 (Australian) season to the end of the 1997 (European) season and then for all seasons from 1997/98-2001 inclusive. This accounts for 514 matches overall or 266 matches in the first five-year period and 248 matches in the second period. This includes both day and day/night matches. For Test cricket, the analysis will be conducted for all seasons from 1992-1997 inclusive and from the beginning of the 1997/98 (Australasian) season to the end of the 2001 (European) season. This accounts for 328 matches overall or 177 matches in the first five-year period and 151 matches in the second. Note that a small number of matches were played on neutral grounds and consequently have been excluded from the study. In addition, results from the 1999 and 2003 ICC Cricket World Cup competitions will also be analysed, but only the results for the nine ICC-sanctioned teams examined in the first part of the study will be considered. Accordingly, all matches comprise a designated home-country team. A tied result is a rare event and the relatively few matches that resulted in a tie have been excluded from the analysis.

Only nine (of the ten) current International Cricket Council (ICC) sanctioned Test-playing nations have been included in the study. Bangladesh has been excluded because of its recent inclusion as a Test-playing nation and its consequent involvement in relatively few ICC-sanctioned matches.

Results are considered in five-year periods because it is assumed that for the majority of teams the core playing group has essentially remained consistent over this period of time. Consequently, it would be expected that any team quality effects would remain consistent within each of the five-year periods but not necessarily across periods. Over longer time periods the core playing group may change dramatically, which suggests that the team quality effect may also dramatically change. Accordingly, this may lead to a misinterpretation of the findings. As a result, the analysis of team performance may not accurately account for the inherent variability in team quality and thus provide only an average measure of a team's relative strength.

4.2 Exploratory analysis of ODI cricket

4.2.1 General analysis

In examining ODI cricket, the Team 2 scores were adjusted for cases when Team 2 won. The adjusted Team 2 scores were estimated via the techniques outlined in Chapter 3. In essence, the methodology developed by Duckworth and Lewis (1998) together with the modifications proposed by de Silva, Pond and Swartz (2001) have been adopted to estimate a projected Team 2 score. This represents the estimated score for Team 2 projected to the exhaustion of available run scoring resources.

During the period 1992/93-1997 the overall winning percentages for Teams 1 and 2 were 50%. For the period 1997/98-2001 the winning percentages for Teams 1 and 2 were 48% and 52% respectively. Neither team enjoyed a substantial winning advantage. Accordingly, the order of the innings has not greatly affected match results. Similarly, winning the coin toss has not influenced the outcome of a match. For the period 1992/93-1997, the percentages of teams winning and losing a match after winning the coin toss were 52% and 48% respectively. For the period 1997/98-2001 the respective percentages were 48% and 52%. A χ^2 test confirms that neither team enjoyed a significant winning advantage after winning the coin toss throughout both study periods with $\left(\chi_1^2 = 0.241,\ p = 0.624\right)$ for the first study period and $\left(\chi_1^2 = 0.258,\ p = 0.611\right)$ for the second study period. This supports the findings of de Silva and Swartz (1997) who established that the team winning the coin toss in ODI cricket was not advantaged in any way.

Table 4.1 provides summary statistics of the overall performances for the home and away teams. For the period 1992/93-1997 home team won 163 matches and lost only 103 (or

61% and 39% respectively). For the ensuing study period, the home team won 150 matches and lost only 98 (or 60% and 40% respectively). A χ^2 test confirms that the home team enjoyed a significant winning advantage over its opponent across both study periods with $\left(\chi_1^2 = 13.5,\ p < 0.001\right)$ for the first period and $\left(\chi_1^2 = 10.9,\ p = 0.001\right)$ for the second. The home team was able to maintain its strong 60% winning advantage over both study periods. Undoubtedly, the home team has maintained a strong winning advantage over the away team throughout the study. During both five-year study periods the home team was also able to score more runs than the away team. The Anderson-Darling test for normality suggests that the home team scores for both periods were not normally distributed. As a result, the non-parametric Mann-Whitney test is used to determine whether the home team was able to score significantly more runs than the away team. The respective test results for the periods 1992/93-1997 and 1997/98-2001 were $(W_{530} = 74489,\ p = 0.021)$ and $\left(W_{494} = 67895,\ p < 0.001\right)$. It is clear that during both study periods the home team was able to score significantly more runs than the away team. The advantage for the home team was 7 and 17 runs for each of the respective study periods. Note that the run scoring potential for both teams also increased markedly across periods, with the mean innings scores increasing by 27 and 17 runs for the home and away teams respectively.

Table 4.1. Summary statistics of the for the home and away team scores in ODI cricket

Period	*Home team*			*Away team*		
	Matches won	*Mean*	*Standard deviation*	*Matches won*	*Mean*	*Standard deviation*
1992/93-1997	163	218	49	103	211	47
1997/98-2001	150	245	54	98	228	54

Tables 4.2 and 4.3 provide summary statistics of the home and away performances for individual teams. During the period 1992/93-1997 Australia, India and South Africa all performed creditably given that they played in a relatively high proportion of matches. England displayed a very strong home performance but this is exaggerated by the fact that it played in only eight matches at home. In contrast, South Africa played 50 matches at

home and was able to win a substantial proportion of them. This highlights a problem when the scheduling of matches is not taken into account and a team's overall performance is subsequently judged independently from its home and away performances. For example, England won less than 50% of its matches overall during this period, which placed them third last. However, if England had played in an equal number of home and away matches the results suggest that it would have won 63% of its matches overall. This now ranks it above all other teams. Note that England's home winning percentage dropped considerably during the second study period. The number of matches it played at home, however, markedly increased. During the first study period a paired *t*-test confirms that there was not a significant difference in the home and away mean scores $\left(T_{16} = 1.09,\ p = 0.306\right)$. However, during the second study period the teams, on average, scored more heavily at home than away from home $\left(T_{16} = 2.61,\ p = 0.016\right)$.

During the first study period, all teams generally performed better at home than away from home. This underscores the HA effect. However, a χ^2 test confirms that only India and South Africa enjoyed a significant HA. The home and away performance differential is most marked for Zimbabwe, India and England who all struggled when playing away from home. Not surprisingly, the top home team performers were also able to consistently produce relatively high scores when playing at home.

During the period 1997/98-2001 the dominance of Australia, Sri Lanka and South Africa is evident, all of which won more than 60% of their matches. Sri Lanka won a high proportion of home matches but struggled away from home. All teams except Pakistan and Zimbabwe generally performed better at home with only Australia and South Africa able to win more than 50% of their matches away from home. A χ^2 test confirms that only New Zealand, however, enjoyed a significant HA during this period. India displayed a propensity to score highly at home, which assisted them in achieving a relatively high home winning percentage. This is also indicative of the fact that nearly all teams were more adept at scoring runs at home rather than away from home.

It is notable that the standard deviations for all teams during both study periods were similar, which highlights the structural limitations unique to ODI cricket; i.e. the level of variability of the scores is controlled somewhat by the limited availability of run scoring resources. It is not expected that this would be the case in Test cricket where the length of each innings is much less controlled.

Table 4.2. Summary statistics of the Team 1 and 2 scores for home and away matches by team in ODI cricket

Team	*Matches played*		*Mean score*		*Standard deviation*		*% wins*		
	Home	*Away*	*Home*	*Away*	*Home*	*Away*	*Overall*	*Home*	*Away*
Period 1992/93-1997									
Australia	38	40	205	225	43	40	53%	58%	48%
England	8	30	248	208	38	43	47%	88%	37%
India	42	30	229	195	49	39	50%	67%	27%
New Zealand	39	27	201	220	50	55	42%	49%	33%
Pakistan	21	42	238	203	43	48	56%	67%	50%
South Africa	50	19	220	202	42	50	58%	66%	37%
Sri Lanka	28	27	216	230	53	42	58%	68%	48%
West Indies	25	31	232	206	50	56	54%	64%	45%
Zimbabwe	15	20	188	203	54	37	17%	33%	5%
Period 1997/98-2001									
Australia	46	34	259	232	48	54	71%	76%	65%
England	22	22	230	231	42	48	39%	41%	36%
India	27	30	274	237	66	40	54%	63%	43%
New Zealand	31	21	243	239	46	56	37%	48%	19%
Pakistan	18	25	232	242	54	77	41%	39%	44%
South Africa	34	29	236	216	63	47	68%	79%	55%
Sri Lanka	29	29	236	219	47	49	62%	83%	41%
West Indies	19	23	246	196	52	52	40%	63%	22%
Zimbabwe	22	35	243	237	57	54	19%	18%	20%

Table 4.3. Home and away performances by team in ODI cricket

Team	*Matches played*		*Matches won*				*% wins*		
	Home	*Away*	*Home*	*Away*	χ_1^2	*p-value*	*Overall*	*Home*	*Away*
Period 1992/93-1997									
Australia	38	40	22	19	0.2	0.639	53%	58%	48%
England	8	30	7	11	0.9	0.346	47%	88%	37%
India	42	30	28	8	11.1	0.001	50%	67%	27%
New Zealand	39	27	19	9	3.6	0.059	42%	49%	33%
Pakistan	21	42	14	21	1.4	0.237	56%	67%	50%
South Africa	50	19	33	7	16.9	<0.001	58%	66%	37%
Sri Lanka	28	27	19	13	1.1	0.289	58%	68%	48%
West Indies	25	31	16	14	0.1	0.715	54%	64%	45%
Zimbabwe	15	20	5	1	2.7	0.102	17%	33%	5%
Period 1997/98-2001									
Australia	46	34	35	22	3.0	0.085	71%	76%	65%
England	22	22	9	8	0.1	0.808	39%	41%	36%
India	27	30	17	13	0.5	0.465	54%	63%	43%
New Zealand	31	21	15	4	6.4	0.012	37%	48%	19%
Pakistan	18	25	7	11	0.9	0.346	41%	39%	44%
South Africa	34	29	27	16	2.8	0.093	68%	79%	55%
Sri Lanka	29	29	24	12	4.0	0.046	62%	83%	41%
West Indies	19	23	12	5	2.9	0.090	40%	63%	22%
Zimbabwe	22	35	4	7	0.8	0.366	19%	18%	20%

In comparing the second five-year period with the first, it is evident that the scoring capacity of teams has generally increased; i.e. an overall mean score for the first five-year period of 214 runs (standard deviation of 48 runs) compared to 237 runs (standard deviation of 55 runs) for the second period. This gives rise to a substantial increase of 23 runs. Figure

4.1 provides box plots for the distributions of all projected scores for each of the five-year periods. It is apparent that during the second five-year period there were some scores considerably higher than expected. Figure 4.2 provides a line plot displaying the mean home and away projected scores (by team) for each of the five-year periods. It is evident that for the majority of teams the mean score substantially increased during the second five-year period. The Anderson-Darling test for normality suggests that the projected scores are not normally distributed. As a consequence, the non-parametric Mann-Whitney test is applied, which confirms that during the second five-year period teams were able to score significantly more runs than during the first period $\left(W_{494} = 287414,\ p < 0.001\right)$. There was also a subsequent increase in the variability of the scores. However, the coefficient of variation suggests that the level of variation has essentially increased in the same proportion as the mean; i.e. no change from 22% for the home team and a marginal increase from 22% to 24% for the away team. The stronger showing in the second study period suggests that teams became more proficient at scoring runs. It can be inferred from anecdotal evidence that over this time there was a growing tendency for teams to use unconventional free flowing batsmen in their top order who could take advantage of early fielding restrictions and subsequently score at a frenetic pace. This approach was mooted by Clarke (1988), who employed dynamic programming techniques to examine optimal scoring rates in ODI cricket. This flies in the face of the more established method of playing ODI cricket up to this time whereby teams cautiously built an innings around a conventional Test team batting line up and only implemented a more audacious approach in the latter portion of their innings. By adopting a more cavalier overall approach teams became more adept at sustaining a solid scoring rate throughout their innings, especially when many unused run scoring resources were at a team’s disposal. This approach has continued up to the time of writing. Other factors that may have contributed to more adventurous stroke play are (a) the practice of making the playing areas of traditionally large grounds, such as the Melbourne Cricket Ground (MCG), smaller and (b) the preparation of wickets that favour a team’s batting strength more so than its bowling strength. It is interesting to note that current thinking espouses the selection of different ODI and Test teams. Australia’s 2004 ODI team for example, consisted of several non-test players.

In comparing the home winning percentages across study periods, the Mann-Whitney test and Figure 4.3 confirm that the HA effect has essentially remained the same over the ten year period of the study $\left(W_{1022} = 93,\ p = 0.536\right)$. However, the larger interquartile range for the second study period; i.e. 37.5% compared to 14% suggests that the HA effect (by team) was more variable during this period.

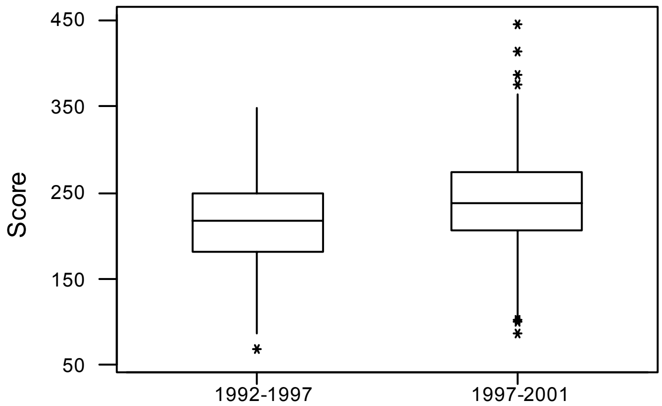

Figure 4.1. Box plots of the distribution of projected scores in ODI cricket for the periods 1992/93-1997 and 1997/98-2001

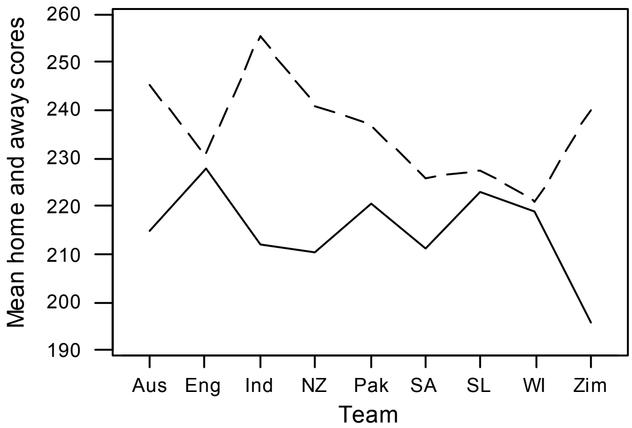

Figure 4.2. Plot of the mean home and away projected scores by team in ODI for the periods 1992/93-1997 (——) and 1997/98-2001 (– – –)

Figure 4.3. Box plots displaying the distribution of the home winning percentages in ODI cricket (by team) for the periods 1992/93-1997 and 1997/98-2001

4.2.2 Analysis of the day/night effect

To explore the effects of playing under lights (i.e. in scheduled day/night fixtures) Tables 4.4 and 4.5 provide the relevant summary statistics for the two five-year study periods. In all cases Team 1 completes its innings in daylight and Team 2 completes the majority of its innings under-lights. A χ^2 test verifies that during the first study period Team 1 did not win significantly more matches than expected $\left(\chi_1^2 = 1.8,\ p = 0.180\right)$ even though it is apparent from Table 4.5 that Team 1, for the most part, was able to score more runs. During the ensuing period, Teams 1 and 2 won 50% of the time. There is no evidence to suggest that during both study periods either team was disadvantaged by the day/night conditions.

In analysing the distribution of projected scores for Teams 1 and 2 in day/night matches the normality assumption is not breached for either of the study periods. An F-test verifies that the variability of the scores for both innings (across study periods) was essentially the same, with $\left(F_{1,\,265} = 0.7,\ p = 0.107\right)$ for the first five-year period and $\left(F_{1,\,247} = 0.8,\ p = 0.252\right)$ for the ensuing period. The two-sample t-test (with assumed equal variances) establishes that during the first study period Team 1 was able to score significantly more runs than Team 2 $\left(T_{530} = 2.2,\ p = 0.015\right)$. However, for the ensuing period the scoring capabilities for both teams were essentially the same $\left(T_{530} = -0.7,\ p = 0.499\right)$. This suggests that there was a day/night effect for the 1992/93-1997 study period, with the scoring capacity of Team 2 disadvantaged somewhat by the conditions. There is no evidence to suggest that Team 2 experienced any disadvantage during the ensuing five-year period. Notably, the variability of the scores in day/night matches has increased markedly for both innings across study periods, with $\left(F_{1,\,513} = 0.5,\ p = 0.006\right)$ for Team 1 and $\left(F_{1,\,513} = 0.6,\ p = 0.028\right)$ for Team 2. Calculation of the coefficient of variation indicates that the proportional increase in the variability relative to the mean for Teams 1 and 2 were 28% and 13% respectively. This is possibly due to the more adventurous approach entertained by teams during the second study period discussed earlier. With players exhibiting a higher level of risk and less control in their play, this possibly led to a higher variability in the capacity of scoring.

In considering the number of wickets lost by Teams 1 and 2 in day/night matches, the Mann-Whitney test verifies that for the first study period the number of wickets lost was essentially the same for both teams. For the following period, however, there is strong evidence suggesting that Team 1, on average, lost significantly more wickets than Team 2 $\left(W_{530} = 9437,\ p = 0.020\right)$. The latter point provides some evidence why the projected scores for Team 2 were potentially higher. Since Team 2 had lost fewer wickets it had more unused run scoring resources at its disposal in the form of wickets. Accordingly, it had the capacity to make more runs.

Analysis of the profile of teams that batted first in day/night matches may also explain why teams produced the scores that they did. In both study periods a high proportion of the teams that batted first comprised the top four teams; i.e. for 66% and 62% of the matches in each of the respective study periods the top four teams batted first. In each case Australia (27% and 27%) and South Africa (23% and 17%) accounted for a high 50% and 44% of the teams batting first. As a consequence, since the top four teams have the superior batting strength one would expect the first innings scores to be potentially higher. Conversely, since the top four teams would also have the superior bowling strength one would expect the second innings scores to be potentially lower. This was possibly the case with the first study period but not necessarily the second.

Table 4.4. Win and loss statistics for the day/night fixtures in ODI cricket

	Win	*Loss*	*Total*
	Period 1992/93-1997		
Team 1 (Day)	46	34	80
Team 2 (Night)	34	46	80
Total	80	80	160
	Period 1997/98-2001		
Team 1 (Day)	46	46	92
Team 2 (Night)	46	46	92
Total	92	92	184

Table 4.5. Summary statistics of the scores made in the day/night matches in ODI cricket

Period	*Team 1 (Day)*				*Team 2 (Night)*			
	Mean (runs)	*Standard deviation (runs)*	*Wickets lost*		*Mean (runs)*	*Standard deviation (runs)*	*Wickets lost*	
			No.	*Mean*			*No.*	*Mean*
1992/93-1997	220	40	1967	7.4	205	48	1807	6.8
1997/98-2001	235	55	1911	7.7	241	62	1683	6.8

4.2.3 Analysis of regional effects

To account for any regional effects we will assume that the nine ICC Test playing nations are divided up into five distinct geographical regions. This presupposes that the playing conditions unique to each region are similar. The regions are divided such that Regions 1 is England; Region 2 is the West Indies; Region 3 covers the sub-continent Test playing nations India, Pakistan and Sri Lanka; Region 4 includes the Australasian Test playing countries Australia and New Zealand and Region 5 represents the African nations South Africa and Zimbabwe. Table 4.6 provides the summary statistics for each region. A one-way analysis of variance confirms that there is no significant difference in the scoring potential across regions for the first period of study $\left(F_{4,\,1325} = 0.83,\ p = 0.506\right)$. However, for the ensuing period, there is strong evidence to suggest that the innings scores were significantly different $\left(F_{4,\,1245} = 5.26\ ,\ p < 0.001\right)$. The Tukey family error rate comparison test confirms that the scores produced in Region 3 and 4 were both significantly higher than those produced in Regions 1 and 2. This is possibly due to some of the stronger batting teams such as India (Region 3, mean score $= 274$ runs) and Australia (Region 5, mean score $= 259$ runs) residing in these regions. Since most teams play a majority of their matches at home one would expect the home scores of the stronger batting teams to be relatively higher. In contrast, England (Region 1), with a mean home sore of 230 runs had one of the lowest average home scores.

Table 4.7 summarises match results and uses the χ^2 test to compare the win/loss ratio by region across study periods. Note that matches that were contested in the same region have been ignored. In general, the analysis confirms that, for both study periods, there was no evidence of a regional effect. However, there is some evidence to suggest that during the second study period teams in the Australasian region displayed a winning advantage.

Table 4.6. Summary statistics of the projected scores by region in ODI cricket

	Region	*Mean*	*Standard deviation*
	Period 1992/93-1997		
1	England	218	54
2	West Indies	217	45
3	India, Pakistan and Sri Lanka	217	48
4	Australia and New Zealand	213	47
5	South Africa and Zimbabwe	207	45
	Period 1997/98-2001		
1	England	216	54
2	West Indies	215	58
3	India, Pakistan and Sri Lanka	244	57
4	Australia and New Zealand	246	55
5	South Africa and Zimbabwe	231	46

Table 4.7. Summary of match results by region in ODI cricket

Region	*Number of wins*	*Number of losses*	χ_1^2 *value*	*p-value*
		Period 1992/93-1997		
1	18	20	0.1	0.746
2	30	26	0.3	0.593
3	79	63	1.8	0.179
4	58	64	0.3	0.587
5	41	53	1.5	0.216
		Period 1997/98-2001		
1	17	27	2.2	0.132
2	17	25	1.5	0.217
3	54	44	1.0	0.312
4	63	43	3.8	0.052
5	51	63	1.3	0.261

4.3 Exploratory analysis of Test cricket

4.3.1 General analysis

Table 4.8 provides the overall number and percentage of wins, draws and losses by team in Test cricket across both study periods. For the period 1992-1997 the differences between the performances of the top four teams were marginal. For the period 1997/98-2001 the emerging dominance of Australia and South Africa is clearly evident. The low percentage of draws for Australia and Pakistan suggests that these teams adopted a more attacking style of play. By contrast, New Zealand played in a high percentage of draws. This implies that New Zealand tended to play more defensively. Table 4.9 uses the χ^2 test to compare the number of wins and losses by team across both study periods. For the first study period, Australia, in particular, won significantly more matches than it lost. In contrast, England, New Zealand and Zimbabwe lost significantly more matches than it won. For the ensuing period, Australia continued its significant winning dominance. South Africa also won significantly more matches than it lost. Conversely, the West Indies and Zimbabwe displayed a significant losing tendency.

Figure 4.4 displays the distribution of first innings scores for each of the study periods. The mean and standard deviation of the first innings scores for the period 1992-1997 were respectively 320 and 129 runs for Team 1 and 317 and 123 runs for Team 2. For the ensuing five-year period the mean and standard deviation were respectively 303 and 126 runs for Team 1 and 330 and 131 runs for Team 2. In comparing the distribution of first innings scores the Anderson-Darling normality test confirms that scores for each period were not normally distributed. However, the interquartile ranges for the distribution of scores for the respective study periods were 179 and 181 runs. This suggests that the variability in the scores were essentially the same. A Mann-Whiney test confirms that the scoring capacity of teams also effectively remained the same $\left(W_{326} = 116750.5,\ p = 0.849\right)$.

Table 4.8. Summary of overall Test cricket results

Team	*Matches played*	*Wins*		*Draws*		*Losses*	
Period 1992-1997							
Australia	58	29	50%	13	22%	16	28%
England	57	13	23%	19	33%	25	44%
India	31	13	42%	11	35%	7	23%
New Zealand	39	7	18%	13	33%	19	49%
Pakistan	40	19	48%	10	25%	11	28%
South Africa	32	15	47%	9	28%	8	25%
Sri Lanka	35	7	20%	13	37%	15	43%
West Indies	40	17	43%	13	33%	10	25%
Zimbabwe	22	1	5%	11	50%	10	45%
Period 1997/98-2001							
Australia	42	29	69%	6	14%	7	17%
England	44	14	32%	11	25%	19	43%
India	27	8	30%	8	30%	11	41%
New Zealand	30	8	27%	11	37%	11	37%
Pakistan	30	8	27%	8	27%	14	47%
South Africa	38	21	55%	12	32%	5	13%
Sri Lanka	26	11	42%	6	23%	9	35%
West Indies	40	11	28%	6	15%	23	58%
Zimbabwe	25	3	12%	8	32%	14	56%

Table 4.9. Comparison of Test cricket results

Team	*Matches played*	*Number of wins*	*Number of losses*	χ_1^2 *value*	*p-value*
		Period 1992-1997			
Australia	58	29	16	3.8	0.053
England	57	13	25	3.8	0.052
India	40	13	7	1.8	0.180
New Zealand	31	7	19	5.5	0.019
Pakistan	35	19	11	2.1	0.144
South Africa	39	15	8	2.1	0.144
Sri Lanka	32	7	15	2.9	0.088
West Indies	40	17	10	1.8	0.178
Zimbabwe	22	1	10	7.4	0.007
		Period 1997/98-2001			
Australia	42	29	7	13.4	<0.001
England	44	14	19	0.8	0.384
India	38	8	11	0.5	0.491
New Zealand	27	8	11	0.5	0.491
Pakistan	30	8	14	1.6	0.201
South Africa	40	21	5	9.8	0.002
Sri Lanka	26	11	9	0.2	0.655
West Indies	30	11	23	4.2	0.040
Zimbabwe	25	3	14	7.1	0.008

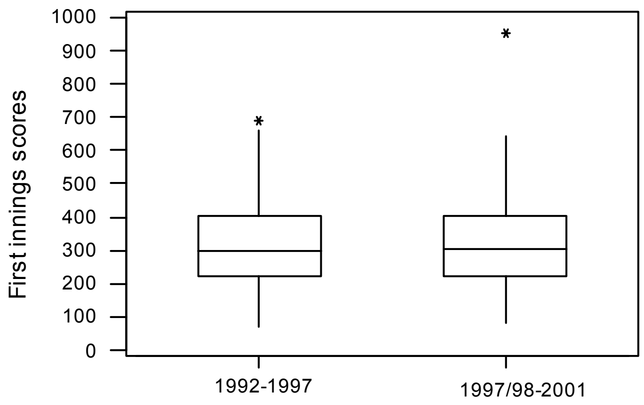

Figure 4.4. Box plot of the distribution of first innings scores in Test cricket

Table 4.10 provides the percentage of wins, draws and losses after a first innings lead had been established. For the period 1992-1997 it is not surprising that the majority of teams displayed a tendency to win after leading on the first innings. For the most part the top five teams demonstrated an ability to both establish and then capitalise on a first innings lead. Australia, undoubtedly, was the most proficient team at establishing a winning position on the first innings. The low percentage of drawn results for both Australia and Pakistan, after leading on the first innings, reflects their attacking mindset. The mean scores for Teams 1 and 2 were 320 and 317 runs which resulted in an average lead for the team batting first of only 3 runs. However, the respective mean scores for the home and away teams were 351 and 306 runs. This resulted in a substantial average lead of 25 runs for the home team.

For the period 1997/98-2001 both Australia and South Africa were able to establish a first innings lead in a high proportion of matches. All teams except Zimbabwe showed a strong inclination to win after gaining a first innings lead. However, only the top four ranked teams established a lead more than 50% of the time. The importance of a first innings lead is demonstrated by South Africa and New Zealand, which had virtually identical results after a first innings lead had been established. However South Africa led almost twice as often as New Zealand. Australia's extremely low percentage of draws, after leading on the first innings, contrasts the results for South Africa and could indicate a propensity to go for wins even if it risks losing. A fast scoring rate in the first innings would also allow time for both teams to force a win. Of the other teams, Sri Lanka and the West Indies have a lower percentage of draws than losses after leading on the first innings. By contrast, India, New Zealand and England had a high proportion of draws compared to losses after setting up a first innings lead. The mean scores for Teams 1 and 2 were 303 and 330 runs which resulted in an average lead for the team batting second of a considerable 27 runs. The respective mean scores for the home and away teams were 349 and 316 runs. This resulted in a substantial average lead of 33 runs for the home team.

Tables 4.11 and 4.12 compare the home and away performances, with the latter accounting for order of innings. For the period 1992-1997 the home team respectively won, drew and lost 39%, 32% and 29% of its matches. This demonstrates a marginal winning advantage for the home team. However, from Table 4.12, if we compare wins and losses only, a χ^2 test verifies that the home team did not win significantly more matches than it lost $\left(\chi_1^2 = 2.4,\ p = 0.122\right)$. When Team 1 represented the home team it displayed a marginal winning advantage over its opposition; i.e. 40% compared to 38%, but displayed a more pronounced losing tendency when it represented Team 2; i.e. 38% compared to 23%. Nonetheless, a χ^2 test for independence verifies that the order of innings was essentially independent of location during this period $\left(\chi_2^2 = 4.4,\ p = 0.108\right)$.

For the period 1997/98-2001 the home team won 46%, drew 26% and lost only 28% of its matches. This suggests a substantial overall HA for this study period. From Table 4.12, this is supported by a χ^2 test, which confirms that the home won significantly more matches than it lost $\left(\chi_1^2 = 6.5,\ p = 0.011\right)$. The home team displayed a very strong winning advantage over the away team when it represented Team 2; i.e. 61% compared to only 20%. Team 2 won 49% and lost only 26% of its matches overall. A χ^2 test for independence verifies that during this period winning was highly dependent upon the order of innings $\left(\chi_2^2 = 12.5,\ p = 0.002\right)$. The team batting second secured a significant winning advantage. This contradicts the established orthodoxy of electing to bat first when the captain wins the coin toss since teams have undoubtedly benefited from batting second.

Tables 4.13 and 4.14 focus on the home and away performances of individual teams, with the latter providing a statistical account of each team's home ground performances. A χ^2 test confirms that only Australia and India displayed a significant HA during the 1992-1997 period. Notably, India also displayed a strong tendency to draw matches when playing away from home during this period. For the ensuing period, only Australia and South Africa displayed a significant HA.

The box plots in Figure 4.5 compare the distribution of the first innings leads of Team 1 over the two study periods. The Anderson-Darling normality test confirms that the differentials are normally distributed. The standard deviation of the differentials for the two study periods are 174 and 182 runs respectively. An *F*-test confirmed that the variability of Team 1's first innings leads, over the two study periods, were not significantly different $\left(F_{1,\,326} = 0.92,\ p = 0.580\right)$. Note that the three outliers evident during the first study period arose when Team 1 amassed a score in excess of 600 runs and dismissed its opposition for a score close to 200 runs. In two of these instances, Australia was opposed to England in the same Test series.

Table 4.15 provides a summary of the teams' first innings batting and bowling performances. The differentials in the last column provide a measure of the team's average first innings lead. For the period 1992-1997 the emerging dominance of Australia is in evidence with its lead, on average, being 23 runs better than the next best performed team. For the period 1997/98-2001 the findings underscore the dominance of Australia and South Africa and conversely, the weakness of Zimbabwe. Surprisingly, nearly 100 runs separated Australia and South Africa from the rest of the teams during this period.

Table 4.10. Test cricket results after a first innings lead had been established

Team	*Matches where leading*	*% matches leading*	*% wins after leading*	*% draws after leading*	*% losses after leading*
			Period 1992-1997		
Australia	36	62%	75%	14%	11%
England	18	32%	44%	50%	6%
India	19	61%	63%	32%	5%
New Zealand	17	44%	29%	41%	29%
Pakistan	20	50%	65%	15%	20%
South Africa	22	69%	59%	27%	14%
Sri Lanka	15	43%	40%	47%	13%
West Indies	21	53%	62%	33%	5%
Zimbabwe	8	36%	13%	63%	25%
			Period 1997/98-2001		
Australia	38	90%	76%	5%	19%
England	14	32%	43%	50%	7%
India	14	52%	43%	43%	14%
New Zealand	11	37%	64%	27%	9%
Pakistan	13	33%	54%	23%	23%
South Africa	27	71%	63%	30%	7%
Sri Lanka	15	58%	67%	13%	20%
West Indies	13	33%	62%	15%	23%
Zimbabwe	6	24%	17%	33%	50%

Table 4.11. Summary of matches won by the home team in Test cricket

Result	*1992-1997*	*1997/98-2001*
Win	69	70
Draw	56	38
Loss	52	43
Total	177	151

Table 4.12. Summary of home and away performance and the order of innings in Test cricket

	Matches won by the home team	*Matches drawn by the home team*	*Matches lost by the home team*	*Total*
Period 1992-1997				
Home team bats first	39	36	23	98
Home team bats second	30	20	29	79
Total	69	56	52	177
Period 1997/98-2001				
Home team bats first	24	23	28	75
Home team bats second	46	15	15	76
Total	70	38	43	151

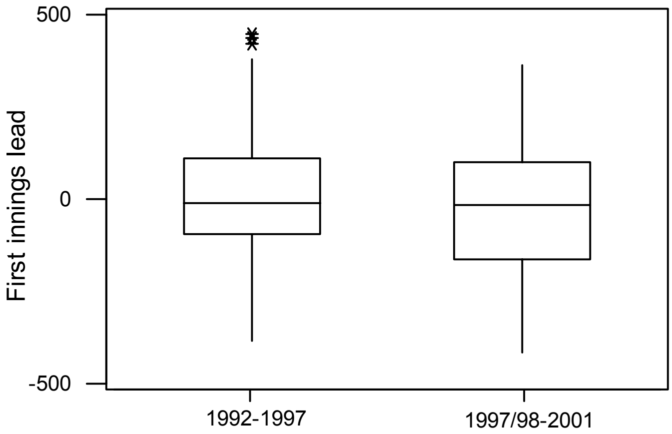

Figure 4.5. Box plot of the first innings lead for Team 1 in Test cricket

Table 4.13. Summary of individual Test cricket home results

Team	*Matches played*		*Wins*		*Draws*		*Losses*	
	Home	*Away*	*Home*	*Away*	*Home*	*Away*	*Home*	*Away*
Period 1992-1997								
Australia	26	32	15	14	4	9	7	9
England	35	22	9	4	12	7	14	11
India	15	16	12	1	1	10	2	5
New Zealand	21	18	4	3	7	6	10	9
Pakistan	13	27	6	13	4	6	3	8
South Africa	19	13	9	6	6	3	4	4
Sri Lanka	17	18	4	3	8	5	5	10
West Indies	19	21	9	8	7	6	3	7
Zimbabwe	12	10	1	0	7	4	4	6
Period 1997/98-2001								
Australia	22	20	17	12	4	2	1	6
England	24	20	9	5	5	6	10	9
India	14	13	6	2	5	3	3	8
New Zealand	14	16	4	4	5	6	5	6
Pakistan	16	14	4	4	6	2	6	8
South Africa	14	24	12	9	2	10	0	5
Sri Lanka	16	10	7	4	3	3	6	3
West Indies	18	22	9	2	4	2	5	18
Zimbabwe	13	12	2	1	4	4	7	7

Table 4.14. Comparison of individual home team performances in Test cricket

Team	*Home wins*	*Home draws*	*Home losses*	χ_2^2 *value*	*p-value*
Period 1992-1997					
Australia	15	4	7	7.5	0.024
England	9	12	14	1.1	0.581
India	12	1	2	14.8	0.001
New Zealand	4	7	10	2.6	0.276
Pakistan	6	4	3	1.1	0.584
South Africa	9	6	4	2.0	0.368
Sri Lanka	4	8	5	1.5	0.465
West Indies	9	7	3	2.9	0.229
Zimbabwe	1	7	4	4.5	0.105
Period 1997/98-2001					
Australia	17	4	1	19.7	<0.001
England	9	5	10	1.8	0.417
India	6	5	3	1.0	0.607
New Zealand	4	5	5	2.6	0.109
Pakistan	4	6	6	4.0	0.046
South Africa	12	2	0	7.1	0.008
Sri Lanka	7	3	6	1.6	0.444
West Indies	9	4	5	2.3	0.311
Zimbabwe	2	4	7	2.9	0.232

Table 4.15. Batting and bowling result summary for the first innings of a Test-match

Team	*Batting*		*Bowling*		*Differential*
	Mean	*Standard deviation*	*Mean*	*Standard deviation*	*(Bat-Bowl)*
Period 1992-1997					
Australia	356	148	275	102	81
England	311	120	370	138	-59
India	363	126	306	111	58
New Zealand	265	107	340	140	-74
Pakistan	314	116	298	118	15
South Africa	328	92	282	116	46
Sri Lanka	274	97	342	137	-67
West Indies	345	146	324	125	22
Zimbabwe	284	113	320	105	-36
Period 1997/98-2001					
Australia	382	116	242	100	140
England	275	116	339	137	-64
India	297	180	333	91	-36
New Zealand	319	120	329	158	-10
Pakistan	284	96	307	132	-23
South Africa	374	116	259	119	115
Sri Lanka	316	125	297	122	19
West Indies	237	84	294	108	-57
Zimbabwe	234	107	391	143	-157

4.3.2 Analysis of regional effects

Table 4.16 provides the summary statistics for each region. A one-way analysis of variance confirms that there is no significant difference in first innings scores across regions for the first period of study $\left(F_{172,\,4} = 0.58,\ p = 0.674\right)$. However, for the ensuing period, there is strong evidence to suggest that the first innings scores were significantly different $\left(F_{146,\,4} = 5.59,\ p < 0.001\right)$. The Tukey family error rate comparison test confirms that the innings scores produced in Region 3 were significantly higher than those estimated in Region 1 and the scores produced in Region 4 were significantly higher than those produced in both Regions 1 and 2. As was the case with ODI cricket, this is possibly due to some of the stronger batting teams such as Australia and Sri Lanka residing in these regions. Since most teams play a majority of their matches at home one would expect the home scores of the stronger batting teams to be relatively higher.

Table 4.17 summarises match results and uses the χ^2 test to compare outcomes, by region, across study periods. Note that since it can be assumed that intra-regional teams enjoy the same regional advantage intra-regional match results have been ignored. The subsequent analysis confirms that there was no regional effect during the first study period. For the second study period, however, the West Indies displayed a significant losing tendency whereas teams from the Australian region displayed a very strong winning advantage.

Table 4.16. Summary statistics of the first innings scores by region in Test cricket

	Region	*Mean*	*Standard deviation*
	Period 1992-1997		
1	England	345	146
2	West Indies	311	121
3	India, Pakistan and Sri Lanka	315	117
4	Australia and New Zealand	319	140
5	South Africa and Zimbabwe	310	103
	Period 1997/98-2001		
1	England	262	111
2	West Indies	273	108
3	India, Pakistan and Sri Lanka	331	150
4	Australia and New Zealand	360	113
5	South Africa and Zimbabwe	311	123

Table 4.17. Summary of match results by region in Test cricket

Region	*Number of wins*	*Number of draws*	*Number of losses*	χ_1^2 *value*	*p-value*
		Period 1992-1997			
1	13	19	25	3.8	0.150
2	17	13	10	1.9	0.397
3	30	28	24	0.7	0.711
4	32	22	31	2.1	0.343
5	15	20	17	0.7	0.694
		Period 1997/98-2001			
1	14	11	19	2.2	0.328
2	11	6	23	11.5	0.003
3	17	14	24	2.9	0.238
4	32	15	13	10.9	0.004
5	22	20	17	0.6	0.725

4.4 Conclusions

It was ascertained that teams in ODI cricket generally improved significantly in their run-scoring capacity over the ten season period of the study. This underscores the attitudinal change which accompanied ODI cricket in the mid-1990s whereby teams restructured their teams in order to expose more free-flowing batsmen higher in the batting order. This led to the achievement of generally higher scores. Up until the mid-1990s the composition of ODI cricket teams mirrored those of Test cricket. The emergence of Australia and South Africa as forces in ODI cricket was also evident. Zimbabwe clearly struggled over the period of the study. It was established that there was a significant overall HA effect at play throughout the ten years of the study. As a consequence, the home team was able to consistently score more runs and consistently win more matches than its opponents. In contrast, team quality factors appeared to become less pronounced over time. There was some evidence of a day/night effect in ODI cricket during the first study period, with Team 1 scoring significantly more runs than Team 2. It was also apparent that the variability of the scores in day/night matches increased markedly (in both innings) across study periods. There was also some evidence suggesting that there was a regional effect during the second period of the study, with the sub-continental and Australasian regions, in particular, displaying a capacity to produce generally higher scores. This possibly arose because the stronger batting nations resided in these regions. There was also some evidence to suggest that during the second study period teams in the Australasian region displayed a winning advantage.

In Test cricket, both Australia and South Africa emerged as the dominant nations. Australia, in particular, was a prevailing force in both and Test and ODI cricket. Interestingly, Australia played in relatively few draws over the study period, which underscores its attacking style of play. Not unexpectedly, the setting up of a first innings lead provided teams with a strong winning advantage. The home team was more effective than its opponents in setting up a first innings lead and as a result enjoyed a strong winning advantage. Only India displayed a significant HA during the first study period whereas both Australia and South Africa enjoyed a significant HA during the ensuing period. There was some evidence of a regional effect in Test cricket during the second study period, with the sub-continental and Australasian regions, in particular, displaying a tendency to score more heavily than its opponents. However, teams from the Australasian region were more effective at converting this advantage into a winning result. Although summary statistics provide an indication of relative team strength, they are confounded by effects such as HA and the order of innings. This can compromise their efficacy. To compound the problem, the ODI and Test cricket calendars are not balanced (since some teams play more series against stronger opponents) and because in the majority of ODI competition and Test series one team has a HA. It follows that a proper modelling of scores needs to be undertaken to gauge the extent to which effects such as HA and the order of innings impact on the variability of match outcomes, innings scores and runs margins.

CHAPTER 5
MODELLING DOMESTIC CRICKET

5.1 Introduction

The exploratory analysis of performance factors in domestic cricket detailed in Chapter 2 provides an overall measure of how match outcomes have been influenced by pre-determined effects but does not accurately gauge the degree of influence. In modelling two nationally-based cricket competitions, namely the Pura Cup in Australia and the Frizzell County Championship in England, binomial and multinomial logistic models will be employed (with the use of the logit link function) to gauge the extent to which the observed variation in match outcomes is critically affected by first innings performance measures such as the establishment of a first innings lead, HA and winning the coin toss. Logistic regression techniques are used because the match outcome response variable for either competition is categorical.

In analysing the Pura Cup, initially, a binary logistic model is fitted to the two possible match outcomes of a win and a loss. Secondly, a multinomial (ordinal) logistic model is fitted to the point-margins of $6, 4, 2, -2, -4$ and -6. In analysing the County Championship a multinomial (ordinal) logistic regression is fitted to the three possible match outcomes of win, tie and loss. In both competitions the observed variation in the match outcomes for Team 1 are modelled as a function of the (signed) first innings lead; a common home team advantage and the result of the coin toss. In conducting the regression analyses it is assumed that the logit link function and the co-variates are linearly related. A multiple linear regression model is also fitted to the first innings margins to quantify the extent to which the observed variation in the margins can be attributed to the establishment of a first innings lead; playing at home and winning the coin toss.

5.2 Modelling the Pura Cup competition

5.2.1 Fitting a binary logistic model to the match outcomes

If the conditional probability of a win or loss for Team 1 is denoted by γ, the outcome of a match is modelled as

$$\ln\left(\frac{\gamma}{1-\gamma}\right) = \alpha_0 + \alpha_1 h + \alpha_2 x + \alpha_3 t + \alpha_4 b \tag{5.1}$$

where $h = 1$ or 0 indicates whether or not Team 1 was the home team; x is the (signed) first innings lead of Team 1; $t = 1$ or 0 indicates whether or not Team 1 won the coin toss and $b = 1$ or 0 signifies whether or not Team 1 trailed on the first innings. Note that the latter variable is an important indicator since winning a match on points in the Pura Cup is not commensurate with the size of a first innings lead. For example, it is far more difficult for a team to win a match on points after trailing by one run than it is to win after leading by one run even though the differential between the two scenarios is a marginal two runs. This anomaly (or discontinuity) arises at $x = 0$ because if a team leads on the first innings it has two winning options open to it: it can either draw a match (then win on points) or it can win outright and attract the maximum point allocation. If a team trails on the first innings, however, it has only one winning option open to it: an outright result. This has proven to be a perennially difficult task.

The respective parameter estimates for model (5.1) are provided in Table 5.1. Application of the Pearson and deviance goodness-of-fit tests suggests model (5.1) provides an adequate fit of the data. For model (5.1), the HA effect and the establishment of a first innings lead were both very strong predictors of a winning outcome. The significance of the negative trail effect term suggests that teams trailing on the first innings, not surprisingly, showed a strong losing tendency. The odds ratio of 2.87 for the HA effect indicates that the odds of winning for the away team were, on average, 2.87 times the odds of winning for the home team. There was no evidence to suggest that teams gained a winning advantage by winning the coin toss.

Assuming that Team 1 is the home team, by transposing model (5.1), the probability that the home team wins on points is given as

$$\Pr\left(\text{Win}\,\middle|\,h,x,t,b\right)=\frac{\exp\left(\alpha_0+\alpha_1 h+\alpha_2 x+\alpha_3 t+\alpha_4 b\right)}{1+\exp\left(\alpha_0+\alpha_1 h+\alpha_2 x+\alpha_3 t+\alpha_4 b\right)}$$

Assuming that Team 1 wins the coin toss and establishes a first innings lead of x runs, the probability that the home team wins on points is given as

$$\Pr\left(\text{Win}\,\middle|\,h=1,x,t=1,b=0\right)=\frac{\exp\left(\alpha_0+\alpha_1+\alpha_2 x+\alpha_3\right)}{1+\exp\left(\alpha_0+\alpha_1+\alpha_2 x+\alpha_3\right)}$$

Assuming that Team 1 wins the coin toss and trails on the first innings by x runs, the probability that the home team wins on points is given as

$$\Pr\left(\text{Win}\,\middle|\,h=1,x,t=1,b=1\right)=\frac{\exp\left(\alpha_0+\alpha_1-\alpha_2 x+\alpha_3+\alpha_4\right)}{1+\exp\left(\alpha_0+\alpha_1-\alpha_2 x+\alpha_3+\alpha_4\right)}$$

If Team 1 is the away team, the subsequent probabilities of the away team winning, after having won the coin toss and leading and trailing on the first innings, are respectively defined as

$$\Pr\left(\text{Win}\,\middle|\,h=0,x,t=1,b=0\right)=\frac{\exp\left(\alpha_0+\alpha_2 x+\alpha_3\right)}{1+\exp\left(\alpha_0+\alpha_2 x+\alpha_3\right)}$$

$$\Pr\left(\text{Win}\,\middle|\,h=0,x,t=1,b=1\right)=\frac{\exp\left(\alpha_0-\alpha_2 x+\alpha_3+\alpha_4\right)}{1+\exp\left(\alpha_0-\alpha_2 x+\alpha_3+\alpha_4\right)}$$

To gauge the extent of the HA effect and the effect associated with the (signed) first innings lead we can assume that two equally matched teams are level on runs at the completion of the first innings. Using the parameter estimates provided in Table 5.1 and assuming that Team 1 wins the coin toss, the probabilities that the home team wins and loses on points after establishing a first innings lead of one run are estimated to be 0.79 and 0.21 respectively. Whereas the probabilities that the home team wins and loses after trailing by one run on the first innings are estimated to be 0.41 and 0.59 respectively. Conversely, the probabilities of the away team winning and losing on points after having won the coin toss and leading by one run on the first innings are estimated to be 0.57 and 0.43 respectively. The probabilities that the away team wins and loses after having won the coin toss and trailing by one run at the completion of the first innings are estimated to be 0.19 and 0.81 respectively. The significance of the trail effect cannot be overstated: a differential of only two runs has led to a 93% average increase in the probability of the home team winning and a considerable 200% increase in the estimated probability for the away team winning. These results highlight the highly significant advantage attributed to both the HA effect and the establishment of a first innings lead. Figure 5.1 provides a plot displaying the estimated probability of winning a Pura Cup match on points for the home and away teams for (signed) first innings leads up to 200 runs. The discontinuity at $x = 0$ highlights the clear winning advantage for the team leading on the first innings for leads of any magnitude.

To test the efficacy of model (5.1) the matches can be divided into a training set and a test set. The parameter estimates generated for the training set can subsequently be used to predict the match outcomes for the test set. Assume that the training and test sets are represented by the first and second 161 matches respectively. Application of the model to both sets generates successful classification rates of 92% and 94% respectively. Note that if the parameter estimates in Table 5.1 are applied to all 322 matches the successful classification rate is 94%. The consistency of these results suggests that there is no evidence of any over-fitting and so model (5.1) is a reliable predictor of a winning match outcome. Note that it is not surprising that the classification rate is so high for the Pura Cup because the probability of winning is not continuous across the innings boundaries. The leading team is thus provided with a significant winning advantage. As a consequence, it would be expected that predictions for match outcomes are not highly variable.

Table 5.1. Parameter estimates for the fitting of a binary logistic model to the outcomes of the Pura Cup competition for the period 1990-2000

Parameter	*Term*	*Coefficient*	*Standard error*	*p-value*	*Odds ratio*
α_0	Intercept	-0.2776	0.4070	0.495	
α_1	Home	1.053	0.3466	0.002	2.87
α_2	Lead	0.009466	0.002463	<0.001	1.01
α_3	Coin toss	0.5570	0.3422	0.104	1.75
α_4	Trail	-1.7065	0.5162	0.001	0.18

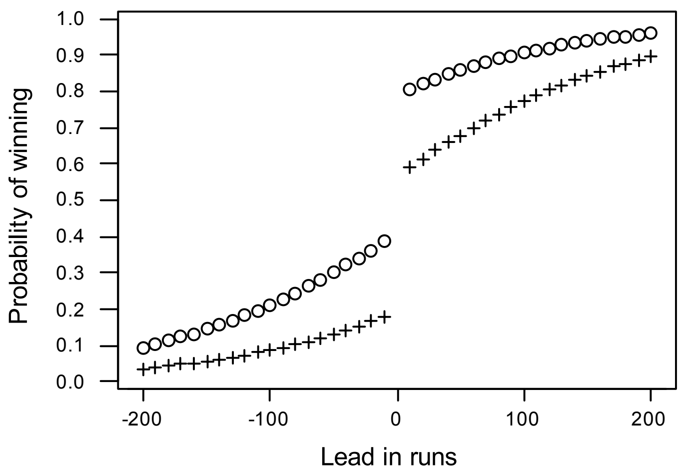

Figure 5.1. The estimated probability of winning a Pura Cup match on points against an equal opponent for the home (○) and away (+) teams for (signed) first innings leads up to 200 runs for the period 1990-2000

5.2.2 Fitting an multinomial (ordinal) logistic model to the point-margins

In analysing the range of possible point-margins in the Pura Cup the application of a multinomial (ordinal) logistic model makes sense because of the implicit order evident in the margins. If the cumulative conditional probability of achieving a points-margin of $6,\ 4,\ 2,\ -2,\ -4$ or -6 is denoted by γ_w for Team 1, the outcome of a match is modelled as

$$\ln\left(\frac{\gamma_w}{1-\gamma_w}\right) = \beta_{0w} + \beta_1 h + \beta_2 x + \beta_3 t \tag{5.2}$$

where $w = 0, 1, 2, 3, 4$ for the respective cumulative probabilities of acquiring a points margin of $6,\ 4,\ 2,\ -2$ and -4. $h = 1$ or 0 indicates whether or not Team 1 was the home team; x is the (signed) first innings lead of Team 1; $t = 1$ or 0 indicates whether or not Team 1 won the coin toss. It is not necessary to include the trail effect variable, as was the case with model (5.1), because the response variable has been defined so that all winning scenarios are distinguishable. For example, a margin of six points suggests that the winning team secured an outright result after leading on the first innings, whereas a margin of four points suggests that the winning team won outright after trailing on the first innings.

The respective parameter estimates for model (5.2) is provided in Table 5.2. Application of the Pearson and deviance goodness-of-fit tests suggests model (5.2) provides an adequate fit of the data.

Table 5.2. Parameter estimates for the prediction of match outcomes for the team batting first in the Pura Cup for the period 1990-2000

Parameter	*Term*	*Coefficient*	*Standard error*	*p-value*	*Odds ratio*
β_{00}	Intercept (6)	-2.3921	0.2598	<0.001	
β_{01}	Intercept (6, 4)	-2.0357	0.2503	<0.001	
β_{02}	Intercept (6, 4, 2)	-0.7791	0.2267	0.001	
β_{03}	Intercept (6, 4, 2, -2)	0.2668	0.2237	0.233	
β_{04}	Intercept (6, 4, 2, -2, -4)	0.8267	0.2297	<0.001	
β_1	Home	0.7944	0.2217	<0.001	2.21
β_2	Lead	0.0111696	0.0009738	<0.001	1.01
β_3	Coin toss	0.2757	0.2218	0.214	1.35

For model (5.2), both the HA effect and the establishment of a first innings lead were very strong predictors of a winning points margin. The odds ratio of 2.21 for the HA effect suggests that the odds of the away team winning were, on average, 2.21 times the odds of the home team winning. There is no evidence to suggest that teams gained a significant points advantage by winning the coin toss. If Team 1 is the home team, by transposing (5.2), the probability that the home team wins outright after winning the coin toss and leading by x runs on the first innings (and thus winning six points to nil) is given as

$$\Pr\left(\text{Win}\,|h=1,x,t=1\right)=\frac{\exp\left(\beta_{00}+\beta_1+\beta_2x+\beta_3\right)}{1+\exp\left(\beta_{00}+\beta_1+\beta_2x+\beta_3\right)}$$

The probability that the home team wins outright after winning the coin toss and trailing by x runs on the first innings (and thus winning six points to two) is given as

$$\Pr\left(\text{Win}\,|h=1,x,t=1\right)=\frac{\exp\left(\beta_{01}+\beta_1-\beta_2x+\beta_3\right)}{1+\exp\left(\beta_{01}+\beta_1-\beta_2x+\beta_3\right)}-\frac{\exp\left(\beta_{00}+\beta_1-\beta_2x+\beta_3\right)}{1+\exp\left(\beta_{00}+\beta_1-\beta_2x+\beta_3\right)}$$

The probability that the home team wins after having won the coin toss and leading by x runs on the first innings and then drawing the match (and thus winning two points to nil) is given as

$$\Pr\left(\text{Win}\left|h=1,x,t=1\right.\right)=\frac{\exp\left(\beta_{02}+\beta_1+\beta_2x+\beta_3\right)}{1+\exp\left(\beta_{02}+\beta_1+\beta_2x+\beta_3\right)}-\frac{\exp\left(\beta_{01}+\beta_1+\beta_2x+\beta_3\right)}{1+\exp\left(\beta_{01}+\beta_1+\beta_2x+\beta_3\right)}$$

The probability that the home team loses after having won the coin toss and trailing by x runs on the first innings and then drawing the match (and thus losing nil points to two) is given as

$$\Pr\left(\text{Loss}\left|h=1,x,t=1\right.\right)=\frac{\exp\left(\beta_{03}+\beta_1-\beta_2x+\beta_3\right)}{1+\exp\left(\beta_{03}+\beta_1-\beta_2x+\beta_3\right)}-\frac{\exp\left(\beta_{02}+\beta_1-\beta_2x+\beta_3\right)}{1+\exp\left(\beta_{02}+\beta_1-\beta_2x+\beta_3\right)}$$

The probability that the home team loses outright after winning the coin toss and leading by x runs on the first innings (and thus losing two points to six) is given as

$$\Pr\left(\text{Loss}\left|h=1,x,t=1\right.\right)=\frac{\exp\left(\beta_{04}+\beta_1+\beta_2x+\beta_3\right)}{1+\exp\left(\beta_{04}+\beta_1+\beta_2x+\beta_3\right)}-\frac{\exp\left(\beta_{03}+\beta_1+\beta_2x+\beta_3\right)}{1+\exp\left(\beta_{03}+\beta_1+\beta_2x+\beta_3\right)}$$

The probability that the home team loses outright after winning the coin toss and trailing by x runs on the first innings (and thus losing nil points to six) is given as

$$\Pr\left(\text{Loss}\left|h=1,x,t=1\right.\right)=1-\frac{\exp\left(\beta_{04}+\beta_1-\beta_2x+\beta_3\right)}{1+\exp\left(\beta_{04}+\beta_1-\beta_2x+\beta_3\right)}$$

Using the parameter estimates presented in Table 5.2 and assuming that Team 1 wins the coin toss, each of the home team winning and losing scenarios [as provided by model (5.2)] are outlined in Table 5.3.

If Team 1 is the away team, the probability the away team wins outright after winning the coin toss and leading by x runs on the first innings (and thus winning six points to nil) is given as

$$\Pr\left(\text{Win}\left|h=0,x,t=1\right.\right)=\frac{\exp\left(\beta_{00}+\beta_2x+\beta_3\right)}{1+\exp\left(\beta_{00}+\beta_2x+\beta_3\right)}$$

The probability that the away team wins outright after winning the coin toss and trailing by x runs on the first innings (and thus winning six points to two) is given as

$$\Pr\left(\text{Win}\left|h=0,x,t=1\right.\right)=\frac{\exp\left(\beta_{01}-\beta_2x+\beta_3\right)}{1+\exp\left(\beta_{01}-\beta_2x+\beta_3\right)}-\frac{\exp\left(\beta_{00}-\beta_2x+\beta_3\right)}{1+\exp\left(\beta_{00}-\beta_2x+\beta_3\right)}$$

The probability that the away team wins after having lost the coin toss and leading by x runs on the first innings and then drawing the match (and thus winning two points to nil) is given as

$$\Pr\left(\text{Win}\left|h=0,x,t=1\right.\right)=\frac{\exp\left(\beta_{02}+\beta_2x+\beta_3\right)}{1+\exp\left(\beta_{02}+\beta_2x+\beta_3\right)}-\frac{\exp\left(\beta_{01}+\beta_2x+\beta_3\right)}{1+\exp\left(\beta_{01}+\beta_2x+\beta_3\right)}$$

The probability that the away team loses after having won the coin toss and trailing by x runs on the first innings and then drawing the match (and thus losing nil points to two) is given as

$$\Pr\left(\text{Loss}\left|h=0,x,t=0\right.\right)=\frac{\exp\left(\beta_{03}-\beta_2x+\beta_3\right)}{1+\exp\left(\beta_{03}-\beta_2x+\beta_3\right)}-\frac{\exp\left(\beta_{02}-\beta_2x+\beta_3\right)}{1+\exp\left(\beta_{02}-\beta_2x+\beta_3\right)}$$

The probability that the away team loses outright after winning the coin toss and leading by x runs on the first innings (and thus losing two points to six) is given as

$$\Pr\left(\text{Loss}\left|h=0,x,t=1\right.\right)=\frac{\exp\left(\beta_{04}+\beta_2x+\beta_3\right)}{1+\exp\left(\beta_{04}+\beta_2x+\beta_3\right)}-\frac{\exp\left(\beta_{03}+\beta_2x+\beta_3\right)}{1+\exp\left(\beta_{03}+\beta_2x+\beta_3\right)}$$

The probability that the away team loses outright after winning the coin toss and trailing by x runs on the first innings (and thus losing nil points to six) is given as

$$\Pr\left(\text{Loss}\left|h=0,x,t=1\right.\right)=1-\frac{\exp\left(\beta_{04}-\beta_2x+\beta_3\right)}{1+\exp\left(\beta_{04}-\beta_2x+\beta_3\right)}$$

Using the parameter estimates presented in Table 5.2 and assuming that Team 1 wins the coin toss, each of the away team winning and losing scenarios [as provided by model (5.2)] are outlined in Table 5.4. Comparison of Tables 5.3 and 5.4 highlights the significant advantage enjoyed by the home team, especially when teams faced similar circumstances. For example the home team was, on average, 91% more likely than its opposition to win outright (and thus obtain the maximum point allocation). Figure 5.2 displays a plot of the average probabilities of obtaining an outright result for the home and away teams for (signed) first innings leads up to 200 runs. A discontinuity occurs at $x = 0$ because the trailing team, in effect, has to generate an eight-point turnaround in order to achieve an outright result, whereas for the leading team to win outright it needs to only procure a further four points. The former situation has consistently proven to be a difficult task. Figure 5.3 displays a plot of the average probabilities of winning on points after a match has been drawn for the home and away teams for first innings leads up to 200 runs. The plot suggests that for average leads of the order $x \geq 66$ runs the probability of the away team winning exceeds the probability of the home team winning. This apparent anomaly occurs because with average leads of this magnitude the home team, with its strong winning advantage, was expected to secure an outright result rather than play out a draw. Note that average leads of the order $x = 30$ and $x = 101$ runs for the home and away teams respectively would have maximised their chances of at least winning on points after a draw ensued. This further emphasises the advantage of playing at home. To examine this situation in more detail Figures 5.4 and 5.5 display plots of the average probability of winning against an equal opponent after the respective home and away teams have established a first innings lead; i.e. by either winning the match outright or winning on points when a match is drawn. These plots suggest that for average leads of the order $x \in (0, 44]$ the home team was more likely to win on points after drawing a match rather than secure an outright result otherwise it was more likely to win outright. Whereas for average leads of the order $x \in (0, 115]$ the away team was more likely to win on points after drawing a match rather than secure an outright result, otherwise it was more likely to win outright. This provides further evidence that the advantage exercised by the home team in the Pura Cup competition has been a substantial one.

Table 5.3. Home team point allocation and probability estimates for each of the winning and losing scenarios after the completion of the first innings in the Pura Cup competition for the period 1990-2000

Scenario	*h*	*x*	*t*	*Points*	*Estimated probability*
Outright win after leading by one run	1	1	1	6-0	0.21
Outright win after trailing by one run	1	-1	1	6-2	0.06
Drawn result after leading by one run	1	1	1	2-0	0.30
Drawn result after trailing by one run	1	-1	1	0-2	0.22
Outright loss after leading by one run	1	1	1	2-6	0.08
Outright loss after trailing by one run	1	-1	1	0-6	0.13
				Total	1.00

Table 5.4. Away team point allocation and probability estimates for each of the winning and losing scenarios after the completion of the first innings in the Pura Cup competition for the period 1990-2000

Scenario	*h*	*x*	*t*	*Points*	*Estimated probability*
Outright win after leading by one run	0	1	1	6-0	0.11
Outright win after trailing by one run	0	-1	1	6-2	0.04
Drawn result after leading by one run	0	1	1	2-0	0.23
Drawn result after trailing by one run	0	-1	1	0-2	0.26
Outright loss after leading by one run	0	1	1	2-6	0.12
Outright loss after trailing by one run	0	-1	1	0-6	0.25
				Total	1.01

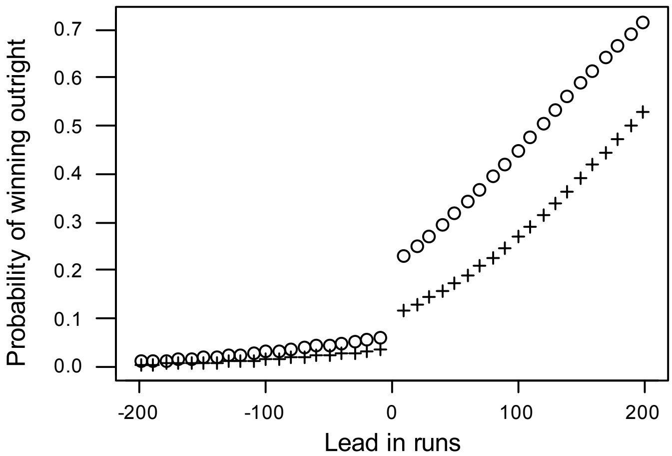

Figure 5.2. The estimated probability of winning outright in a Pura Cup match against an equal opponent for the home (○) and away (+) teams for (signed) first innings leads up to 200 runs for the period 1990-2000

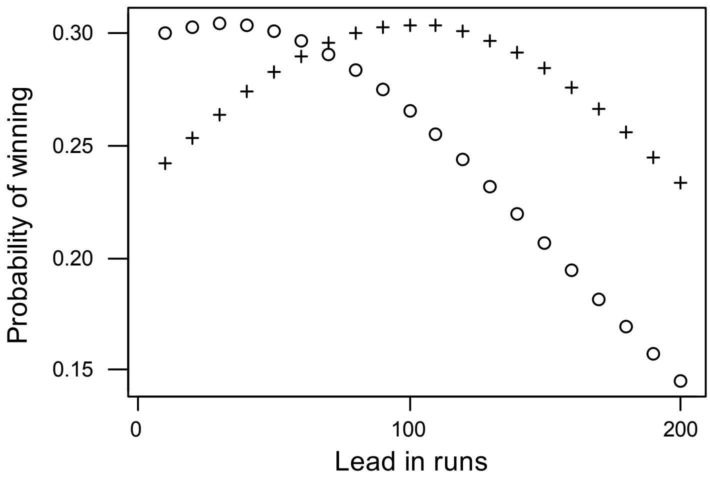

Figure 5.3. The estimated probability of winning on points against an equal opponent after a match has been drawn in a Pura Cup match for the home (○) and away (+) teams for first innings leads up to 200 runs for the period 1990-2000

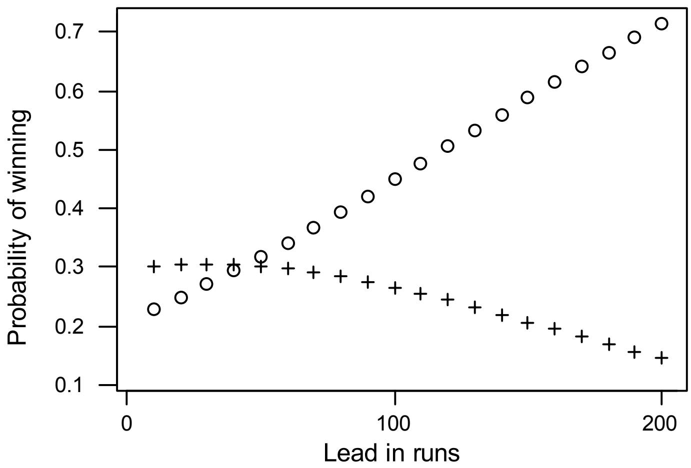

Figure 5.4. The estimated probability of winning outright (□) and on points against an equal opponent after a match has been drawn (+) in a Pura Cup match for the home team for first innings leads up to 200 runs for the period 1990-2000

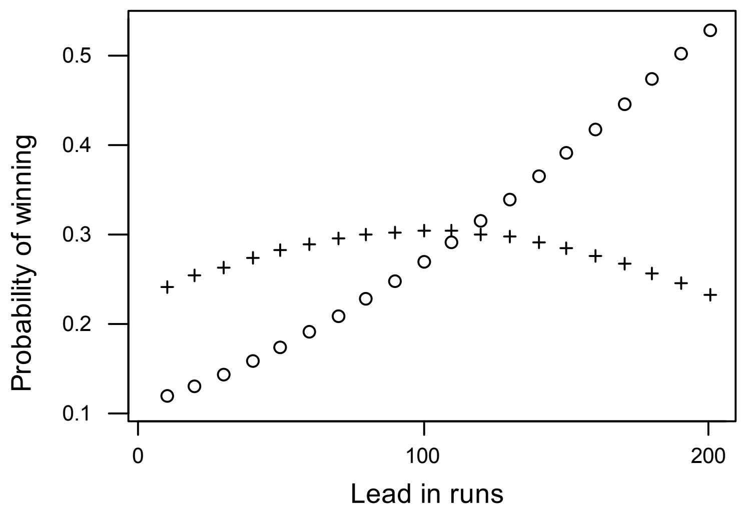

Figure 5.5. The estimated probability of winning outright (□) and on points against an equal opponent after a match has been drawn (+) in a Pura Cup match for the away team for first innings leads up to 200 runs for the period 1990-2000

5.2.3 Fitting a linear model to the first innings run differentials

In modelling the first innings of the Pura Cup competition it is assumed that the principal team objective is to optimise performance levels in order to establish a substantial first innings lead. This will not only ensure a win if a drawn result ensues but sets a team up for an outright result and the maximum allocation of points. Thus, the first innings performance provides a reliable measure of a team's relative strength. Penultimate and final innings performances are not explicitly considered because teams tend to adopt a more calculated approach and accordingly adapt their style of play as a strategic response to what has occurred in the first innings. As a consequence, a team's second innings performances are more reactionary and likely to lack the consistent approach that is conspicuous in the first innings. In summary, second innings performances are not generally commensurate with first innings performances because (a) the game situation and (b) the state of a deteriorating wicket usually require a more cautious team approach.

To quantify the advantage (in runs) attributed to factors such as the establishment of a first innings lead, playing at home and winning the coin toss, the first innings margin can be modelled as

$$w_{ij} = u_i - u_j + h + f + t + \varepsilon_{ij} \tag{5.3}$$

where the indices $i, j = 1, \ldots, 6$ represent the six Australian states and the response variable w_{ij} denotes the expected first innings margin. The parameter u_i is a measure of the relative ability of team i; the common home parameter is h if team i is the home team and is $-h$ otherwise; the batting order parameter is f if team i batted first and is $-f$ otherwise; the coin toss parameter is t if team i won the coin toss and is $-t$ otherwise. ε_{ij} is a zero-mean random error with constant variance. The error term is included because the first innings margin separating two teams will not necessarily be repeated each time they meet under the same circumstances. The parameters are each plus and minus because the response variable represents a dual positive and negative result. For example, a 45 runs first innings lead for the home team is concurrently a 45 run deficit for the away team. Using a design matrix of indicator variables, a multiple linear regression model is fitted to the margins. For convenience $\sum_{i=1}^{6} u_i = 600$ to ensure that the average team rating is 100. For each of the models the Anderson-Darling test for normality verifies that the residuals are normally distributed. The resultant least squares parameter estimates are provided in Table 5.5. These in essence represent team ratings relative to the average team rating of 100. The findings confirm the long-term dominance of Western Australia and Queensland over the period of the study. The least squares parameter estimates for h, f and t were 33 runs ($p < 0.01$), 13 runs ($p = 0.134$) and 24 runs ($p = 0.006$) respectively. Clearly, the home team and the team winning the coin toss enjoyed a significant first innings runs advantage. Tables 5.1 and 5.2 suggest that the home team was able to capitalise on its advantage and display a strong winning tendency. However, this was not the case with the team winning the coin toss. There is a strong positive correlation between the first innings team ratings and the overall number of wins and the accumulated points (by team) of 0.93 ($p = 0.003$) and 0.90 ($p = 0.014$) respectively. This suggests that first innings strength in the Pura Cup is a strong indicator of a team's overall strength.

Table 5.5. Least squares parameter estimates for the fitting of the first innings margins of the Pura Cup competition for the period 1990-2000

Team	*Rating*
New South Wales	85
Queensland	127
South Australia	61
Tasmania	89
Victoria	105
Western Australia	134

The ratings provided in Table 5.5 can be used to estimate the probability that a team is able to defeat its opponent in a particular Pura Cup match. For example, suppose that Victoria plays New South Wales at home with Victoria winning the coin toss and electing to bat first. Victoria's expected first innings lead is $105 - 85 + 33 + 24 + 13 = 90$ runs. From model (5.1) the probabilities that Victoria wins and loses on points are estimated to be 0.90 and 0.10 respectively. On the other hand, if New South Wales had won the coin toss and elected to bat first it is expected to trail on the first innings by 90 runs. From model (5.1) its respective probabilities of winning and losing are 0.06 and 0.94. From model (5.2), the probability that Victoria is able to achieve an outright result after leading by 90 runs on the first innings is estimated to be a solid 0.42. Whereas the probability that New South Wales is able to achieve an outright result after trailing by 90 runs on the first innings is estimated to be a negligible 0.03. However, the probabilities that Victoria wins and loses on points after playing out a draw are 0.28 and 0.72 respectively. The losing probability is relatively high because with the lead in excess of 78 runs, Victoria, being the home team, is expected to win outright rather than play out a draw.

5.3 Modelling the Frizzell County Championship

5.3.1 Fitting a multinomial (ordinal) logistic model to the match outcomes

In analysing the range of possible match outcomes in the County Championship the application of a multinomial (ordinal) logistic model makes sense because of the implicit order evident in the possible outcomes of a win, tie and loss. If the cumulative conditional probability of achieving a result of a win, tie or loss is denoted by γ_w for Team 1, the outcome of a match is modelled as

$$\ln\left(\frac{\gamma_w}{1-\gamma_w}\right) = \beta_{0w} + \beta_1 h + \beta_2 x + \beta_3 t + \beta_4 p \tag{5.4}$$

where $w = 0 \text{ or } 1$ for the respective cumulative probabilities of acquiring a win or tie. $h = 1 \text{ or } 0$ indicates whether or not Team 1 was the home team; x is the (signed) first innings lead of Team 1; $t = 1 \text{ or } 0$ signifies whether or not Team 1 won the coin toss and p is the number of bonus points received by Team 1.

The respective parameter estimates for model (5.4) is provided in Table 5.6. Application of the Pearson and deviance goodness-of-fit tests suggests model 5.4 provides an adequate fit of the data. The establishment of a first innings lead only was a very strong predictor of a winning outcome. There is no evidence to suggest that teams were advantaged by playing at home, winning the coin toss or procuring first innings bonus points. In contrast, the HA effect was significant in the Pura Cup competition. One reason why the HA effect may not be prevalent in the County Championship is that teams do not regularly play on a home ground per se. Matches are often played at neutral locations even though one of the teams is the designated home team. Teams may attract a supportive home crowd but familiarity with conditions and travel issues may not uniquely advantage one of the teams. In contrast, teams in the Pura Cup regularly play at designated home grounds so the home team could benefit from both regular home crowd support and exposure to familiar local conditions.

It is interesting to observe that in the County Championship the accumulation of first innings bonus points was not a strong predictor of a winning match outcome, regardless of the number of bonus points awarded. This suggests that any advantage gained by earning first innings bonus points was outweighed by the additional 14 points awarded for securing an outright result. To investigate this further assume that the additional points earned by winning outright is one point less; i.e. 13 points. A multinomial (ordinal) logistic regression analysis confirms that the awarding of bonus points under this system would significantly contribute to a winning outcome. This suggests that the points-system adopted for the County Championship has been carefully engineered to encourage teams to play for outright results rather than rely on a first innings points-advantage to secure a win (on points) if a match is drawn. In the Pura Cup competition, first innings points are only awarded to the team that leads on the first innings. However, in contrast to the County Championship, this grants the leading team with a significant advantage over its opponent since it is provided with two winning options; i.e. (a) a drawn result will secure a two points to nil victory and (b) an outright result will secure a six points to nil victory. In contrast, the trailing team must win outright in order to secure a points victory.

From model (5.4) the respective probability that Team 1 wins, ties and loses on points in a County Championship match are calculated to be

$$\Pr\left(\text{Win}\,\middle|\,h,x,t,p\right)=\frac{\exp\left(\beta_{00}+\beta_1 h+\beta_2 x+\beta_3 t+\beta_4 p\right)}{1+\exp\left(\beta_{00}+\beta_1 h+\beta_2 x+\beta_3 t+\beta_4 p\right)}$$

$$\Pr\left(\text{Tie}\,\middle|\,h,x,t,p\right)=\frac{\exp\left(\beta_{01}+\beta_1 h+\beta_2 x+\beta_3 t+\beta_4 p\right)}{1+\exp\left(\beta_{01}+\beta_1 h+\beta_2 x+\beta_3 t+\beta_4 p\right)}-\frac{\exp\left(\beta_{00}+\beta_1 h+\beta_2 x+\beta_3 t+\beta_4 p\right)}{1+\exp\left(\beta_{00}+\beta_1 h+\beta_2 x+\beta_3 t+\beta_4 p\right)}$$

$$\Pr\left(\text{Loss}\,\middle|\,h,x,t,p\right)=1-\frac{\exp\left(\beta_{01}+\beta_1 h+\beta_2 x+\beta_3 t+\beta_4 p\right)}{1+\exp\left(\beta_{01}+\beta_1 h+\beta_2 x+\beta_3 t+\beta_4 p\right)}$$

If two equally matched teams are opposed to each other we can assume that the first innings lead is zero and points are tied on 4 points. If Team 1 represents the home team and assuming it wins the coin toss, its respective probability of a win, tie and loss are estimated to be 0.44, 0.09 and 0.47. Conversely, assuming the away team wins the coin toss its probability of a win; tie and loss are respectively estimated to be 0.40, 0.09 and 0.51. With all things being equal at the completion of the first innings, the home team enjoyed a marginal winning advantage over the away team.

To test the efficacy of model (5.4) the parameter estimates can be generated for the first 105 matches and tested on the remaining 104 matches. The subsequent successful classification rates for both sets are 77% and 74% respectively. When the parameter estimates in Table 5.6 are used for the entire data set the successful classification rate is 77%. The consistency of the results suggests that there is no evidence of any over-fitting and thus model (5.4) is a reliable predictor of a winning match outcome. The classification rates are notably lower than those for the Pura Cup competition. This disparity most likely arises because in the County Championship the probability of winning is continuous across the innings boundaries. Under these circumstances it is not as difficult for the trailing team to secure a win on points as it is in the Pura Cup. As a result, this makes the prediction of match outcomes more highly variable.

Table 5.6. Parameter estimates for the prediction of match outcomes for the team batting first in the Frizzell County Championship for the period 2000-2002

Parameter	*Term*	*Coefficient*	*Standard error*	*p-value*	*Odds ratio*
β_{00}	Intercept (Win)	-0.9512	0.5214	0.0709	
β_{01}	Intercept (Win and tie))	-0.5601	0.5186	0.280	
β_1	Home	0.1343	0.3299	0.684	1.14
β_2	Lead	0.009658	0.3979	<0.001	1.01
β_3	Coin toss	0.0702	0.001397	0.856	1.07
β_4	Bonus points	0.11248	0.09265	0.225	1.12

5.3.2 Quantifying first innings performance factors

To quantify the advantage (in runs) attributed to first innings factors such as the establishment of a first innings lead, playing at home and winning the coin toss, the first innings margin between team i and team j can be modelled as

$$w_{ij} = u_i - u_j + h + f + t + \varepsilon_{ij} \tag{5.5}$$

where the indices $i, j = 1, \ldots, 14$ represent the 14 Division 1 Counties and the response variable w_{ij} denotes the expected first innings margin. The parameter u_i is a measure of the relative ability of team i; the common home parameter is h if team i is the home team and is $-h$ otherwise; the batting order parameter is f if team i batted first and is $-f$ otherwise; the coin toss parameter is t if team i won the coin toss and is $-t$ otherwise. ε_{ij} is a zero-mean random error with constant variance. ε_{ij} is a zero-mean random error with constant variance. Using a design matrix of indicator variables, a multiple linear regression model is fitted to the margins. For convenience $\sum_{i=1}^{14} u_i = 1400$ to ensure that the average team rating is 100. For each of the models the Anderson-Darling test for normality verifies that the residuals are normally distributed. The resultant parameter estimates are provided in Table 5.7. The findings highlight the vast team disparities over the period of the study. The first innings dominance of the top four teams is highly significant, with these teams, on average, rated 58 better than average. In contrast, the bottom four teams are rated, on average, a substantial 76 runs below par. The least squares parameter estimates for h, f and t were 23 runs ($p = 0.040$), 15 runs ($p = 0.278$) and 11 runs ($p = 0.423$) respectively. The home team enjoyed a significant first innings runs advantage but was not advantaged by batting first or winning the coin toss. This is not supported by Table 5.6, which suggests that the home team was unable to capitalise on its propensity to establish a first innings lead. There is a moderate positive correlation between the first innings team ratings and the overall number of wins and the accumulated points (by team) of 0.56 ($p = 0.039$) and 0.64 ($p = 0.013$) respectively. This suggests that first innings strength in the County Championship is only a moderate indicator of a team's overall strength.

The ratings provided in Table 5.7 can be used to estimate the probability that a team is able to defeat its opponent in a particular Division 1 County Championship match. For example, suppose that Surrey plays Hampshire at home with Surrey winning the coin toss and electing to bat first. Assume that Team 1 secured four first innings bonus points. Surrey's expected lead is $198-87+23+15+11=160$ runs. If Surrey is Team 1, the probability it wins, ties and loses against Hampshire are respectively 0.78, 0.05 and 0.17. Conversely, if Hampshire is Team 1 and it wins the coin toss and elected to bat first it is expected to trail by 62 runs. Its respective probabilities of a win, tie and loss are 0.30, 0.08 and 0.62. Surrey is undoubtedly a stronger team than Hampshire but the advantage of playing at home has increased Hampshire's chance of winning by a substantial amount. Figure 5.6 provides a plot displaying the estimated probability of winning a County Championship match on points for the home and away teams for (signed) first innings leads up to 200 runs. In each case it is assumed that the home and away teams are represented by Team 1 whereby it has won the coin toss and earned four first innings bonus points. Undoubtedly, any advantage enjoyed by the home team is marginal. To have a better than 50% chance of winning the required average leads for the home and away teams are $x \geq 30$ runs and $x \geq 44$ runs respectively.

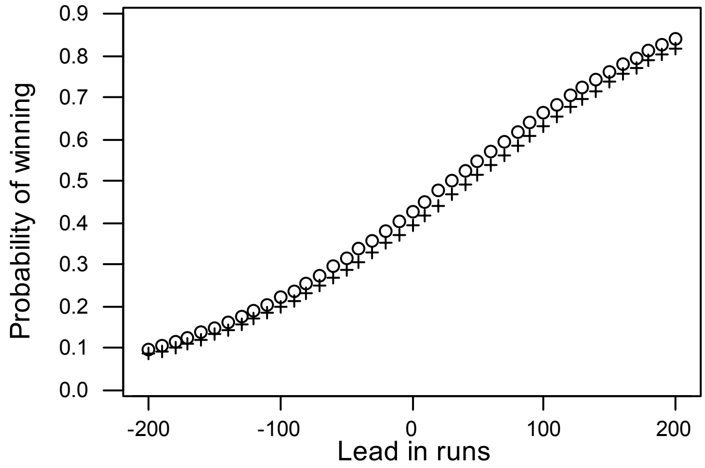

Figure 5.6. The estimated probability of winning against an equal opponent for the home (○) and away (+) teams in a Frizzell County Championship match for first innings leads up to 200 runs for the period 2000-2002

Table 5.7. Least squares parameter estimates for the fitting of the first innings margins of the Frizzell County Championship for the period 1990-2000

Team	*Rating*
Derbyshire	38
Durham	101
Essex	-4
Glamorgan	9
Hampshire	87
Kent	103
Lancashire	152
Leicestershire	109
Northamptonshire	54
Somerset	112
Surrey	198
Sussex	158
Warwickshire	143
Yorkshire	141

5.4 Comparison of the Pura Cup and the Frizzell County Championship

Comparison of the domestic competitions conducted in Australia and England, not surprisingly, suggest that establishing a first innings lead was a very strong predictor of a winning match outcome. The home team in either competition was able to establish a significant first innings runs advantage; i.e. 33 and 23 runs respectively in the Pura Cup and the County Championship. However, only home teams in the Pura Cup competition were able to capitalise on this advantage and regularly secure a win on points. Teams winning the coin toss in the Pura Cup were also able to gain a first innings runs advantage but this did not readily result in a points win. The first innings ratings suggest that first innings strength was strong indicator of a team's winning capacity in the Pura Cup but not in the County Championship.

The discontinuity that occurs in the Pura Cup at $x = 0$ does not occur in the County Championship because at the first innings boundary the same winning options are open to both teams. Thus, the probability of winning is continuous across the innings boundaries. In the Pura Cup, however, the leading and trailing teams have different winning options open to them and the probability of winning is thus discontinuous across the change of innings; i.e. the leading team has two winning options open to it whereas the trailing team is limited to only one winning option. As a consequence, the leading team in the Pura Cup has a stronger winning chance than the leading team in the County Championship. Not surprisingly, the prediction of match outcomes in the County Championship is thus more highly variable than in the Pura Cup. It is interesting to observe that in the Pura Cup, the difference between marginally leading and trailing by one run, results in a sizeable difference in winning chances for the respective leading and trailing teams. In the County Championship teams attract first innings bonus points but because bonus points are awarded to both teams, teams are not specifically penalised by trailing on the first innings. Accordingly, it is not unlikely that the trailing team is in fact the team leading on points at the completion of the first innings. However, there is no evidence to suggest that teams gained a significant winning advantage by earning first innings bonus points.

The coefficient of determination values for the modelling of the first innings margins for the Pura Cup and the County Championship were 0.15 and 0.39 respectively, which suggests that the least squares model was unable to account for a high 85% and 61% of the variation in the innings margins. This highlights the highly variable nature of the innings margins, with the Pura Cup generating an especially high level of unpredictability.

5.5 Conclusions

The match outcomes in the Pura Cup and the Frizzell County Championship were modelled using logistic regression techniques. Since the outcomes in a Pura Cup match are binary (win/loss) a binary logistic model is fitted to the outcomes whereas in the County

Championship the match outcomes are trichotomous (win/tie/loss) and so a multinomial (ordinal) logistic model is fitted to the match outcomes. A similar model was also fitted to the point-margins in the Pura Cup.

It was established that HA and the first innings lead were very strong predictors of a winning match outcome in the Pura Cup. However, only the latter was a strong predictor in the County Championship. It is most likely that the HA effect is not as prevalent in the County Championship because teams are expected to play at a diverse number of locations, thus preventing them from developing innate knowledge of localised conditions. There was no evidence to suggest that teams were advantaged by winning the coin toss in either competition. There was also no evidence suggesting that the accumulation of bonus points in the County Championship was a strong predictor of a winning outcome. It appears that in the County Championship the allocation of points has been (either consciously or unconsciously) carefully engineered so as to discourage teams from relying solely on first innings bonus points as an avenue to a points-victory. The probabilities of winning and losing are not continuous across the change of innings in the Pura Cup competition. As a consequence, a marginal runs differential can result in a critical difference in the probabilities of winning and losing. This anomaly arises because the trailing team must win outright in order to secure a win 'on points' whereas the leading team need only draw a match to secure a win. This situation is not evident in the Frizzell County Championship because both competing teams have access to the same pool of performance based bonus points. In effect, the trailing team can still be ahead on points at the completion of the first innings. As a consequence, the leading team in the Pura Cup has a stronger winning chance than the leading team in the County Championship. Not surprisingly, it was established that the prediction of match outcomes in the County Championship is more highly variable than in the Pura Cup.

In fitting a multiple linear regression model to the first innings differentials it was established that across competitions the home team gained a significant first innings runs advantage over its opposition. However, only home teams in the Pura Cup were able to effectively capitalise on this advantage in the penultimate and final innings and display a winning tendency. The resulting least squares ratings provided a gauge of a team's overall strength relative to the average team rating of 100. In the Pura Cup, the top two rated teams were Western Australia and Queensland. The top two teams in the County Championship were Surrey and Sussex. It was established that the first innings ratings were a strong indicator of a team's winning capacity in the Pura Cup but not in the County Championship.

CHAPTER 6
MODELLING ONE-DAY INTERNATIONAL (ODI) CRICKET

6.1 Introduction

Chapter 3 introduced the D/L rain interruption rules methodology and described how it can be used to calculate a projected score for Team 2 when it wins with untapped run-scoring resources at its disposal. It was argued in Chapter 3 that the resultant projected victory margin provides a more informative measure of the extent of Team 2's victory than the current methodology and provides an accurate gauge of Team 2's relative superiority. Chapter 4 used exploratory data techniques to provide a cursory examination of team performance in ODI cricket over two successive five year study periods. This provided some details of the effects, such as HA, impacting on team performance in ODI cricket. This chapter will initially examine ODI matches (excluding the Cricket World Cup competition results) and then analyse the 1999 and 2003 Cricket World Cup competitions. Note that the Cricket World Cup competition is a self contained tournament with all teams, bar the host nation, playing on neutral grounds. As a consequence, any HA effect can be ignored since (a) the host nation is not expected to play any of its matches on a neutral ground and (b) the visiting nations are not able to play any of its matches at its home ground.

In modelling ODI cricket we have a choice of modelling (a) the match outcomes (win or loss); (b) the victory margins (including the projected margins when Team 2 wins) or (3) the innings scores (including the projected Team 2 scores when Team 2 wins). By fitting a binary logistic model to the match outcomes we can quantify the extent to which specific performance factors critically affect the binary outcome of a win or a loss. By fitting models to either the victory margins or scores we can also quantify the extent to which effects such as overall team strength impact upon a team's scoring potential. Note that the latter two models provide a more sensitive measure of team performance than simply modelling wins and losses. For example, a win by 100 runs is a more decisive victory than a 1 run win. In both instances, however, a logistic model does not distinguish between the degrees of victory; i.e. a win is simply categorized as a win regardless of the size of the win. Conversely, when modelling victory margins and scores the extent of the victory is taken into account and thus provides a more reliable gauge of the relative differences in strength between opposing teams. Chapter 8 will model the innings scores in order to gauge the degree to which a team's attack (batting) and defensive (bowling) strength explains the observed variation in the team scores.

6.2 Fitting a binary logistic model to the match outcomes

In modelling match outcomes the binary response variable (for Team 1) is categorical; i.e. a win or a loss. A binary logistic regression model, with the application of the logit link function, is fitted to the match outcomes in order to gauge the extent to which the observed variation in the binary match outcome of a win or a loss is critically affected by specific performance measures such as playing at home, playing in a specific geographical region, winning the coin toss, order of innings and batting under lights. In conducting the analysis it is assumed that the logit link function and the chosen co-variates are linearly related. If the probability of a win or loss for Team 1 is denoted by γ, the outcome of a match is modelled as

$$\ln\left(\frac{\gamma}{1-\gamma}\right) = \beta_0 + \beta_1 h + \beta_2 r + \beta_3 t + \beta_4 n \tag{6.1}$$

where $h = 1 \text{ or } 0$ indicates whether or not Team 1 was the home team; $r = 1 \text{ or } 0$, signifies whether or not Team 1 was from a different region than its opponent; $t = 1 \text{ or } 0$ indicates whether or not Team 1 won the coin toss and $n = 1 \text{ or } 0$ signifies whether or not the match was a day/night fixture.

In fitting model (6.1) to the match outcomes for Team 1 we obtain the parameter estimates provided in Table 6.1. The application of the Pearson, deviance and Hosmer-Lemeshow goodness-of-fit tests suggest that for both study periods model (6.1) provides an adequate fit of the data. The findings clearly demonstrate that HA was a consistently strong predictor of a winning outcome over the ten year period of the study. To appreciate the extent of the HA, the respective odds ratios for each study period signify that the odds of the away team winning were, on average, 2.61 and 2.35 times the odds of the home team winning. There is also strong evidence to suggest that during the first study period there was a regional disadvantage, with Team 1 tending to lose when opposed to teams from a different geographical region. However, there is no evidence to suggest that teams in general gained a winning advantage by winning the coin toss. This is consistent with the findings of de Silva and Swartz (1997) in their extensive analysis of ODI cricket, where it was established that the coin toss did not have a significant bearing on match outcomes. Similarly, for both study periods, there is no evidence of a significant day/night effect. This is a surprising result given that it was demonstrated in Chapter 4 that during the first five-year period Team 1, when batting in daylight, was able to firstly score substantially more runs than its opposition and secondly display a tendency to win. This suggests that the day/night effect was possibly confounded by the effects of the other explanatory variables. The intercept term, with $h = 0,\ r = 0,\ t = 0,\ n = 0$ is both negative and significant for the second study period. This suggests that, in general, the away team, having lost the coin toss and batting first, was significantly disadvantaged when it was opposed to teams from the same geographical region in day only matches.

To estimate the probability of Team 1 winning an ODI match, 6.1 can be transposed to give

$$\Pr\left(\text{Win}\middle|h,\ r,\ t,\ n\right) = \frac{\exp\left(\beta_0 + \beta_1 h + \beta_2 r + \beta_3 t + \beta_4 n\right)}{1 + \exp\left(\beta_0 + \beta_1 h + \beta_2 r + \beta_3 t + \beta_4 n\right)}$$

Assume that Team 1 is the home team and is from a different region than its opponent. If Team 1 wins the coin toss and elects to bat first in a day/night match, then the average probability of Team 1 winning is estimated to be

$$\Pr\left(\text{Win}\middle|h = 1,\ r = 1,\ t = 1,\ n = 1\right) = \frac{\exp\left(\beta_0 + \beta_1 + \beta_2 + \beta_3 + \beta_4\right)}{1 + \exp\left(\beta_0 + \beta_1 + \beta_2 + \beta_3 + \beta_4\right)}$$

The respective probability estimates of the home team winning a match during each of the study periods were a substantial 0.63 and 0.62 respectively. The probabilities of the home team losing were thus only 0.37 and 0.38. This confirms the strong winning advantage enjoyed by the home team (across both study periods) and suggests that the HA effect remained consistent throughout the ten year period of the study. However, if we take account of the regional disadvantage that confronted Team 1 when opposed to teams from different geographical regions during the first study period the respective probabilities of the home team winning and losing are now estimated to be 0.81 and

0.19. This underscores the significant advantage enjoyed by Team 1 when it was the home team opposed to teams from the same geographical region. In fact its winning probability has increased by a sizeable 29%. This is a surprising result given that it would be expected that teams from the same region are exposed to similar playing conditions. This suggests that other factors such as travel and crowd support were possibly at play.

The respective probability that Team 1 wins a match under the same conditions when it is the away team is estimated to be

$$\Pr\left(\text{Win}\middle| h=0, r=1,\ t=1,\ n=1\right)=\frac{\exp\left(\beta_0+\beta_2+\beta_3+\beta_4\right)}{1+\exp\left(\beta_0+\beta_2+\beta_3+\beta_4\right)}$$

Thus the probability estimates of the away team winning and losing during the first study period when opposed to teams from a different region were respectively 0.40 and 0.60 and during the ensuing period were respectively 0.41 and 0.59. If we factor in the disadvantage experienced by teams from the same geographical period during the first study period (i.e. $r=0$), the respective winning and losing probability estimates for the away team are now 0.63 and 0.37. Its winning probability has increased by a considerable 54%. This underscores the advantage enjoyed by teams when opposed to teams from the same region during this period.

To examine whether there was an order of innings effect we can find the probability that the home team wins given that the away team elected to bat first after winning the coin toss. This is commensurate with finding the probability that Team 1 loses given that it was the away team. It follows that 6.1 can be transposed to give

$$\Pr\left(\text{Loss}\middle| h=0, r=1,\ t=1,\ n=1\right)=\frac{1}{1+\exp\left(\beta_0+\beta_2+\beta_3+\beta_4\right)}$$

Thus, for the respective study periods, the average probability that Team 2 won given that it was the home team were 0.60 and 0.59. These results suggest that there was not a significant order of innings effect since the probabilities that Team 1 won, given that it was the home team, were similarly 0.63 and 0.62 for the respective study periods.

To test the efficacy of model (6.1) for the first study period the parameter estimates can be generated for the first 133 matches (training set) and then used to predict the match outcomes of the remaining 133 matches (test set). The subsequent successful classification rates for both sets are 58% and 64% respectively. When the parameter estimates in Table 6.1 are used to predict the match outcomes for the entire data set the successful classification rate is 63%. For the second study period, the training and test sets are the first and second 124 matches respectively. The respective successful classification rates for both sets are 57% and 59%. When the parameter estimates in Table 6.1 are used for the entire data set the successful classification rate is 54%. The consistency of the results across both study periods suggests that there is no evidence of any over-fitting and thus model (6.1) is a modest predictor of a winning match outcome.

Table 6.1. Parameter estimates for fitting a binary logistic regression model to the match outcomes (win or loss) in ODI matches

Parameter	*Term*	*Coefficient*	*Standard error*	*p-value*	*Odds ratio*
			Period 1992/93-1997		
β_0	Intercept	0.3907	0.4717	0.408	
β_1	Home	0.9589	0.2620	<0.001	2.61
β_2	Region	-0.9326	0.4505	0.038	0.39
β_3	Coin toss	-0.0954	0.2649	0.719	0.91
β_4	Day/night	0.2262	0.2893	0.434	1.25
			Period 1997/98-2001		
β_0	Intercept	-0.8161	0.4022	0.042	
β_1	Home	0.8546	0.2624	0.001	2.35
β_2	Region	0.3790	0.3600	0.292	1.46
β_3	Coin toss	-0.1643	0.2703	0.543	0.85
β_4	Day/night	0.2383	0.2775	0.390	1.27

6.3 Modelling the victory margins

6.3.1 Fitting a linear model to the victory margins

The projected winning margin in an ODI match played between the team i and team j is modelled as

$$w_{ij} = u_i - u_j + f + t + n + \varepsilon_{ij} \tag{6.2}$$

where the indices $i, j = 1,\ldots,9$ represent the nine ICC Test-playing nations and the response variable w_{ij} denotes the expected first innings margin. The parameter u_i is a measure of the relative ability of team i; the order of innings parameter is f if team i batted first and is $-f$ otherwise; the coin toss parameter is t if team i won the coin toss and is $-t$ otherwise; the day/night parameter is n if team i batted first in a day/night match, is $-n$ if team i batted second in a day/night match and is 0 otherwise. ε_{ij} is a zero-mean random error with constant variance. If we also take account of the HA effect then model (6.2) can be modified to

$$w_{ijk} = u_i - u_j + h_{ik} + f + t + n + \varepsilon_{ijk} \tag{6.3}$$

where the indices $i, j, k = 1,\ldots,9$ represent the nine ICC Test-playing playing nations and the parameter h_{ik} represents the HA effect. When $k = i$, the HA parameter is modelled as either a common HA, h (6.3a) or a team's individual HA, h_i (6.3b). In the latter case it is assumed that all teams enjoy an advantage that is independent of all other teams irrespective of whether teams compete in the same geographical region or not. To account for any regional effects model (6.2) can be further modified to

$$w_{ijlm} = u_i - u_j + r_{lm} + f + t + n + \varepsilon_{ijlm} \tag{6.4}$$

where the indices $l, m = 1,\ldots,5$ represent the five geographical regions, with team i belonging to region l and team j belonging to region m. The parameter r_{lm} represents the regional effect. When teams i and j belong to different regions $r_{lm} = r_l$ otherwise if $l = m$ it is assumed that teams i and j enjoy the same regional advantage and so

$r_{lm} = 0$. Using a design matrix of indicator variables, a least squares regression model is fitted to the differentials. For convenience $\sum_{i=1}^{9} u_i = 900$ to ensure that the average team rating is 100.

6.3.2 Period 1992/93-1997

In fitting models (6.2), (6.3) and (6.4) to the projected ODI victory margins for the first five-year period we obtain the least squares parameter estimates presented in Tables 6.2 and 6.3. As was the case the case with domestic cricket the least squares parameter estimates represent team ratings relative to the average team rating of 100. The common and individual HA versions of model (6.3) are referred to as model (6.3a) and (6.3b). The Anderson-Darling test for normality verifies that for all models the residuals are normally distributed.

In order to draw statistical inferences about the effectiveness of models (6.2), (6.3) and (6.4) in explaining the observed variation in the distribution of the victory margins Table 6.4 uses analysis of variance techniques as employed by Harville and Smith (1994) to compare the efficacy of each of the models. This analysis suggests that model (6.3a), with the inclusion of the single common HA parameter, provides the best fit of the data. Nonetheless it is evident from models (6.3b) and (6.4) that England enjoyed both a significant individual HA and a significant regional advantage throughout the study period. The least square parameter estimates generated by model (6.3a) for h, f, t and n were 7 runs ($p = 0.014$), 13 runs ($p < 0.01$), 2 runs ($p = 0.539$) and -4 runs ($p = 0.489$) respectively. Undoubtedly, during this period, the HA effect and batting first were strong predictors of the victory margin. There is no evidence to suggest, however, that winning the coin toss and batting first (in daylight) in day/night matches made a significant contribution to the victory margin. The coefficient of determination, $r^2 = 0.64$ underscores the moderate variability of the victory margins, with 36% of the observed variation remaining unexplained. This underscores the variable nature of ODI cricket.

6.3.3 Period 1997/98-2001

The results for the second study period are summarised in Tables 6.5 and 6.6. The appropriate tests confirm that the normality assumption was not breached. Table 6.7 compares the efficacy of each of the models, which verifies that model (6.4), with the fitting of the five regional parameters, provided the best fit of the data. The least square parameter estimates generated by model (6.4) for *f*, *t* and *n* were -7 runs ($p = 0.190$), 1 run ($p = 0.989$) and 0 runs ($p = 0.997$) respectively. In particular, the West Indies region and teams from the subcontinent enjoyed a significant runs advantage during this period. Model (6.3b) confirms that Sri Lanka and the West Indies enjoyed a significant HA of 42 and 88 runs respectively. This is also reflected in their high home winning percentages of 83% and 63% respectively. Interestingly, the West Indies was a lowly ranked team during this period, which suggests that by comparison its away performances were especially mediocre. This is reflected in its poor away winning percentage of only 22%. There was no perceived runs advantage gained by batting first or winning the coin toss. Similarly, there is no evidence of a significant day/night effect. The coefficient of determination for model (4.3b) is $r^2 = 0.55$.

Table 6.2. Least squares parameter estimates for models (6.2), (6.3a) and (6.3b) in ODI cricket for the period 1992/93-1997

Team	*Model (6.2)*	*Model (6.3a)*	*Model (6.3b)*	*Team HA*	*p-value*
Australia	105	105	105	11	0.367
England	104	108	100	38	0.041
India	100	99	95	15	0.236
New Zealand	98	97	94	11	0.362
Pakistan	100	101	103	4	0.721
South Africa	110	107	109	4	0.742
Sri Lanka	110	109	110	6	0.646
West Indies	115	115	123	-9	0.513
Zimbabwe	58	59	63	-3	0.864

Table 6.3. Least squares parameter estimates for model (6.4) in ODI cricket for the period 1992/93-1997

Team	*Model (6.4)*	*Region*	*Overall regional advantage*	*p-value*
Australia	104	Region 1	37	0.047
England	102	Region 2	-9	0.497
India	100	Region 3	8	0.371
New Zealand	94	Region 4	14	0.150
Pakistan	102	Region 5	8	0.470
South Africa	107			
Sri Lanka	110			
West Indies	124			
Zimbabwe	59			

Table 6.4. Comparison of models (6.2), (6.3) and (6.4) in ODI cricket victory margins for the period 1992/93-1997

Model	*Source*	*DF*	*SS*	R^2	*MS*	*F-ratio*	*p-value*
Model (6.2)	Regression	12	936206	0.64			
Model (6.3a) compared with model (6.2)	Regression	1	12367		12367	6.1	0.014
	Residual error	254	513329		2021		
Model (6.3b) compared with model (6.2)	Regression	9	22458		2495	1.2	0.295
	Residual error	246	503238		2046		
Model (6.4) compared with model (6.2)	Regression	5	27561		5512	2.8	0.018
	Residual error	250	498135		1993		
Model (6.3a)	Regression	13	948573	0.65			
Model (6.3b) compared with model (6.3a)	Regression	8	10091		1261	0.6	0.778
	Residual error	246	503238		2046		
Model (6.4) compared with model (6.3a)	Regression	4	12530		3133	1.6	0.175
	Residual error	250	500799		2003		
	Total	267	1461902				

Table 6.5. Least squares parameter estimates for models (6.2), (6.3a) and (6.3b) in ODI cricket for the period 1997/98-2001

Team	*Model (6.2)*	*Model (6.3a)*	*Model (6.3b)*	*Team HA*	*p-value*
Australia	132	129	136	7	0.630
England	94	94	111	-14	0.492
India	99	100	99	19	0.292
New Zealand	88	85	77	26	0.166
Pakistan	98	100	117	-16	0.430
South Africa	127	125	128	3	0.851
Sri Lanka	116	116	100	42	0.021
West Indies	85	86	56	88	<0.001
Zimbabwe	61	64	77	-19	0.297

Table 6.6. Least squares parameter estimates for model (6.4) in ODI cricket for the period 1997/98-2001

Team	*Model (6.4)*	*Region*	*Overall regional advantage*	*p-value*
Australia	135	Region 1	-21	0.295
England	117	Region 2	82	<0.001
India	87	Region 3	41	0.006
New Zealand	89	Region 4	11	0.427
Pakistan	96	Region 5	-7	0.591
South Africa	136			
Sri Lanka	107			
West Indies	57			
Zimbabwe	76			

Table 6.7. Comparison of models (6.2), (6.3) and (6.4) in ODI cricket victory margins for the period 1997/98-2001

Model	*Source*	*DF*	*SS*	R^2	*MS*	*F-ratio*	*p-value*
Model (6.2)	Regression	12	1076949	0.52			
Model (6.3a) compared	Regression	1	48697		48697	11.9	0.001
with model (6.2)	Residual error	236	964062		4085		
Model (6.3b) compared	Regression	9	129940		14438	3.7	<0.001
with model (6.2)	Residual error	228	882819		3872		
Model (6.3a)	Regression	13	1125646	0.54			
Model (6.3b) compared	Regression	8	81243		10155	2.6	0.010
with model (6.3a)	Residual error	228	882819		3872		
Model (6.4)	Regression	17	1174310	0.56			
Model (6.3b) compared	Regression	4	223635		5909	1.9	0.111
with model (6.4)	Residual error	228	691763		3034		
	Total	249	2089708				

6.4 Estimating probabilities

6.4.1 Examining residuals

Since the residuals generated by models 6.2 and 6.3 are normally distributed and since we know the standard deviation, the normal distribution can be used to estimate the expected winning probabilities of the opposing home and away teams.

If the error, ε, in the victory margin, w with $\varepsilon \sim N\left(0, \sigma^2\right)$, then the estimated probability of a team achieving a margin greater than 0 (with the inclusion of a 0.5 continuity correction) is given as

$$\begin{aligned}\Pr\left(w+\varepsilon > 0.5\right) &= \Pr\left(\varepsilon > 0.5 - w\right) \\ &= \Pr\left(Z > \frac{0.5-w}{\sigma}\right) \\ &= \Pr\left(Z < \frac{w-0.5}{\sigma}\right) \\ &= \Phi\left(\frac{w-0.5}{\sigma}\right)\end{aligned}$$

where Z is the standard normal and $\Phi(z)$ is the area under the normal curve to the left of z.

6.4.2 Period 1992/93-1997

From model (6.3a), the standard deviation of the residuals, σ is 45.0, with the expected victory margin calculated as

$$w = \text{Home rating} - \text{Away rating} + \text{Bat first effect} + \text{Toss effect} + \text{Night effect}$$

To illustrate how the probability estimates are calculated suppose Australia plays Zimbabwe in an ODI match at home and bats first after winning the coin toss. Australia's predicted victory margin, w is $w = 105 + 7 + 13 + 2 - 59 = 68$ runs. The probability that Australia's wins is estimated to be

$$\begin{aligned}
\Pr(68 + \varepsilon > 0.5) &= \Pr(\varepsilon > 0.5 - 68) \\
&= \Pr\left(Z > \frac{0.5 - 68}{45}\right) \\
&= \Pr(Z > -1.5) \\
&= \Pr(Z < 1.5) \\
&= \Phi(1.5) \\
&= 0.93
\end{aligned}$$

Thus, the probability estimate for Zimbabwe winning is $1 - 0.93 = 0.07$.

If the roles were reversed and Zimbabwe's captain wins the coin toss and elects to bat first, Zimbabwe's predicted victory margin is $w = 59 + 7 + 13 + 2 - 105 = -24$ runs, i.e. Zimbabwe would be expected to lose by 24 runs. The subsequent winning probabilities for Zimbabwe and Australia are estimated to be 0.29 and 0.71 respectively. The projected average probabilities of the home team winning (for all teams) are provided in Table 6.8. In all calculations it is assumed that the match is played in daylight and the home team won the coin toss elected to bat first. To calculate the probability of the away team winning simply subtract the home winning probability from 1. The row averages represent the estimated home winning probability whereas the column averages represent the estimated away losing probability. The bolded probability of 0.68 along the diagonal represents the estimated probability of the home team winning against an equally rated team. This isolates the advantage attributed to the HA effect and batting first after winning the coin toss. With no effects, the probability that the home team wins is 0.5. Thus, the combined HA, batting first, winning the coin toss and the day/night effect have increased the expected probability of the home team winning by a considerable 36%. Apportioning the combined effect, we have the HA, batting first, winning the coin toss and the day/night effect contributing 9.7%, 18%, 2.8% and 5.5% respectively to the increase. Table 6.9 provides the estimated home winning probabilities for all teams together with the actual winning percentages. From Table 6.9, if $p =$ the estimated home winning probability and $n =$ the number of home games played, then the estimated standard error $= \sqrt{\dfrac{\hat{p}(1-\hat{p})}{n}}$. The calculation of the standard errors suggests that, in the main, teams performed within expectations. During this period, however, Australia, New Zealand and the West Indies modestly underperformed at home.

Table 6.8. Estimated winning probabilities in ODI cricket for the period 1992/93-1997

	Team	*Away team*									
		Aust	Eng	Ind	NZ	Pak	SA	SL	WI	Zim	*Ave.*
Home team	Australia	**0.68**	0.66	0.73	0.74	0.71	0.67	0.65	0.60	0.93	**0.71**
	England	0.71	**0.68**	0.75	0.76	0.74	0.69	0.68	0.63	0.94	**0.74**
	India	0.63	0.61	**0.68**	0.70	0.67	0.62	0.60	0.55	0.91	**0.66**
	New Zealand	0.62	0.59	0.67	**0.68**	0.65	0.60	0.58	0.53	0.91	**0.64**
	Pakistan	0.65	0.63	0.70	0.71	**0.68**	0.63	0.62	0.57	0.92	**0.68**
	South Africa	0.70	0.68	0.74	0.76	0.73	**0.68**	0.67	0.62	0.94	**0.73**
	Sri Lanka	0.71	0.69	0.76	0.77	0.74	0.70	**0.68**	0.63	0.94	**0.74**
	West Indies	0.76	0.74	0.80	0.81	0.78	0.74	0.73	**0.68**	0.96	**0.79**
	Zimbabwe	0.29	0.27	0.34	0.36	0.32	0.28	0.26	0.22	**0.68**	**0.29**
	Average	**0.63**	**0.61**	**0.69**	**0.70**	**0.67**	**0.62**	**0.60**	**0.54**	**0.93**	**0.68**

Table 6.9. Estimated winning probabilities for all teams in ODI cricket for the period 1992/93-1997

Team	*Estimated home winning probability*	*Number of games played at home*	*Standard error*	*Actual home winning percentage*
Australia	71%	38	7.4%	58%
England	74%	8	15.6%	88%
India	66%	42	7.3%	67%
New Zealand	64%	39	7.7%	49%
Pakistan	68%	21	10.2%	67%
South Africa	73%	50	6.3%	66%
Sri Lanka	74%	28	8.3%	68%
West Indies	79%	25	8.1%	64%
Zimbabwe	29%	15	11.7%	33%
Average	68%	30	9.2%	62%

6.4.3 Period 1997/98-2001

From model (6.4), the standard deviation of the residuals, σ is 62.0, with the expected victory margin calculated as

$$w = \text{Home rating} - \text{Away rating} + \text{Region effect} + \text{Bat first effect} + \text{Toss effect} + \text{Night effect}$$

Table 6.10 provides the resulting probability estimates. The bolded probabilities along the diagonal represent the estimated probability of the home team winning, augmented by the regional effect, against an equally rated team. This isolates the advantage attributed to any regional effect and batting first after winning the coin toss. The combined regional effect, together with the effects attributed to batting first, winning the coin toss and batting in daylight have only increased the expected probability of the home team winning by a moderate 16%. Table 6.11 provides the resulting estimated home winning probabilities for all teams and their actual regional winning percentages. The value of 0.58 represents the estimated winning probability for each home regional team when opposed to teams from a different region. From Table 6.11, calculation of the standard errors suggests that, on average, teams performed as expected.

Nevertheless, Pakistan performed significantly below expectations at home whereas South Africa and Sri Lanka performed modestly better than average on their home ground.

During this period the dominance of Australia, in particular, is clearly evident, with its estimated probability of winning at home against all opposition being at least 50%. The highly ranked Australia was able to consistently convert its strong relative standing into a winning outcome. In contrast, the lowly ranked Zimbabwe's chances of winning at home, for the most part, were especially low. Only when it was opposed to the West Indies did its estimated home winning probability exceed 50%. The column averages in Table 6.11 also highlight Australia's superiority during this period, with its opponents, when it played away from home, having only a 37% chance of winning. South Africa also enjoyed the same away winning advantage. Table 6.12 provides a summary of the regional advantage enjoyed by teams throughout the study period. These results especially underscore the regional advantage enjoyed by the West Indies and the teams from the subcontinent.

Table 6.10. Estimated winning probabilities in ODI cricket for the period 1997/98-2001

			Away team by region									
			4	1	3	4	3	5	3	2	5	
			Aust	Eng	Ind	NZ	Pak	SA	SL	WI	Zim	*Ave.*
Home team by region	Aust	4	**0.53**	0.64	0.80	0.79	0.76	0.52	0.70	0.91	0.85	**0.75**
	Eng	1	0.23	**0.33**	0.52	0.50	0.46	0.23	0.39	0.70	0.59	**0.45**
	Ind	3	0.41	0.53	**0.71**	0.70	0.66	0.41	0.59	0.85	0.77	**0.62**
	NZ	4	0.25	0.35	0.54	**0.53**	0.48	0.25	0.41	0.72	0.61	**0.45**
	Pak	3	0.47	0.59	0.76	0.75	**0.71**	0.46	0.65	0.88	0.81	**0.67**
	SA	5	0.42	0.54	0.72	0.71	0.67	**0.41**	0.60	0.85	0.77	**0.66**
	SL	3	0.54	0.65	0.81	0.80	0.77	0.54	**0.71**	0.91	0.85	**0.73**
	WI	2	0.48	0.60	0.77	0.76	0.72	0.48	0.66	**0.89**	0.82	**0.66**
	Zim	5	0.12	0.19	0.35	0.33	0.29	0.12	0.24	0.54	**0.41**	**0.27**
	Average		**0.37**	**0.51**	**0.66**	**0.67**	**0.60**	**0.37**	**0.53**	**0.80**	**0.76**	**0.58**

Table 6.11. Estimated winning probabilities for all teams in ODI cricket for the period 1997/98-2001

Team	*Estimated home winning probability*	*Number of games played at home*	*Standard error*	*Actual home winning percentage*
Australia	75%	46	6.4%	76%
England	45%	22	10.6%	41%
India	62%	27	9.3%	63%
New Zealand	45%	31	8.9%	48%
Pakistan	67%	18	11.1%	39%
South Africa	66%	34	8.1%	79%
Sri Lanka	73%	29	8.2%	83%
West Indies	66%	19	10.9%	63%
Zimbabwe	27%	22	9.5%	18%
Average	58%	28	9.3%	57%

Table 6.12. Summary of the regional advantage enjoyed by teams in ODI cricket for the period 1997/98-2001

Team	*Region*	*Expected regional runs advantage*	*Expected probability of winning on a regionally neutral ground*	*Expected probability of winning with a regional advantage*	*Result of regional advantage*
Australia	4	11	69%	75%	Up 9%
England	1	-21	58%	45%	Down 22%
India	3	41	38%	62%	Up 63%
New Zealand	4	11	39%	45%	Up 15%
Pakistan	3	41	44%	67%	Up 52%
South Africa	5	-7	70%	66%	Down 6%
Sri Lanka	3	41	51%	73%	Up 43%
West Indies	2	82	20%	66%	Up 230%
Zimbabwe	5	-7	31%	27%	Down 10%
Average		21	47%	58%	Up 23%

6.5 Modelling the ICC Cricket World Cup

6.5.1 Introduction

The ICC Cricket World Cup is contested between seeded teams that have been divided into two groups. The preliminary phase involves the Group Matches whereby teams from within each group play each other in a round-robin competition. The top three teams from each group then play each other in the Super-Six phase. In both the Group and Super-Six phases the teams are awarded 4 points for a win and 2 points for a tie or no result. The losing team receives no points. In order to reward teams that have performed well against strong opposition the six teams that qualify for the Super-Six phase carry forward the points earned in the Group Matches. It follows that if a team defeats another qualifier it receives an additional four points whereas if it defeats a non-qualifier it receives an additional one point. If a Group match is tied or there was no result a team will receive a further two points or half a point depending on whether the respective opponent was a qualifier or non-qualifier. The top four teams from the Super-Six phase then progress to the semi-finals. In the semi-final stage, the first and fourth placed teams and the second and third placed teams are opposed to other. The winners of the semi-finals then contest the Final.

In modelling the ICC Cricket World Cup, both the 1999 and the 2003 competitions are analysed. Note that only the nine ICC nations examined in the previous sections of this chapter will be used to compare a team's overall performance in ODI cricket. The competition uses a seemingly extemporized set of matches to define the world champion, the structure of which raises many questions. In the 1999 Cricket World Cup, for example, 30 preliminary matches were devoted to finding the best six out of 12 teams, some of which were undoubtedly not in the same class as the best; a further nine matches were needed to eliminate a further two teams and yet only three matches were devoted to producing a single winner out of the four remaining teams. In a similar vein, a well-documented criticism of the 2003 Cricket World Cup was that an exorbitant number of matches were invested in the Group phase of the competition, a substantial number of which were one-sided. With the addition of two extra teams in the 2003 competition, this meant that a considerable 42 preliminary matches had to be played. Notably, this represented the entire number of matches played in the 1999 Cricket World Cup. Nonetheless, the number of preliminary matches was reduced somewhat due to some of the matches being officially abandoned due to rain. In order to give the greatest chance to the better teams fewer matches could be used in the early stages when the variability in team strength is high and more matches in the later stages when teams are ostensibly more evenly matched. In the latter case, the number of matches played will have to take account of the high variability in match outcomes when teams of comparable quality are opposed to each other. This is to avoid having random factors (or luck) having too much influence on match outcomes. Many other considerations also come into play, such as giving all teams a minimum number of matches and giving the weaker countries experience against the stronger teams. In any event, whatever structure is ultimately used it should not compromise nor lose sight of its primary goal of crowning the best side as the world champion.

6.5.2 Fitting a linear model to the victory margins

The winning margin, w_{ij} in a Cricket World Cup match played between team i and team j can be modelled as

$$w_{ij} = u_i - u_j + f + t + \varepsilon_{ij} \tag{6.5}$$

where the indices $i = 1, \ldots, 12$ and $i = 1, \ldots, 14$ represent the 12 and 14 nations who respectively competed for the 1999 and 2003 Cricket World Cups. The parameter u_i is a measure of the relative ability of team i; the order of innings parameter is f if team i batted first and is $-f$ otherwise; the coin toss parameter is t if team i won the coin toss and is $-t$ otherwise. ε_{ij} is a zero-mean random error with constant variance. Note that the projected winning Team 2 scores were estimated using the D/L methodology as outlined in Chapter 3. Using a design matrix of indicator variables, a least squares regression model is fitted to the differentials and for convenience, $\sum_{i=1}^{12} u_i = 1200$ and $\sum_{i=1}^{14} u_i = 1400$ to ensure that the average team rating in each Cricket World Cup is 100.

In fitting model (6.5) to the victory margins for all matches played in the 1999 and 2003 Cricket World Cups we obtain the least square parameter estimates provided in Table 6.13, together with the official top four ranked teams. The Anderson-Darling test for normality confirms that the residuals are normally distributed for both the 1999 and

2003 data. For the 1999 Cricket World Cup, the least square parameter estimates for f and t were 11 runs ($p = 0.446$) and 0 runs ($p = 0.983$) respectively. For 2003, the respective parameter estimates for f and t were 11 runs ($p = 0.341$) and -5 runs ($p = 0.636$). There is no evidence to suggest that in either of the Cricket World Cups batting first or winning the coin toss were strong predictors of the victory margins.

In the 1999 Cricket World Cup there were two preliminary matches in the Group stage that warrant further examination. In a match played between Bangladesh and Pakistan, a student t-residual greater than 2.0 was generated. In this match, the unfancied Bangladesh defeated the previously unbeaten Pakistan by a substantial 62 runs. Furthermore with a Cook's D statistic of 0.2, this match had the highest influence throughout the tournament. The result of the match was immaterial to any placing in the Cricket World Cup and only team pride was at stake. However, the unexpected outcome raises questions concerning the attitude of the teams involved and suggests that the teams conspired to fix the outcome of the match. In another instance, it was reported in the 'The Age' newspaper (1/6/99) that in the Australia versus West Indies match, Australia blatantly manipulated the match and purposely adopted a 'go-slow' approach to ensure that the West Indies, rather than New Zealand, qualified for the Super-Six stage. This advantaged Australia since it carried the two points for beating the West Indies forward into the Super-Six stage. These two examples highlight a major problem associated with tournaments of this nature, in that once match results are known teams are in a position to unfairly influence the progress of others.

The dominance of Australia, especially in the 2003 Cricket World Cup, is considerable. It not only won both competitions but was rated significantly above the average rating of 100. The West Indies was ranked relatively high in both Cricket World Cups but was unable to consistently convert this advantage into a winning result. Interestingly, in the 2003 Cricket World Cup, Kenya made it through to the semi-finals yet was rated considerably below average. This suggests it was able to win a number of close matches when opposing teams had exhausted similar levels of run-scoring resources. Note that the linear modelling process also independently rated the Cricket World Cup champion (Australia) as the best performed team. This highlights the advantages of using linear modelling techniques to rate teams in tournaments of this nature since performances can be gauged independent of the tournament outcome. An added advantage is that a team's overall performance can be effectively compared and contrasted with the overall performance of other competing teams.

The outcome of an ODI match can be unduly influenced by random factors such as a dropped catch, a missed run out or a fielding error, which may ultimately seal the fate of a team's chances of winning a tournament. In contrast, team ratings provide an accurate measure of team performance independent of these effects. Nonetheless, the tournament structure of the Cricket World Cup, though problematic, at the very least has ensured that the most deserved team has ultimately won the tournament.

Table 6.13. Summary of team performance in the 1999 and 2003 Cricket World Cups of Cricket

Team	*1999*			*2003*		
	Rating	*Estimated position*	*Actual top four teams*	*Rating*	*Estimated position*	*Actual top four teams*
Australia	147	1.5	**1**	202	1	**1**
Bangladesh	66	9		-8	13	
Canada	Did not compete	Did not compete	Did not compete	25	12	
England	107	7		136	6	
India	127	4.5		158	3	**2**
Kenya	22	12		81	10	**4**
Namibia	Did not compete	Did not compete	Did not compete	-17	14	
Netherlands	Did not compete	Did not compete	Did not compete	37	11	
New Zealand	127	4.5	**4**	142	5	
Pakistan	124	6	**2**	105	8	
Scotland	47	11		Did not compete	Did not compete	Did not compete
South Africa	147	1.5	**3**	156	4	
Sri Lanka	59	10		121	7	**3**
West Indies	130	3		174	2	
Zimbabwe	80	8		89	9	

6.6 Comparison of ODI ratings across study periods

Table 6.14 provides the least squares ratings for the 1992/93-1997 and 1997/98-2001 study periods together with each team's expected home winning probability. These results suggest that both Australia and South Africa have been the dominant ODI teams over the ten year period. The West Indies expected home winning probability for the second study period is in stark contrast with its rating position. This suggests that it underperformed considerably away from home.

To compare average performances across periods we cannot use the team ratings as a comparison measure because they have been designed to average 100. Thus, any statistical comparison would incorrectly suggest that team performances have essentially remained constant. It makes more statistical sense to compare the expected home winning probabilities. Nonetheless, the non-parametric Mann-Whitney test confirms that relative team strength, in effect, has remained constant over the two study periods $\left(W_8 = 101.5,\ p = 0.170\right)$. The interquartile ranges of the expected home winning probabilities for each study period were 9% and 41% respectively. This suggests that team strength was more highly variable during the second study period. As a consequence, it would have been more likely for a relatively stronger team to defeat its weaker opponent during this time than during the previous study period.

Table 6.14. Overall ODI projected team ratings and Estimated winning probabilities across study periods

Team	*1992/93-1997*		*1997/98-2001*	
	Rating	*Expected home winning probability*	*Rating*	*Expected home winning probability*
Australia	105	71%	136	74%
England	108	74%	111	44%
India	99	66%	99	54%
New Zealand	97	64%	77	58%
Pakistan	101	68%	117	70%
South Africa	107	73%	128	33%
Sri Lanka	109	74%	100	29%
West Indies	115	79%	56	95%
Zimbabwe	59	29%	77	27%

6.7 Conclusions

It fitting a binary logistic model to the match outcomes in ODI cricket (win/loss) it was ascertained that throughout both study periods there was a very strong HA effect, with HA being a very strong predictor of a winning match outcome. There was also strong evidence to suggest that there was a regional effect during the first study period, with teams tending to lose when opposed to teams from different geographical regions. However, there was no evidence to suggest that teams were significantly advantaged by either winning the coin toss or batting first (in daylight) in day/night matches. There was also no evidence of an order of innings effect, with the probabilities of the home team winning and losing in either innings being similar across study periods.

In fitting a multiple linear regression model to the victory margins it was established that during the first five year study period, both the home team and Team 1 enjoyed a significant runs advantage over its opponents. During this period, England especially enjoyed a significant HA. For the ensuing study period both Sri Lanka and the West Indies enjoyed a significant HA. The resulting least squares ratings provided a gauge of a team's overall strength relative to the average team rating of 100. Clearly, Australia and South Africa were the consistently dominant teams. In the main, relative team strength remained constant throughout the ten year study period, however, the team effect was more variable during the second study period. During the second study period there was evidence suggesting that team performances were influenced by a regional effect. The West Indies, in particular, appeared to be advantaged by its geographical location.

The modelling of the 1999 and 2003 Cricket World Cups provided the opportunity to examine a self contained competition, with all teams, bar the host nation(s), playing on neutral grounds. As a consequence, the HA effect was defused. Linear modelling techniques confirmed that Australia was the best rated team throughout both tournaments. There was no evidence to suggest that teams gained a significant advantage by winning the coin toss or batting first.

The outcome of an ODI match can be unduly influenced by random factors, which may ultimately seal the fate of a team’s chances of winning a tournament. In contrast, linear modelling techniques, and the resulting team ratings, provide an accurate measure of a team’s overall performance independent of these effects relative to the overall performance of competing teams.

CHAPTER 7
MODELLING TEST CRICKET

7.1 Introduction

This chapter will expand on the conventional exploratory analysis conducted in Chapter 4 and employ linear and logistic modelling procedures to quantify factors affecting team performance in the first innings of a test match.

In modelling performances in Test cricket multiple linear regression techniques will be used to model the first innings run differentials to ascertain the degree to which the differentials can be expressed as a function of HA, batting first and winning the coin toss. The resulting least squares team ratings and any effects associated with HA, order of innings and winning the coin toss can then be quantified. Logistic regression techniques will then be employed to gauge the extent to which first innings performance factors such as HA and the establishment of a first innings lead can explain the observed variation in the match outcomes of a win, draw and loss.As was the case with the analysis of ODI cricket (covered in Chapters 4 and 6), in order to account for the possible disparity in team quality effects across time periods the structure of the analysis will constitute ten years of Test match cricket divided into two five-year periods; i.e. 1992-1997 and 1997/98-2001. This includes 328 matches overall, with 177 matches comprising the first five-year period and 151 matches comprising the second period. Due to Bangladesh being a very recent inclusion as a test-playing nation it has been precluded from the study. A very small number of matches were played on neutral grounds and have been removed from the study. Accordingly, all matches under investigation comprise a designated home-country team. A tied outcome is a rare event and consequently all tied results have been excluded from the analysis. Similarly, matches that were either severely truncated or abandoned due to inclement conditions and consequently produced drawn results have also been excluded from the study. In summary, all matches under investigation have produced results that have not been impeded by indeterminate influences.

7.2 Fitting a linear model to the first innings run differentials

7.2.1 Introduction

In modelling Test cricket, attention will be focussed on the first innings only because it can be assumed that a team goes all out to maximise its first innings lead. A team's first innings performance thus provides a reliable measure of its relative strength. As was the case with the modelling of domestic cricket in Chapter 5, penultimate and final innings performances are not explicitly considered because they tend to be more reactionary and lack the consistency of purpose that is more evident in the first innings.

A team's first innings run differential in a Test match played between the team i and team j is modelled as

$$w_{ij} = u_i - u_j + f + t + \varepsilon_{ij} \tag{7.1}$$

where the indices $i, j = 1,\ldots,9$ represent the nine ICC test-playing nations and the response variable w_{ij} signifies the expected first innings margin. The parameter u_i is a measure of the relative ability of team i; the order of innings parameter is f if team i batted first and is $-f$ otherwise; the coin toss parameter is t if team i won the coin toss and is $-t$ otherwise. ε_{ij} is a zero-mean random error with constant variance. If we take account of the HA effect, model (7.1) can be modified to

$$w_{ijk} = u_i - u_j + h_{ik} + f + t + \varepsilon_{ijk} \tag{7.2}$$

where the indices $i, j, k = 1,\ldots,9$ represent the nine ICC test-playing playing nations and the parameter h_{ik} represents the HA effect. When $k = i$, the HA parameter can be modelled as either a common HA, h (7.2a) or a team's individual HA, h_i (7.2b). In the latter case it is assumed that all teams enjoy an advantage that is independent of all other teams irrespective of whether teams compete in the same geographical region or not. To account for any regional effects model (7.1) can be further modified to

$$w_{ijml} = u_i - u_j + r_{lm} + f + t + \varepsilon_{ijml} \quad (7.3)$$

where the indices $l, m = 1, \ldots, 5$ represent the five geographical regions, with team i belonging to region l and team j belonging to region m. The parameter r_{lm} represents the regional effect. When teams i and j belong to different regions $r_{lm} = r_l$ otherwise if $l = m$ $r_{lm} = 0$. Using a design matrix of indicator variables, a least squares regression model is fitted to the differentials. For convenience $\sum_{i=1}^{9} u_i = 900$ to ensure that the average team rating is 100.

7.2.2 Period 1992-1997

In fitting models (7.1), (7.2) and (7.3) to the first innings run differentials for the period 1992-1997 the Anderson-Darling normality test verifies that the residuals are normally distributed. The resulting least squares parameter estimates are provided in Tables 7.1 and 7.2. As was the case with domestic and ODI cricket these in effect represent team ratings relative to the average team rating of 100. Employing the analysis of variance techniques adopted by Harville and Smith (1994), Table 7.3 examines the effectiveness of each of the models. In comparing models (7.1) and (7.2a), with the fitting of a single HA parameter, the latter has performed significantly better than model (7.1). In comparing models (7.1) and (7.2b), with the addition of nine individual HA parameters, the latter has also performed significantly better than model (7.1). In comparing models (7.2a) and (7.2b), with the addition of eight individual HA parameters, the latter has not significantly improved on model (7.2a). Nonetheless, India and Sri Lanka enjoyed a significant first innings HA during this time. Similarly, model (7.3), with the fitting of four additional regional parameters has not improved significantly on model (7.2a). Nevertheless, the teams from the subcontinent region enjoyed a significant runs advantage during this period. In summary, model (7.2a) is the better predictor of the first innings run differentials. The respective estimates for the parameters *h*, *f* and *t* were 31 runs ($p = 0.012$), -8 runs ($p = 0.556$) and 11 runs ($p = 0.412$). From these estimates, it is clear that the home team, on average, enjoyed a substantial runs advantage over its opposition. Conversely, there is no evidence to suggest that teams gained a significant runs advantage by batting first or winning the coin toss. The coefficient of determination, $r^2 = 0.34$ is low, with the model unable to explain 66% of the variation in the innings differentials. This underlines the highly variable nature of Test cricket.

To illustrate how the first innings ratings work, suppose Australia played Zimbabwe at home with Australia winning the coin toss and electing to bat first. From model (7.2a) Australia's expected first innings lead was a substantial $w = 181 + 31 - 8 + 11 - 36 = 179$ runs. However, if the match was played on Zimbabwe's home ground with Zimbabwe winning the coin toss and electing to bat first, its expected first innings lead was $w = 36 + 31 - 8 + 11 - 181 = -111$ runs; i.e. Zimbabwe was expected to trail by 111 runs. The expected first innings leads for all home and away teams are provided in Table 7.4. The bolded value of 34 runs across the diagonal represents the average lead enjoyed by the home team against a team of equal ability, assuming the home team elected to first after winning the coin toss. The row averages represent the average home team leads whereas the column averages represent the average lead enjoyed by the home team when opposed to each away team. The overall dominance of Australia, South Africa, India and the West Indies during this period is clearly evident, with the home performances of each of these teams considerably better than expected. This is reflected in their solid average home leads of 115, 87, 92 and 72 runs respectively, which resulted in home winning percentages of 58%, 47%, 80% and 47% respectively. There is a very strong positive correlation of 0.90 between the first innings ratings and the overall winning percentages ($p = 0.001$). Not unexpectedly, this suggests that first innings relative strength was a strong predictor of a winning outcome during this period. The dominance of each of these teams is also reflected in the column averages of -47, -19, -24 and -4 runs respectively, which suggests that they were also expected to lead on the first innings when playing away from home.

Table 7.1. Least squares parameter estimates for models (7.1), (7.2a) and (7.2b) in Test cricket for the period 1992-1997

Team	*Model (7.1)*	*Model (7.2a)*	*Model (7.2b)*	*Team HA*	*p-value*
Australia	179	181	181	50	0.287
England	73	67	86	13	0.783
India	159	158	111	132	0.031
New Zealand	28	27	30	27	0.608
Pakistan	92	101	119	-34	0.567
South Africa	159	153	179	-4	0.944
Sri Lanka	37	39	-4	122	0.032
West Indies	137	138	197	-78	0.155
Zimbabwe	36	36	2	80	0.274

Table 7.2. Least squares parameter estimates for model (7.3) in Test cricket for the period 1992-1997

Team	*Model (7.3)*	*Region*	*Overall regional advantage*	*p-value*
Australia	199	Region 1	15	0.751
England	77	Region 2	-63	0.253
India	122	Region 3	114	0.008
New Zealand	42	Region 4	0	0.994
Pakistan	70	Region 5	24	0.632
South Africa	161			
Sri Lanka	1			
West Indies	179			
Zimbabwe	49			

Table 7.3. Comparison of models (7.1), (7.2) and (7.3) for Test cricket first innings differentials for the period 1992-1996/97

Model	*Source*	*DF*	*SS*	R^2	*MS*	*F-ratio*	*p-value*
Model (7.1)	Regression	11	1911643	0.31			
Model (7.2a) compared with model (7.1)	Regression	1	156660		156660	6.4	0.012
	Residual error	166	4072876		24535		
Model (7.2b) compared with model (7.1)	Regression	9	427588		47510	2.0	0.043
	Residual error	158	3801948		24063		
Model (7.2a)	Regression	12	2068303	0.34			
Model (7.2b) compared with model (7.2a)	Regression	8	270928		33866	1.4	0.200
	Residual error	158	3801948		24063		
Model (7.3) compared with model (7.2a)	Regression	4	147258		36815	1.5	0.205
	Residual error	162	3925618		24232		
	Total	178	6141179				

Table 7.4. Average (signed) first innings leads in Test cricket for the period 1992-1997

	Team	*Away team*									
		Aust	*Eng*	*Ind*	*NZ*	*Pak*	*SA*	*SL*	*WI*	*Zim*	*Ave.*
Home team	Australia	**34**	148	57	188	114	62	176	77	179	**115**
	England	-80	**34**	-57	74	0	-52	62	-37	65	**1**
	India	11	125	**34**	165	91	39	153	54	156	**92**
	New Zealand	-120	-6	-97	**34**	-40	-92	22	-77	25	**-39**
	Pakistan	-46	68	-23	108	**34**	-18	96	-3	99	**35**
	South Africa	6	120	29	160	86	**34**	148	49	151	**87**
	Sri Lanka	-108	6	-85	46	-28	-80	**34**	-65	37	**-27**
	West Indies	-9	105	14	145	71	19	133	**34**	136	**72**
	Zimbabwe	-111	3	-88	43	-31	-83	31	-68	**34**	**-30**
	Average	**-47**	**67**	**-24**	**107**	**33**	**-19**	**95**	**-4**	**98**	**34**

7.2.3 Period 1997/98-2001

The least squares parameter estimates for the fitting of models to the first innings run differentials are provided in Tables 7.5 and 7.6. Table 7.7 compares the efficacy of each of the models. In summary, for the period 1997/98-2001, model (7.2a) is the better predictor of the first innings run differentials. The respective estimates for the parameters h, f and t were 30 runs ($p = 0.019$), -18 runs ($p = 0.161$) and 0 runs ($p = 0.966$). Notably, teams of the subcontinent region continued to enjoy a significant runs advantage during this period. From these estimates, it is clear that the home team, in general, has continued to enjoy a significant runs advantage over its opposition. However, there is no evidence to suggest that teams were advantaged by batting first or winning the coin toss. The low coefficient of determination, $r^2 = 0.44$ confirms the variable nature of Test cricket.

The expected first innings leads for all home teams in opposition to a team of equal ability are provided in Table 7.8. Throughout the study period Australia and South Africa, in particular, continued to be rated considerably above average, with Sri Lanka and Pakistan a very distant third and fourth. The expected first innings leads for Australia, South Africa, Sri Lanka and Pakistan were 136, 119, 37 and 14 runs respectively. This is reflected in their respective home winning percentages of 77%, 86%, 44% and 25%. The very high average (signed) first innings leads for Australia and South Africa meant that they were consistently in a position of strength at the end of the first innings. Conversely, Zimbabwe's high average first innings deficit meant that it was expected to be in a losing position at the end of the first innings. The negative column averages for Australia, South Africa and Sri Lanka suggests that they teams were also expected to lead on the first innings when playing away from home. There was a moderately strong positive correlation of 0.74 between the first innings ratings and the home winning percentages ($p = 0.023$), which suggests that during this period first innings strength was a moderate predictor of a winning outcome.

Table 7.5. Least squares parameter estimates for models (7.1), (7.2a) and (7.2b) in Test cricket for the period 1997/98-2001

Team	*Model (7.1)*	*Model (7.2a)*	*Model (7.2b)*	*Team HA*	*p-value*
Australia	211	209	213	26	0.612
England	67	67	130	-66	0.196
India	62	58	-8	154	0.019
New Zealand	87	90	93	10	0.869
Pakistan	103	101	113	24	0.689
South Africa	185	194	201	34	0.543
Sri Lanka	129	121	82	90	0.181
West Indies	85	89	61	104	0.058
Zimbabwe	-29	-30	14	-65	0.322

Table 7.6. Least squares parameter estimates for model (7.3) in Test cricket for the period 1997/98-2001

Team	*Model (7.3)*	*Region*	*Overall regional advantage*	*p-value*
Australia	237	Region 1	-68	0.176
England	137	Region 2	102	0.061
India	9	Region 3	130	0.007
New Zealand	104	Region 4	-7	0.878
Pakistan	55	Region 5	-3	0.957
South Africa	221			
Sri Lanka	77			
West Indies	67			
Zimbabwe	-8			

Table 7.7. Comparison of models (7.1), (7.2) and (7.3) for Test cricket first innings differentials for the period 1997/98-2001

Model	*Source*	*DF*	*SS*	R^2	*MS*	*F-ratio*	*p-value*
Model (7.1)	Regression	11	2422263	0.41			
Model (7.2a) compared with model (7.1)	Regression	1	132426		132426	5.6	0.019
	Residual error	140	3316363		23688		
Model (7.2b) compared with model (7.1)	Regression	9	385006		42778	1.8	0.074
	Residual error	132	3063783		23210		
Model (7.2a)	Regression	12	2554689	0.44			
Model (7.3) compared with model (7.2a)	Regression	4	169472		42368	1.8	0.132
	Residual error	136	3146891		23139		
	Total	152	5871052				

Table 7.8. Average (signed) first innings leads in Test cricket for the period 1997/98-2001

	Team	*Away team*									
		Aust	*Eng*	*Ind*	*NZ*	*Pak*	*SA*	*SL*	*WI*	*Zim*	*Ave.*
Home team	Australia	**13**	155	164	132	121	28	101	133	252	**136**
	England	-129	**13**	22	-10	-21	-114	-41	-9	110	**-24**
	India	-138	4	**13**	-19	-30	-123	-50	-18	101	**-34**
	New Zealand	-106	36	45	**13**	2	-91	-18	14	133	**2**
	Pakistan	-95	47	56	24	**13**	-80	-7	25	144	**14**
	South Africa	-2	140	149	117	106	**13**	86	118	237	**119**
	Sri Lanka	-75	67	76	44	33	-60	**13**	45	164	**37**
	West Indies	-107	35	44	12	1	-92	-19	**13**	132	**1**
	Zimbabwe	-226	-84	-75	-107	-118	-211	-138	-106	**13**	**-133**
	Average	**-110**	**50**	**60**	**24**	**12**	**-93**	**-11**	**25**	**159**	**13**

7.3 Comparison of first innings performances across study periods

Table 7.9 provides the first innings team ratings across the two study periods together with the common HA. Both New Zealand and Sri Lanka, coming from a small base, displayed remarkable overall improvement across the study periods. Nevertheless, New Zealand was still rated below par. On the other hand, Sri Lanka moved 21 rating points above average. This possibly highlights the decisive influence of the Sri Lankan spinner Muttiah Muralitheran who, at the time of writing, had recently become the highest wicket taker in Test cricket.

To compare performances across study periods we will contrast the average (signed) first innings leads (by team). Note that we cannot compare the ratings means since, by design, the average rating is 100. The non-parametric Mann-Whitney test confirms that there was essentially no difference in team performance. However, there was some evidence of a significant regional effect during the second study period, with the Australasian region, in particular, displaying a significant runs advantage. This can be best explained by the domination of Australia and the marked improvement in New Zealand's overall performance.

Table 7.9. Comparison of first innings team ratings and the common HA across study periods in Test cricket

Team	*Period*		*Percentage change*
	1992-1997	*1997/98-2001*	
Australia	181	209	Up 15%
England	67	67	No change
India	158	58	Down 63%
New Zealand	27	90	Up 233%
Pakistan	101	101	No change
South Africa	153	194	Up 27%
Sri Lanka	39	121	Up 210%
West Indies	138	89	Down 36%
Zimbabwe	36	-30	Down 183%
Common HA	31 runs	30 runs	Down 3%

7.4 Fitting a multinomial (ordinal) logistic model to the match outcomes

7.4.1 Introduction

In modelling match outcomes in Test cricket the multinomial response variable is categorical; i.e. a win, draw or loss. A multinomial (ordinal) logistic regression model, with the application of the logit link function, will be used to gauge the extent to which the observed variation in the match outcome is critically affected by particular first innings performance measures. A multinomial (ordinal) model is employed because of the order implicit in the response variable. The observed variation in the match outcomes are modelled as a function of its (signed) first innings lead, common home team advantage, regional advantage, the coin toss result and order of innings effect. In conducting the analyses it is assumed that the logit link function and the chosen co-variates are linearly related. If the cumulative conditional probability of a win, draw and loss for Team 1 is denoted by γ_{ijw}, the outcome of a match can be modelled as

$$\ln\left(\frac{\gamma_{ijw}}{1-\gamma_{ijw}}\right) = \beta_{0w} + \beta_1 h + \beta_2 r + \beta_3 x + \beta_4 t + \beta_5 \left(a_i - b_j\right) \qquad (7.4)$$

where $w = 0 \text{ or } 1$ for the respective cumulative probability of a win and draw for Team 1; $h = 1 \text{ or } 0$ signifies whether or not the HA rests with Team 1; x is the (signed) first innings lead of Team 1; $r = 1 \text{ or } 0$ signifies whether or not Team 1 was from a different geographical region than Team 2 and $t = 1 \text{ or } 0$ indicates whether or not Team 1 won the coin toss. The parameter $a_i - b_j$ is the (signed) penultimate and final innings overall rating differential between Team i and Team j for $i, j = 1, \ldots, 9$.

Brooks, Faff and Sokulsky (2002) have also used logistic regression techniques to model the match outcome of a win, draw or loss in Test cricket. By identifying the natural order implicit in the categorical response variable the authors also apply an ordered rather than a nominal response model. The authors attempt to explain the observed variability in the match outcome for each test-playing nation as a function of two team batting variables: ‘batting average’ and ‘attacking batting’; and two team bowling variables: ‘bowling average’ and ‘defensive bowling’. The authors estimate the model parameters by using a probit link function and then calculate the probability of a particular match outcome (win, draw, loss) for any given test match. Note that the fitted value is the match outcome with the maximum probability. The model was able to correctly predict 71% of the match outcomes. By estimating the parameters unique to each test-playing nation the authors were also able to ascertain the general style of play adopted by each team. For example, the model suggests that for the period of the study (1994-1999) Australia was best described by its ‘bowling performance’ whereas England was best described by its ‘batting performance’.

7.4.2 Period 1992-1997

The parameter estimates generated by model (7.4) for the first study period are provided in Table 7.10. Application of the Pearson and deviance goodness-of-fit tests suggests model (7.4) provides an adequate fit of the data. For the period 1992-1997 the establishment of a first innings lead, not surprisingly, was a very strong predictor of a winning outcome. As was discussed in Chapter 4, most teams tended to win after leading on the first innings. However, there is no evidence to suggest that a HA, regional or coin toss effect contributed to a winning outcome. The absence of a HA effect is an unexpected result given that the home team generally enjoyed a significant first innings runs advantage during this period. This suggests that the home team was unable to consistently capitalise on its runs advantage in the penultimate and final innings. The relative strength differential was a modest predictor of a winning outcome during this period. This suggests that during the penultimate and final innings relative team strength was not a significant factor in the shaping of a winning result.

To investigate the respective probabilities of winning, drawing and losing a Test match, model (7.4) can be transposed to give

$$\Pr\left(w=0\,\middle|\,h,\ r,\ x,\ t,\ a_i-b_j\right)=\frac{\exp\left\{\beta_{00}+\beta_1 h+\beta_2 r+\beta_3 h+\beta_4 t+\beta_5\left(a_i-b_j\right)\right\}}{1+\exp\left\{\beta_{00}+\beta_1 h+\beta_2 r+\beta_3 h+\beta_4 t+\beta_5\left(a_i-b_j\right)\right\}}$$

$$\Pr\left(w=1\,\middle|\,h,\ r,\ x,\ t,\ a_i-b_j\right)=\frac{\exp\left\{\beta_{01}+\beta_1 h+\beta_2 r+\beta_3 h+\beta_4 t+\beta_5\left(a_i-b_j\right)\right\}}{1+\exp\left\{\beta_{01}+\beta_1 h+\beta_2 r+\beta_3 h+\beta_4 t+\beta_5\left(a_i-b_j\right)\right\}}$$

The respective probabilities of winning, drawing and losing are subsequently expressed as

$$\Pr\left(\text{Win}\,\middle|\,h,\ r,\ x,\ t,\ a_i-b_j\right)=\Pr\left(w=0\,\middle|\,h,\ r,\ x,\ t,\ a_i-b_j\right)$$

$$\Pr\left(\text{Draw}\,\middle|\,h,\ r,\ x,\ t,\ a_i-b_j\right)=\Pr\left(w=1\,\middle|\,h,\ r,\ x,\ t,\ a_i-b_j\right)-\Pr\left(w=0\,\middle|\,h,\ r,\ x,\ t,\ a_i-b_j\right)$$

$$\Pr\left(\text{Loss}\middle|h,\ r,\ x,\ t,\ a_i - b_j\right) = 1 - \Pr\left(w = 1\middle|h,\ r,\ x,\ t,\ a_i - b_j\right)$$

Assume that in a Test match two equally rated teams from different geographical regions were opposed each other, with Team 1 being the home team. With all things being equal at the completion of the first innings, if the home team wins the coin toss then its probability of winning is

$$\Pr\left(\text{Win}\middle|h = 1,\ r = 1, x = 0,\ t = 1,\ a_i - b_j = 0\right) = \frac{\exp\left(\beta_{00} + \beta_1 + \beta_2 + \beta_4\right)}{1 + \exp\left(\beta_{00} + \beta_1 + \beta_2 + \beta_4\right)}$$

Conversely, if the home team batted second after losing the toss, the probability of the away team winning (i.e. the home team losing) is

$$\Pr\left(\text{Win}\middle|h = 0,\ r = 1, x = 0,\ t = 1,\ a_i - b_j = 0\right) = \frac{\exp\left(\beta_{00} + \beta_2 + \beta_4\right)}{1 + \exp\left(\beta_{00} + \beta_2 + \beta_4\right)}.$$

The respective probability estimates for the home and away teams winning, drawing and losing a Test match against an equally matched team when batting first and second are provided in Table 7.11. In both cases a draw was the most likely result with the home team performing marginally better than the away team when represented as Team 1 and 2. For the home team to have at least a 50% of winning a Test match then

$$\frac{\exp\left(\beta_{00} + \beta_1 + \beta_2 + \beta_3 x + \beta_4\right)}{1 + \exp\left(\beta_{00} + \beta_1 + \beta_2 + \beta_3 x + \beta_4\right)} > 0.5$$

Conversely, if the home team bats second after losing the coin toss we require the probability of the away team losing to be greater than 50%, then

$$1 - \frac{\exp\left(\beta_{01} + \beta_2 + \beta_3 x + \beta_4\right)}{1 + \exp\left(\beta_{01} + \beta_2 + \beta_3 x + \beta_4\right)} > 0.5$$

$$\frac{\exp\left(\beta_{01} + \beta_2 + \beta_3 x + \beta_4\right)}{1 + \exp\left(\beta_{01} + \beta_2 + \beta_3 x + \beta_4\right)} < 0.5$$

The average leads required by the home team if it batted first and second during this period were $x \geq 68$ runs and $x \geq 88$ runs respectively. These results suggest that the home team performed moderately better when represented as Team 1 rather than Team 2. However, in both instances the home team needed to have established at least a sizeable lead in order to have a better than 50% chance of winning.

The effect of the lead on the winning chances of opposing teams is described in Figures 7.1 and 7.2 which display plots of the probabilities of the home team winning, drawing and losing a Test match when batting first and second. Note that Figure 7.1 accounts for average home leads in the range $x \in [-200,\ 200]$ runs whereas Figure7.2 accounts for average away leads in the range $x \in [-200,\ 200]$ runs.

To gauge the efficacy of model (7.4) for the first study period the parameter estimates are generated for the first 89 matches and tested on the remaining 88 matches. The subsequent successful classification rates for both sets are 76% and 74% respectively. When the parameter estimates in Table 7.10 are used for the entire data set the successful classification rate is 71%. The consistency of the results suggests that there is no evidence of any over-fitting and thus model (7.4), for the first study period, is a moderate predictor of a winning match outcome.

Table 7.10. Parameter estimates for the prediction of match outcomes for Team 1 in Test cricket for the period 1992-1997

Parameter	*Term*	*Coefficient*	*Standard error*	*p-value*	*Odds ratio*
β_{00}	Intercept (win)	-1.2090	0.6727	0.072	
β_{01}	Intercept (win and draw)	0.8351	0.6692	0.212	
β_1	Home	0.1936	0.3259	0.552	1.21
β_2	Region	0.2984	0.6051	0.622	1.35
β_3	Lead	0.009803	0.001400	<0.001	1.01
β_4	Coin toss	0.0514	0.3509	0.884	1.05
β_5	$a_i - b_j$	0.003844	0.002200	0.081	1.00

Table 7.11. Probability estimates for the home and away teams represented as Teams 1 and 2 in Test cricket for the period 1992-1997

	Home team			*Away team*		
	Win	*Draw*	*Loss*	*Win*	*Draw*	*Loss*
Team 1	0.34	0.46	0.20	0.30	0.47	0.23
Team 2	0.23	0.47	0.30	0.20	0.46	0.34

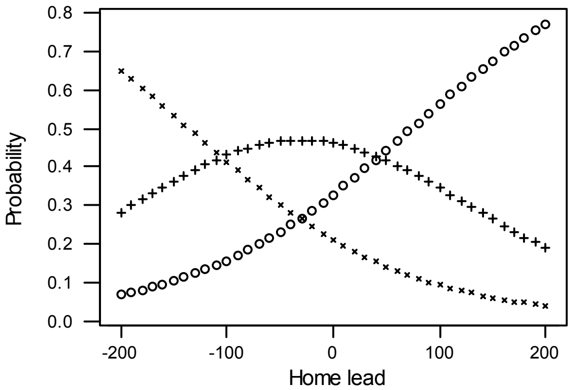

Figure 7.1. The probability that the home team wins (o), draws (+) and loses (×) a Test match when batting first for the period 1992-1997

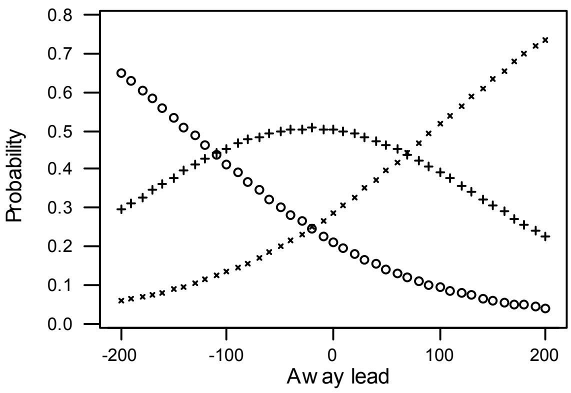

Figure 7.2. The probability that the home team wins (o), draws (+) and loses (×) a Test match when batting second for the period 1992-1997

7.4.3 Period 1997/98-2001

The parameter estimates generated by model (7.4) for the second study period are provided in Table 7.12. The relevant goodness-of-fit tests confirm that the model provides an adequate fit of the data. During this period the first innings lead, HA and relative team strength were all strong predictors of a winning outcome. Note that the odds ratio of 2.23 signifies that the odds of the away team winning were 2.23 times the odds of the away team winning. The home team was able to clearly capitalise on its first innings runs advantage and display a strong winning tendency. It is also apparent that relative team strength was a strong predictor of a winning match outcome. This suggests that relative team strength during the penultimate and final innings was significant in defining a winning result. There is no evidence to suggest that regional or coin toss effects were influential in shaping a winning match outcome.

The probability estimates of the home and away teams winning, drawing and losing when represented as Team 1 and 2 are provided in Table 7.13. This confirms that there was a substantial order of innings effect and accentuates the significant advantage enjoyed by Team 2. Under these conditions the home team's probability of winning when opposed to an equally matched team has, in effect, increased by a considerable 161%. This flies in the face of the conventional wisdom of batting first at all costs. Conversely, these results suggest that by batting second a team was in a position of strength against a team of comparable ability.

To establish whether the advantage can be contrived by electing to bat second after winning the coin toss, the respective probability estimates for the home team winning, drawing and losing under this circumstance were 0.45, 0.36 and 0.19. This suggests that the home team was still a substantial 96% better off when it elected to bat second than when it elected to bat first. It appears that in all circumstances batting second provided a sizeable winning advantage.

The established orthodoxy of electing to bat first after winning the coin toss is clearly under threat. Undoubtedly, Team 2 has displayed a significant winning advantage during this period. The conventional wisdom advocates that teams should bat first after winning the coin toss. It is supposed that this grants a team the opportunity to exploit early favourable conditions. Batting first also protects teams from the vagaries of a fourth innings pitch. This notion probably harks back to the days when wickets were left uncovered and exposed to the elements. Naturally, uncovered wickets quickly deteriorated and so it was customary and sensible during these times to avoid batting last on a 'sticky' wicket. It appears that electing to bat first in contemporary times, with wickets being carefully protected and preserved, is flawed reasoning.

Bhaskar (2003), in his examination of the coin toss in cricket (i.e. both ODI and Test cricket), provides proof that teams, after winning the toss, tend not to make optimal choices, which result in a winning outcome. In making a choice, the author establishes that teams are inclined to overestimate their own strengths and underestimate the strengths of their opponents. This is inferred from the fact that, at the coin toss, there was significant evidence of inconsistency in the decision making process, with teams often acquiescing on who should bat or bowl first.

To highlight this advantage further we can consider the lead required in order for two equally rated sides (from different regions) to have better than 50% chance of winning. If the home side batted first after winning the coin toss it required a lead of the order $x \geq 188$ runs whereas if it batted second, after losing the coin toss, the required range of leads reduces to $x \geq -59$ runs; i.e. the home team could have afforded to trail, on average, by 59 runs. In other words, the home team, when opposed to an equally matched team was 247 runs better off if it batted second. Figures 7.3 and 7.4 display plots of the probabilities of the home team winning, drawing and losing a Test match for average leads in the range $x \in [-200,\ 200]$ runs if it batted first and second after losing the coin toss.

To further examine the order of innings effect refer to Table 7.14, which provides the overall result summary for Teams 1 and 2 during the period of the study. A χ^2 goodness-of-fit test verifies that Team 2, on average, won significantly more matches than expected $\left(\chi_2^2 = 16.7,\ p < 0.001\right)$. Table 7.15 compares the winning capacity of Teams 1 and 2 (by team). The analysis suggests that teams, on average, tended to win more matches than expected when represented as Team 2. When considering individual team performances, however, Table 7.15 suggests that only India, and to a lesser extent, Australia were able to win significantly more matches when represented as Team 2.

To gauge the efficacy of model (7.4) for the second study period the parameter estimates are generated for the first 76 matches and tested on the remaining 75 matches. The subsequent successful classification rates for both sets are 80% and 78% respectively. When the parameter estimates in Table 7.12 are used for the entire data set the successful classification rate is 80%. The consistency of the results suggests that there is no evidence of any over-fitting and thus model (7.4), for the second study period, is a strong predictor of a winning match outcome.

Table 7.12. Parameter estimates for the prediction of match outcomes for Team 1 in Test cricket for the period 1997/98-2001

Parameter	*Term*	*Coefficient*	*Standard error*	*p-value*	*Odds ratio*
β_{00}	Intercept (win)	-1.4305	0.5714	0.012	
β_{01}	Intercept (win and draw)	0.2179	0.5588	0.697	
β_1	Home	0.8011	0.3626	0.027	2.23
β_2	Region	-0.0119	0.5111	0.981	0.99
β_3	Lead	0.006550	0.001367	<0.001	1.01
β_4	Coin toss	-0.5909	0.3590	0.100	0.55
β_5	$a_i - b_j$	0.004984	0.002081	0.017	1.00

Table 7.13. Probability estimates for the home and away teams represented as Teams 1 and 2 in Test cricket for the period 1997/98-2001

	Home team			*Away team*		
	Win	*Draw*	*Loss*	*Win*	*Draw*	*Loss*
Team 1	0.23	0.37	0.40	0.12	0.28	0.60
Team 2	0.60	0.28	0.12	0.40	0.37	0.23

Table 7.14. Overall result summary for teams 1 and 2 in Test cricket for the period 1997/98-2001

	Win	*Draw*	*Loss*
Team 1	39	38	74
Team 2	74	38	39
Total	113	76	113

Table 7.15. Overall result summary (by nation) for teams 1 and 2 in Test cricket for the period 1997/98-2001

Nation	*Team 1*			*Team 2*			χ_2^2 *value*	*p-value*
	Win	*Draw*	*Loss*	*Win*	*Draw*	*Loss*		
Australia	10	5	6	19	1	1	2.8	0.095
England	4	6	11	10	5	8	2.8	0.109
India	1	5	8	7	3	3	4.5	0.034
New Zealand	3	4	7	5	7	4	0.5	0.480
Pakistan	3	3	10	5	5	4	0.5	0.480
South Africa	10	6	2	11	6	3	0.0	0.827
Sri Lanka	4	2	6	7	4	3	0.8	0.366
West Indies	3	2	13	8	4	10	2.3	0.132
Zimbabwe	1	5	11	2	3	3	0.3	0.564
Total	39	38	74	74	38	39		

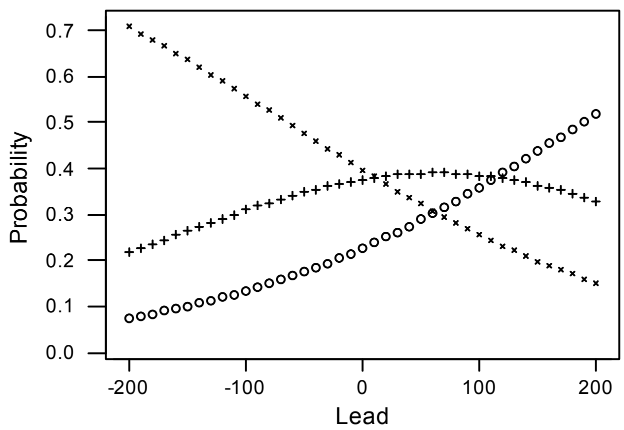

Figure 7.3. The probability that the home team wins (o), draws (+) and loses (×) a Test match when batting first for the period 1997/98-2001

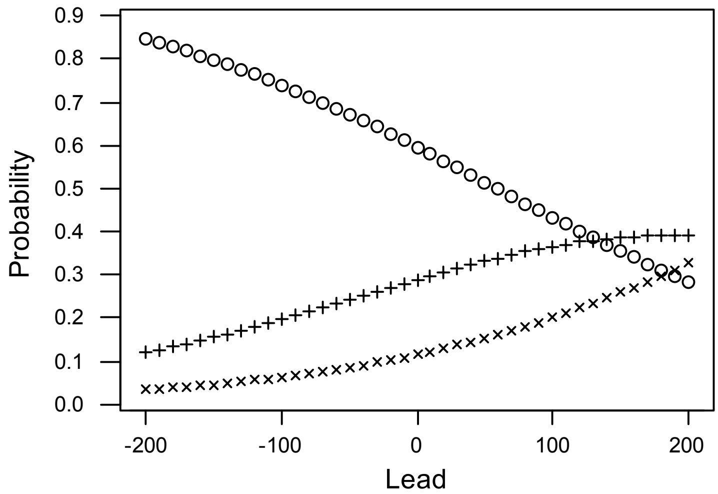

Figure 7.4. The probability that the home team wins (o), draws (+) and loses ($\times$) a Test match when batting second for the period 1997/98-2001

7.5 Quantifying the effect of batting second

In order to examine whether the winning trend for Team 2 has continued beyond the 1997/98-2001 study period the ensuing 80 match results can be added to the data base. This extends the study period up to the 2002/03 Australasian season and constitutes 231 matches.

The least squares parameter estimates resulting from the fitting of models (7.1), (7.2) and (7.3) to the first innings run differentials for the period 1997/98-2002/03 are provided in Tables 7.16 and 7.17. The Anderson-Darling test confirms that the normality assumption has not been breached. Table 7.18 compares the efficacy of each of the models, which suggests that Model (7.2a) provides the best fit of the data. The parameter estimates for the HA effect, batting first and winning the coin toss are 30 runs ($p = 0.007$), 0 runs ($p = 0.976$) and 10 runs ($p = 0.395$) respectively. Clearly, there was a significant HA effect during this extended study period. Notably, Australia has dramatically increased its dominance in Test cricket and was rated a considerable 65 rating points ahead of the next best ranked team and 142 rating points better than average. India was rated substantially below average but its highly significant average HA of 118 runs ensured that it generally performed well at home. Sri Lanka was rated marginally better average and together with its high average HA of 115 runs meant that it also exercised a strong home potency. Regional effects, in general, were not significant. Nonetheless, the sub-continental teams enjoyed a significant run-scoring capacity when playing teams from outside the region.

The fitting of model (7.4) to the match outcomes for the extended period generated the parameter estimates provided in Table 7.19. The relevant goodness-of-fit tests suggest that the model provides an adequate fit of the data. The results suggest that a team’s first innings lead, the HA effect and relative team strength were all very strong predictors of a winning match outcome. There is no evidence to suggest that regional effects and winning the coin toss had a significant effect on a winning match outcome. Nonetheless, the negative coefficient for the coin toss parameter intimates that the team winning the coin toss displayed a tendency to lose.

With two equally rated teams (from different regions) opposed to each other and with all things being equal at the end of the first innings, the respective probabilities of the home and away teams winning, drawing and losing being represented as Team 1 and 2 are provided in Table 7.20. The results suggest that the advantage enjoyed previously by Team 2 was still substantial. When represented as Team 2 the home and away teams, on average, were able to respectively perform a substantial 92% and 136% better than when represented as Team 1. As a consequence, Team 2 has continued to be in a position of strength against a team of comparable ability. When the home team elected to bat second after winning the coin toss, the respective probability estimates for the home team winning, drawing and losing were 0.43, 0.43 and 0.14. This suggests that the home team was still a sizeable 65% better off than when it elected to bat first. It appears that batting second, in general, has continued to provide a very strong winning advantage.

To quantify the order of innings effect further we can fit a multinomial (ordinal) logistic model to the home results. If the cumulative conditional probability of a win, draw and loss is denoted by γ_{ijw} for the home team, the outcome of a match can now be modelled as

$$\ln\left(\frac{\gamma_{ijw}}{1-\gamma_{ijw}}\right) = \beta_{0w} + \beta_1 s + \beta_2 r + \beta_3 x + \beta_4 t + \beta_5\left(m_i - n_j\right) \qquad (7.5)$$

where $s = 1$ or 0 signifies whether or not the home team batted second and $m_i - n_j$ represents the rating differential between the home and away teams. The parameter estimates generated by fitting model (7.5) to the match outcomes are provided in Table 7.21. The results confirm that Team 2 enjoyed a significant winning advantage during the extended period, with the average odds of Team 1 winning being a sizeable 2.1 times the odds of Team 2 winning. Note that the region effect parameter is positive and highly significant. However, this is confounded by the fact that the home team invariably plays in its home region. As a consequence, one would expect there to be a significant interaction effect between the regional and home parameters. This is confirmed by re-generating model (7.4) with the inclusion of the interaction effect (Home * Region), which produces a highly significant result. Not surprisingly, since the HA effect during this extended period was significant, the home team, when opposed to teams from different regions, displayed a strong winning tendency.

Table 7.16. Least squares parameter estimates for models (7.1), (7.2a) and (7.2b) in Test cricket for the period 1997/98-2001-2002/03

Team	*Model (7.1)*	*Model (7.2a)*	*Model (7.2b)*	*Team HA*	*p-value*
Australia	244	242	265	3	0.948
England	88	85	120	-28	0.507
India	52	54	17	118	0.018
New Zealand	86	90	112	-14	0.794
Pakistan	125	120	122	32	0.565
South Africa	171	177	189	-5	0.916
Sri Lanka	116	109	53	115	0.043
West Indies	80	81	59	87	0.054
Zimbabwe	-62	-59	-39	-6	0.920

Table 7.17. Least squares parameter estimates for model (7.3) in Test cricket for the period 1997/98-2001-2002/03

Team	*Model (7.3)*	*Region*	*Overall regional advantage*	*p-value*
Australia	283	Region 1	-28	0.516
England	123	Region 2	82	0.066
India	17	Region 3	119	0.002
New Zealand	119	Region 4	-24	0.536
Pakistan	75	Region 5	-4	0.912
South Africa	192			
Sri Lanka	61			
West Indies	67			
Zimbabwe	-37			

Table 7.18. Comparison of models (7.1), (7.2) and (7.3) for Test cricket first innings differentials for the period 1997/98-2001-2002/03

Model	*Source*	*DF*	*SS*	R^2	*MS*	*F-ratio*	*p-value*
Model (7.1)	Regression	11	3813374	0.38			
Model (7.2a) compared with model (7.1)	Regression	1	204772		204772	7.5	0.007
	Residual error	220	6008931		27313		
Model (7.2a)	Regression	12	4018146	0.40			
Model (7.2b) compared with model (7.2a)	Regression	8	286838		35855	1.3	0.245
	Residual error	212	5722093		26991		
Model (7.3) compared with model (7.2a)	Regression	4	247455		61864	0.4	0.809
	Residual error	216	5761476		26674		
	Total	232	10027077				

Table 7.19. Parameter estimates for the prediction of match outcomes for Team 1 in Test cricket for the period 2001/02-2002/03

Parameter	*Term*	*Coefficient*	*Standard error*	*p-value*	*Odds ratio*
β_{00}	Intercept (win)	-1.6853	0.5094	0.001	
β_{01}	Intercept (win and draw)	0.0887	0.4947	0.858	
β_1	Home	0.7458	0.2947	0.011	2.11
β_2	Region	0.1800	0.4623	0.697	1.20
β_3	Lead	0.007980	0.00113	<0.001	1.01
β_4	Coin toss	-0.2844	0.2968	0.338	0.75
β_5	$a_i - b_j$	0.003446	0.001565	0.028	1.00

Table 7.20. Probability estimates for the home and away teams represented as Teams 1 and 2 in Test cricket for the period 1997/98-2002/03

	Home team			*Away team*		
	Win	*Draw*	*Loss*	*Win*	*Draw*	*Loss*
Team 1	0.26	0.41	0.33	0.14	0.26	0.50
Team 2	0.50	0.26	0.14	0.33	0.41	0.26

Table 7.21. Parameter estimates for the prediction of match outcomes for the home team in Test cricket for the period 2001/02-2002/03

Parameter	*Term*	*Coefficient*	*p-value*	*Odds ratio*
β_{00}	Intercept (win)	-1.7162	<0.001	
β_{01}	Intercept (win and draw)	0.0925	0.843	
β_1	Second	0.7431	0.014	2.10
β_2	Region	1.1134	0.016	3.04
β_3	Lead	0.008110	<0.001	1.01
β_4	Coin toss	-0.3489	0.243	0.71
β_5	$m_i - n_j$	0.003630	0.023	1.00

7.6 Conclusions

In fitting a multiple linear regression model to the first innings margins it was established that there was a common HA effect throughout both study periods, with the home team enjoying a significant runs advantage over its opposition. This duly helped the home team to establish a significant first innings lead. Not surprisingly, a team's first innings lead was shown to be a very strong predictor of a winning match outcome during the second study period. Conversely, there was no evidence to suggest that teams were advantaged by either batting first or winning the coin toss. Even though the home team enjoyed a significant first innings runs advantage during the first study period this did not generally translate into a winning outcome. This suggests that penultimate and final innings factors possibly played a prominent role in defining match results. The resulting least squares ratings also provided a measure of a team's overall strength relative to the average team rating of 100. It was ascertained that Australia and South Africa emerged as the stand out nations, with both teams performing substantially better than average.

It was established that the sub-continent teams in general enjoyed a significant first innings runs advantage. This could be put down to the fact that teams in this region were in the best position to exploit unique local playing conditions.

In fitting a multinomial (ordinal) logistic model to the match outcomes it was established that there was a significant overall HA effect across both study periods. This underlines the benefit in being able to exploit local conditions. Cricket is played in a broad range of geographical locations and as a result, pitch conditions can vary markedly. For example, the dry wickets of the sub-continent are predisposed to spin bowlers whereas the harder wickets in Australia tend to favour quicker bowlers. In both cases, the conditions in essence suit players that can best exploit these conditions. This underscores Australia's dominance as it was able to perform consistently well in a variety of conditions.

During the second study period there was strong evidence suggesting that Team 2 rather than Team 1 was in a position of strength and as a consequence displayed a strong winning tendency. This flies in the face of conventional thinking which discourages teams from batting second (and hence generally last) if it wins the coin toss. There was substantial evidence suggesting that this trend continued beyond the second study period. Not surprisingly, the HA effect and the first innings lead also continued to be strong predictors of a winning match outcome.

Comparison of the Test and ODI ratings across study periods suggest that any correlation between team strength was marginal. For the first study period the correlation coefficient was 0.426 ($p = 0.253$) whereas for the ensuing period the correlation coefficient increased slightly to 0.632 ($p = 0.068$). These results suggest that Test team strength is not necessarily a strong predictor of ODI team strength and vice versa. This underscores the fact that teams, in general, are more effective at playing one form of the game more so than the other.

CHAPTER 8
AN ATTACK AND DEFENCE MODEL FOR ODI CRICKET

8.1 Introduction

Cricket has two distinct phases: batting and bowling, each of which provide an indication of a team's attacking and defensive capabilities. Generally, the objective of the batting team is to utilise its attacking prowess and maximise its score by making as many runs as possible whereas the bowling team endeavours to utilise its defensive powers and optimise its performance by restricting the batting team to as low a score as possible. In ODI cricket there are two innings only, with a win or loss being the most likely outcome. A match outcome can be construed as the combined effect of the batting (attacking) and bowling (defensive) capabilities of the respective teams.

In Chapter 6, when quantifying the affect of specific innings performance factors in ODI cricket the (signed) innings differential was used as the response variable in a multiple linear regression model. This represented the combined strength differential between the competing teams. Least squares ratings were then generated to provide a measure of a team's relative overall strength. The model did not distinguish between batting or bowling strength. To differentiate between the effect of a team's relative attacking and defensive strength the response variable in a multiple linear regression model will be the actual scores, which represent the combined outcome of the competing team's batting and bowling capabilities. The subsequent batting and bowling ratings can then be used to pinpoint a team's specific strength. Ordinal logistic regression techniques will then be applied to gauge, among other effects, the degree to which a team's batting and bowling strength can explain the observed variation in the match outcomes.

The analysis of the attacking and defensive capabilities of sporting teams has been conducted in some sports such as rugby league and soccer but generally has attracted only a passing interest. This is surprising given the obvious attacking and defensive forms evident in many sports including cricket. Lee (1999) used a bivariate negative binomial regression model to account for the attacking and defensive capabilities of teams in rugby league and concluded that a team's ability to defend was more important than their offensive capabilities. Dixon and Coles (1997) also incorporated attacking and defensive parameters in a bivariate Poisson model when modelling scores in English soccer and found that the teams higher on the league table had the higher average attack and defence ratings.

8.2 Fitting a linear attack and defence model to the innings scores

8.2.1 Introduction

The innings scores in an ODI match played between the batting team i and the bowling team j can be modelled as

$$s_{ij} = A + a_i - b_j + t + n_{\text{bat}} + n_{\text{bowl}} + d + \varepsilon_{ij} \tag{8.1}$$

where the indices $i, j = 1, \ldots, 9$ represent the nine ICC test-playing nations and the response variable s_{ij} denotes the expected first innings score. The intercept A represents the expected score between two average teams on a neutral ground and a_i and b_j signify the batting and bowling ratings of teams i and j respectively. The coin toss parameter is t if team i wins the coin toss and is 0 otherwise; the batting day/night parameter is n_{bat} if team i batted second (under lights) in a day/night match and is 0 otherwise; the bowling day/night parameter is n_{bowl} if team i bowled second in a day/night match and is 0 otherwise. d signifies whether team i batted second and is 0 otherwise. ε_{ij} is a zero-mean random error with constant variance. If we also take account of the HA effect in a match between the batting team i and the bowling team j on ground k then model (8.1) can be modified to

$$s_{ijk} = u_i - u_j + h_{ik} + t + n_{\text{bat}} + n_{\text{bowl}} + d + \varepsilon_{ijk} \tag{8.2}$$

The parameter h_{ik} represents the HA effect. When $k = i$, the HA parameter can be modelled as either a common HA, h (8.2a) or a team's individual batting HA, h_i (8.2b) and is 0 otherwise. For model (8.2) it is assumed that all teams enjoy an advantage that is independent of all other teams irrespective of whether teams compete in the same geographical region or not. If we also account for any regional effects in a match between the batting team i and the bowling team j in home region m or away region l then model (8.1) can be modified to

$$s_{ijlm} = A + a_i - b_j + r_{lm} + t + n_{\text{bat}} + n_{\text{bowl}} + d + \varepsilon_{ijlm} \tag{8.3}$$

where the indices $l, m = 1, \ldots, 5$ represent the five geographical regions, with team i belonging to region l and team j belonging to region m. The parameter r_{lm} represents the resultant regional batting and bowling effect. When teams i and j belong to different regions $r_{lm} = r_l$ otherwise if $l = m$ $r_{lm} = 0$. Using a design matrix of indicator variables, a least squares regression model is fitted to the innings scores. For convenience, $\sum_{i=1}^{9} a_i = 900$ and $\sum_{j=1}^{9} b_j = 900$, which ensures that the average batting and bowling ratings are each 100. Accordingly, ratings above and below this figure provide evidence on how well a team has performed relative to the average performance as both a batting and bowling team. In summary, the above models attempt to quantify the degree to which a team's batting and bowling strength; the HA effect; playing in particular geographical regions; winning the coin toss; batting and bowling at night (in day/night fixtures) and batting second explain the observed variation in the innings scores.

8.2.2 Period 1992/93-1997

In fitting models (8.1), (8.2) and (8.3) to the innings scores for the first five-year period of the study we obtain the least squares parameter estimates presented in Tables 8.1 and 8.2. These essentially represent the respective batting and bowling ratings relative to the average rating of 100. The Kolmogorov-Smirnov normality test suggests that the residuals generated by each model are normally distributed.

Employing the analysis of variance techniques adopted by Harville and Smith (1994), Table 8.2 examines the effectiveness of each of the models. It follows that model (8.2b), with the inclusion of eight individual HA parameters provides the best fit of the innings scores. The least squares parameter estimates for A, t, n_{bat}, n_{bowl} and d are 216 runs, 3 runs ($p = 0.480$), 1 run ($p = 0.912$), 5 runs ($p = 0.511$) and -14 runs ($p = 0.005$) respectively. There is strong evidence suggesting that Team 2, on average, tended to score significantly less runs than expected. This may have been due to tiredness or the psychological effects associated with chasing a total. The model also suggests that Australia, on average, scored significantly less runs than expected on its home ground whereas England, India, Pakistan and the West Indies tended to score significantly more runs than expected when playing at home. Model (8.3) did not provide the best fit of the scores but it does suggest that teams from England, the West Indies and the sub-continental regions tended to score significantly more runs than expected when opposed to teams from different geographical regions. Conversely, teams from the Australasian region generally scored significantly less runs than expected when playing teams from different regions.

The batting and bowling ratings can be used to calculate a combined rating, which provides a measure of a team's overall strength. It is calculated as

$$\begin{aligned}\text{Combined rating} &= 100 + (\text{Batting rating} - 100) + (\text{Bowling rating} - 100) \\ &= \text{Batting rating} + \text{Bowling rating} - 100\end{aligned}$$

Table 8.4 provides a summary of the batting, bowling and combined ratings together with the overall winning percentages pro-rated to an average rating of 100. During this period it is apparent that, in the main, teams were evenly matched. Thus, it would be expected that the match outcomes would have been highly variable, with random effects being a contributing factor in defining match outcomes. Nonetheless, Australia, New Zealand and Sri Lanka were each rated at least better than average in both the batting and bowling departments. Conversely, Zimbabwe was rated substantially below average, especially as a bowling team. There is a modest positive correlation of 0.66 ($p = 0.054$) between the combined ratings and the actual overall winning percentages. This implies that, in general, teams were unable to consistently capitalise on their relative overall strength. However, if we compare the separate batting and bowling ratings with the actual overall winning percentages the correlation coefficients are 0.25 ($p = 0.510$) and 0.85 ($p\text{-value} = 0.003$)

respectively. This suggests that a team's bowling proficiency was the substantially stronger indicator of a team's winning potential. Figure 8.1 provides boxplots of the batting, bowling and combined ratings together with the overall winning percentages (pro-rated to an average rating of 100). The plots highlight the degree to which Zimbabwe underperformed during this period. Its bowling prowess, in particular, was significantly below expectations. This is underscored by its very low overall winning percentage.

To illustrate how the ratings work suppose that Australia plays Zimbabwe in an ODI match on a neutral ground. Australia's batting rating of 118 suggests that it generally performed 18 runs better than expected against an average team. Whereas Zimbabwe's bowling rating of 77 suggests that, when bowling, it generally performed 23 runs worse than expected. Thus its opponents were expected to score 23 runs more than average. Thus, Australia batting against Zimbabwe's bowling attack would be expected to score $18+23=41$ runs more than average. Similarly, Zimbabwe batting against Australia's bowling attack would be expected to score $1+10=11$ fewer runs than average. Thus we would expect Australia to defeat Zimbabwe on a neutral ground by a considerable $41+11=52$ runs. This margin can also be obtained by subtracting the combined rating of Zimbabwe from that of Australia; i.e. $119-67=52$ runs.

Table 8.1. Least squares parameter estimates for models (8.1), (8.2a) and (8.2b) in ODI cricket for the period 1992/93-1997

Team		*Model (8.1)*	*Model (8.2a)*	*Model (8.2b)*	*Overall team HA*	*p-value*
Australia	Bat	105	105	118	-24	0.031
England	Bat	104	106	99	42	0.025
India	Bat	103	102	85	36	0.001
New Zealand	Bat	93	93	109	-19	0.109
Pakistan	Bat	99	100	93	32	0.011
South Africa	Bat	100	98	90	17	0.177
Sri Lanka	Bat	109	109	119	-13	0.302
West Indies	Bat	104	105	96	28	0.028
Zimbabwe	Bat	82	82	90	-10	0.535
Australia	Bowl	100	100	101		
England	Bowl	100	102	102		
India	Bowl	97	96	98		
New Zealand	Bowl	104	104	104		
Pakistan	Bowl	100	101	100		
South Africa	Bowl	111	109	109		
Sri Lanka	Bowl	101	100	100		
West Indies	Bowl	110	111	109		
Zimbabwe	Bowl	76	76	77		

Table 8.2. Least squares parameter estimates for model (8.3) in ODI cricket for the period 1992/93-1997

Team		*Model (8.3)*	*Region*	*Overall regional advantage*	*p-value*
Australia	Bat	115	Region 1	28	0.031
England	Bat	99	Region 2	41	0.028
India	Bat	96	Region 3	22	0.004
New Zealand	Bat	106	Region 4	-17	0.033
Pakistan	Bat	98	Region 5	6	0.540
South Africa	Bat	99			
Sri Lanka	Bat	106			
West Indies	Bat	97			
Zimbabwe	Bat	83			
Australia	Bowl	104			
England	Bowl	104			
India	Bowl	96			
New Zealand	Bowl	105			
Pakistan	Bowl	99			
South Africa	Bowl	110			
Sri Lanka	Bowl	97			
West Indies	Bowl	109			
Zimbabwe	Bowl	77			

Table 8.3. Comparison of models (8.1), (8.2) and (8.3) for the innings scores in ODI cricket for the period 1992/93-1997

Model	*Source*	*DF*	*SS*	R^2	*MS*	*F-ratio*	*p-value*
Model (8.1)	Regression	23	26085865	0.46			
Model (8.2a) compared with model (8.1)	Regression	1	6184		6184	2.8	0.095
	Residual error	510	1134421		2224		
Model (8.2b) compared with model (8.1)	Regression	9	79228		8803	4.2	<0.001
	Residual error	502	1061377		2114		
Model (8.3) compared with model (8.1)	Regression	5	48882		9776	4.5	0.001
	Residual error	506	1091723		2158		
Model (8.3)	Regression	28	26134747	0.49			
Model (8.2b) compared with model (8.3)	Regression	4	30346		7587	3.6	0.007
	Residual error	502	1061377		2114		
	Total	534	27226470				

Table 8.4. Team ratings in ODI cricket for the period 1992/93-1997

Team	*Batting rating*	*Bowling rating*	*Combined rating*	*Overall winning % pro-rated to an average rating of 100*
Australia	118	101	119	110
England	99	102	101	97
India	85	98	83	103
New Zealand	109	104	113	87
Pakistan	93	100	93	116
South Africa	90	109	99	120
Sri Lanka	119	100	119	120
West Indies	96	109	105	112
Zimbabwe	90	77	67	35

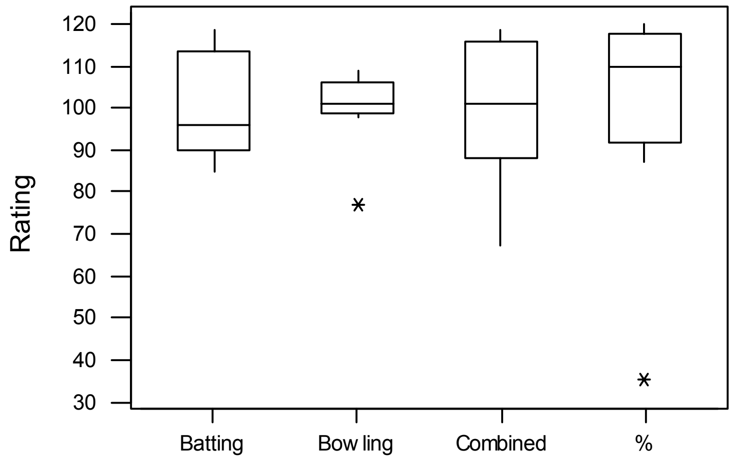

Figure 8.1. Boxplots of the distribution of ratings and overall winning percentages in ODI cricket for the period 1992/93-1997

8.2.3 Period 1997/98-2001

In fitting models (8.1), (8.2) and (8.3) to the innings scores for the second five-year period of the study we obtain the least squares parameter estimates presented in Tables 8.5 and 8.6. The relevant tests suggest that the residuals are normally distributed.

Using analysis of variance techniques, Table 8.6 compares models (8.1), (8.2) and (8.3). In summary, model (8.3), with the inclusion of the five regional parameters provides the best fit of the innings scores. The least squares parameter estimates for A, t, n_{bat} , n_{bowl} and d are 220 runs, 0 runs ($p = 0.966$), -5 runs ($p = 0.529$), 4 runs ($p = 0.546$) and 11 runs ($p = 0.143$) respectively. It was apparent during this period that teams from the sub-continental regions enjoyed a significant scoring advantage when opposed to teams from different geographical regions. In support of this, Model (8.2b) suggests that India and Pakistan, in particular, tended to score significantly more runs than expected when playing at home. There was no evidence to suggest that Team 2 was disadvantaged during this period.

Table 8.7 provides a summary of the batting, bowling and combined ratings, together with the overall winning percentages pro-rated to an average rating of 100. Undoubtedly, Australia and South Africa performed considerably better than expected during this period, with both teams emerging as relatively much stronger teams. They were rated significantly above average in both the batting and bowling departments. England, Pakistan and Sri Lanka performed better than expected with the ball but modestly underperformed with the bat. Zimbabwe performed significantly below expectations with the ball but displayed some improvement as a batting team. There is a large disparity between the batting and bowling rankings of England and Pakistan. In both instances bowling strength was far more effective than batting proficiency.

There is a very strong positive correlation of 0.86 ($p\text{-value} = 0.003$) between the combined ratings and the actual overall winning percentages. This implies that teams, in general, were able to consistently capitalise on their overall strength. If we compare the separate batting and bowling ratings with the actual overall winning percentages the correlation coefficients are 0.62 ($p = 0.073$) and 0.79 ($p = 0.011$) respectively. This suggests that as was the case with the previous study period, a team's bowling prowess more so than its batting strength was the stronger indicator of its winning potential. This trend is a surprising outcome given that one-day cricket is generally perceived as favouring the stronger batting teams.

Table 8.5. Least squares parameter estimates for models (8.1), (8.2a) and (8.2b) in ODI cricket for the period 1997/98-2001

Team		*Model (8.1)*	*Model (8.2a)*	*Model (8.2b)*	*Overall team HA*	*p-value*
Australia	Bat	116	115	119	9	0.476
England	Bat	83	83	90	0	0.984
India	Bat	114	115	106	33	0.019
New Zealand	Bat	97	96	91	23	0.114
Pakistan	Bat	98	99	87	46	0.005
South Africa	Bat	106	105	116	-4	0.781
Sri Lanka	Bat	111	111	111	15	0.266
West Indies	Bat	88	88	83	30	0.081
Zimbabwe	Bat	87	88	98	-10	0.469
Australia	Bowl	115	114	116		
England	Bowl	111	111	112		
India	Bowl	85	85	86		
New Zealand	Bowl	90	89	90		
Pakistan	Bowl	100	101	102		
South Africa	Bowl	121	120	120		
Sri Lanka	Bowl	106	106	103		
West Indies	Bowl	98	98	96		
Zimbabwe	Bowl	75	76	76		

Table 8.6. Least squares parameter estimates for model (8.3) in ODI cricket for the period 1997/98-2001

Team		*Model (8.3)*	*Region*	*Overall regional advantage*	*p-value*
Australia	Bat	118	Region 1	30	0.074
England	Bat	92	Region 2	0	0.996
India	Bat	98	Region 3	36	<0.001
New Zealand	Bat	98	Region 4	13	0.187
Pakistan	Bat	89	Region 5	-7	0.458
South Africa	Bat	121			
Sri Lanka	Bat	99			
West Indies	Bat	84			
Zimbabwe	Bat	102			
Australia	Bowl	114			
England	Bowl	110			
India	Bowl	90			
New Zealand	Bowl	90			
Pakistan	Bowl	104			
South Africa	Bowl	116			
Sri Lanka	Bowl	109			
West Indies	Bowl	94			
Zimbabwe	Bowl	72			

Table 8.7. Comparison of models (8.1), (8.2) and (8.3) for the innings scores in ODI cricket for the period 1997/98-2001

Model	*Source*	*DF*	*SS*	R^2	*MS*	*F-ratio*	*p-value*
Model (8.1)	Regression	23	29561299	0.45			
Model (8.2a) compared with model (8.1)	Regression	1	24348		24348	9.1	0.003
	Residual error	474	1260643		2660		
Model (8.2b) compared with model (8.1)	Regression	9	58278		6475	2.5	0.008
	Residual error	466	1226713		2632		
Model (8.3) compared with model (8.1)	Regression	5	53980		10796	4.1	0.001
	Residual error	470	1231011		2619		
Model (8.2a)	Regression	24	29585647	0.46			
Model (8.2b) compared with model (8.2)	Regression	8	33930		4241	1.6	0.122
	Residual error	466	1226713		2632		
Model (8.3) compared with model (8.2a)	Regression	4	29632		7408	2.8	0.026
	Residual error	470	1231011		2619		
	Total	498	30846290				

Table 8.8. Team ratings in ODI cricket for the period 1997/98-2001

Team	*Batting rating*	*Bowling rating*	*Combined rating*	*Overall winning % pro-rated to an average rating of 100*
Australia	118	114	132	148
England	92	110	102	81
India	98	90	88	113
New Zealand	98	90	88	77
Pakistan	89	104	93	86
South Africa	121	116	137	142
Sri Lanka	99	109	108	129
West Indies	84	94	78	84
Zimbabwe	102	72	74	40

Figure 8.2. Boxplots of the distribution of ratings and overall winning percentages in ODI cricket for the period 1997/98-2001

8.3 Fitting a multinomial (ordinal) logistic model to the match outcomes

To investigate the degree to which a range of factors including a team's batting and bowling strength affect match outcomes we can fit a binary logistic model to the match outcome of a win or a loss. If the conditional probability of Team 1 winning or losing is denoted by γ_{ij}, the outcome of an ODI match can be modelled as

$$\ln\left(\frac{\gamma_{ij}}{1-\gamma_{ij}}\right)=\beta_0+\beta_1 h+\beta_2 r+\beta_3 n+\beta_4 t+\beta_5\left(a_i-b_j\right)+\beta_6\left(a_j-b_i\right) \qquad (8.4)$$

where $h=1 \text{ or } 0$ signifies whether or not the HA rests with Team1; $r=1 \text{ or } 0$ signifies whether or not Team 1 was from a different geographical region than Team 2; $n=1 \text{ or } 0$ indicates whether or not Team 1 played in a day/night match and $t=1 \text{ or } 0$ signifies whether or not Team 1 won the coin toss. For $i, j=1,\ldots,9$, the parameter a_i-b_j is the (signed) rating differential between the batting team i and the bowling team j and a_j-b_i is the (signed) rating differential between the batting team j and the bowling team i. Tables 8.9 and 8.10 provide the parameter estimates for the respective study periods.

The results suggest that across study periods there was a highly significant HA winning effect. The scoring ability for the home team, however, was only moderately during the first study period. This suggests that even a modest scoring advantage for the home team has not stopped it from having a strong winning advantage. The strength differential between Team 1's batting and Team 2's bowling was a strong predictor of a winning match outcome during the first study period, with Team 1's batting being superior to Team 2's bowling. In contrast, there was no evidence to suggest that Team 2's batting was superior to Team 1's bowling. This confirms that batting strength more so than bowling strength was the better predictor of a winning match outcome during this period. This supports the conventional notion that the stronger batting teams are generally the better performers in one-day cricket. For the second study period, however, there is no evidence to suggest that Team 1's batting strength was superior to Team 2's bowling strength. Conversely, the strength differential between Team 2's batting and Team 1's bowling was a very strong predictor of a losing outcome. This confirms that bowling strength more so than batting strength contributed to a winning result during this period. This is a surprising outcome which flies in the face of the conventional wisdom, which suggests that ODI cricket is contrived to favour the stronger batting teams.

To test the efficacy of model (8.4) for the first study period the successful classification rates for the training and test sets are 54% and 46% respectively. When the parameter estimates in Table 8.9 are used to predict the match outcomes for the entire data set the successful classification rate is 55%. For the second study period the respective successful classification rates for both sets are 52% and 50%. When the parameter estimates in Table 8.9 are used for the entire data set the successful classification rate is 52%. The consistency of the results across both study periods suggests that there is no evidence of any over-fitting and thus model (8.4) is a modest predictor of a winning match outcome.

Table 8.9. Parameter estimates for the prediction of match outcomes for Team 1 in ODI cricket for the period 1992/93-1997

Parameter	*Term*	*Coefficient*	*Standard error*	*p-value*	*Odds ratio*
β_0	Intercept term	-0.3927	0.3243	0.226	
β_1	Home	0.8920	0.2604	0.001	2.44
β_2	Region	-0.0931	0.3061	0.761	0.91
β_3	Day/night	-0.0073	0.2627	0.978	0.99
β_4	Coin toss	0.2937	0.2958	0.321	1.34
β_5	$a_i - b_j$	0.021028	0.009553	0.028	1.02
β_6	$a_j - b_i$	-0.006733	0.009199	0.464	0.99

Table 8.10. Parameter estimates for the prediction of match outcomes for Team 1 in ODI cricket for the period 1997/98-2001

Parameter	*Term*	*Coefficient*	*Standard error*	*p-value*	*Odds ratio*
β_0	Intercept term	-0.8420	0.4385	0.055	
β_1	Home	0.8846	0.2895	0.002	2.42
β_2	Region	0.4749	0.3952	0.229	1.61
β_3	Day/night	0.1499	0.3045	0.623	1.16
β_4	Coin toss	-0.2002	0.2896	-0.2002	0.82
β_5	$a_i - b_j$	0.013961	0.008535	0.102	1.01
β_6	$a_j - b_i$	-0.035815	0.008797	<0.001	0.96

8.4 Estimating probabilities

8.4.1 Introduction

Since the residuals generated by models (8.1), (8.2) and (8.3) are normally distributed and since we know the standard deviation, the normal distribution can be used to estimate the expected winning probabilities of the opposing teams.

If Team 1 score ~ $N\left(\mu_2,\, \sigma^2\right)$ and Team 2 score ~ $N\left(\mu_2,\, \sigma^2\right)$ then the score differential is distributed as Team 1 score $-$ Team 2 score ~ $N\left(\mu_1 - \mu_2,\, 2\sigma^2\right)$. It follows that the estimated probability of Team 1 winning (with the inclusion of a 0.5 continuity correction) is given as

$$\begin{aligned}\Pr\left(\text{Team 1 score} - \text{Team 2 score} > 0.5\right) &\approx \Pr\left(Z > \frac{\mu_2 - \mu_1 + 0.5}{\sqrt{2}\sigma}\right)\\ &= \Phi\left(\frac{\mu_1 - \mu_2 - 0.5}{\sqrt{2}\sigma}\right)\end{aligned}$$

where Z is the standard normal and $\Phi(z)$ is the area under the normal curve to the left of z. Note that this assumes that the scores of Teams 1 and 2 are independent. In reality this is highly unlikely since, for example, if Team 1 makes a high score then it is likely that Team 2 will also produce a high score. Thus $\sqrt{2}\sigma$ most likely overestimates the variance which, in turn, leads to a possible overestimate of the winning probabilities for the weaker teams.

8.4.2 Period 1992/93-1997

Applying model (8.1) for the period 1992/93-1997 the standard deviation, σ is estimated to be 46.0. The expected score for Team 1 is

$$s = \text{Average} + \text{Team 1 bat} - \text{Team 2 bowl} + \text{Home effect} + \text{Toss effect}\,.$$

The expected score for Team 2 is

$$s = \text{Average} + \text{Team 2 bat} - \text{Team 1 bowl} - \text{Night bat} + \text{Night bowl} + \text{Toss effect}$$

For example, suppose Australia plays Zimbabwe at home with Australia winning the coin toss and batting first (in daylight). Note that since Australia is Team 2, the expected score for Zimbabwe is reduced by the night bowling effect of 5 runs. It follows that Australia's expected home score (in daylight) is $216+118-77-24+3=236$ runs. Whereas Zimbabwe's expected away score (at night) is $216+90-101+1-5-14=187$ runs. The probability that Australia exceeds Zimbabwe's score and thus wins the match is estimated to be

$$\begin{aligned}\Pr\left(\text{Australia's score} > \text{Zimbabwe's score}\right) &\approx \Pr\left(Z > \frac{187-236+0.5}{\sqrt{2}\times 46}\right)\\ &= \Phi\left(\frac{49-0.5}{\sqrt{2}\times 46}\right)\\ &= 0.77\end{aligned}$$

The probability that Zimbabwe wins is thus estimated to be $1-0.77=0.23$.

If the roles were reversed and Zimbabwe's captain elected to bat first (in daylight) after winning the coin toss, the expected projected scores for Zimbabwe and Australia are 208 and 215 runs respectively. The resulting winning probability for Australia is a modest 0.68. However, Zimbabwe's chance of winning has increased markedly to 0.32. This underscores the substantial disadvantage gained by batting second during this period. The estimated probabilities that Team 1 defeats Team 2 are provided in Table 8.11. The bolded probabilities across the diagonal represent the average probability of Team 1 winning when playing at home. To estimate the probability that Team 2 defeats Team 1 simply subtract the relevant probability from 1. The home team has benefited extensively by batting first during this period, with all home teams, on average, having at least a 50% chance of defeating any of its opponents. The relatively high column averages suggest that during this period all teams tended to struggle when batting second and chasing a target. The value of 0.67 is Team 1's average home winning probability and represents a sizeable advantage. Thus, Team 2's expected winning probability when playing away from home is only 0.33. This underscores the advantage of batting first and setting a target during this period. The subsequent estimated winning probabilities for all teams are provided in Table 8.12 together with the standard errors and the actual winning percentages. Note that the results are distorted by the fact that in some instances the number of Team 1 home games played was low. Calculation of the standard error estimates suggests that, when represented as Team 1, Australia and Sri Lanka performing substantially better than expected at home whereas England, India, Pakistan and the West Indies performed below expectations at home. The estimated probabilities also highlight the modest disparity between the teams, with an estimated winning probability of only 20% separating the top five nations.

Table 8.11. Estimated probabilities that Team 1 defeats Team 2 in ODI cricket for the period 1992/93-1997

	Team	*Team 2*									
		Aust	Eng	Ind	NZ	Pak	SA	SL	WI	Zim	*Ave.*
Team 1	Australia	**0.48**	0.47	0.50	0.46	0.48	0.43	0.48	0.43	0.77	**0.50**
	England	0.83	**0.83**	0.84	0.82	0.84	0.80	0.84	0.80	0.91	**0.83**
	India	0.81	0.80	**0.82**	0.79	0.81	0.77	0.81	0.77	0.89	**0.81**
	New Zealand	0.51	0.50	0.53	**0.49**	0.52	0.46	0.52	0.46	0.65	**0.52**
	Pakistan	0.79	0.79	0.80	0.78	**0.79**	0.75	0.79	0.75	0.88	**0.79**
	South Africa	0.72	0.71	0.73	0.70	0.72	**0.67**	0.72	0.67	0.83	**0.73**
	Sri Lanka	0.55	0.54	0.56	0.53	0.55	0.50	**0.55**	0.50	0.69	**0.55**
	West Indies	0.77	0.77	0.79	0.76	0.78	0.73	0.78	**0.73**	0.87	**0.78**
	Zimbabwe	0.56	0.56	0.58	0.55	0.57	0.52	0.57	0.52	**0.70**	**0.55**
	Average	**0.69**	**0.64**	**0.67**	**0.67**	**0.66**	**0.62**	**0.69**	**0.61**	**0.81**	**0.67**

Table 8.12. Estimated winning probabilities for Team 1 in ODI cricket for the period 1992/93-1997

Team	*Estimated home winning probability for Team 1*	*Number of home games played as Team 1*	*Standard error*	*Actual Team 1 home winning percentage*
Australia	50%	23	10.4%	70%
England	83%	2	26.6%	50%
India	81%	16	9.8%	69%
New Zealand	52%	19	11.5%	53%
Pakistan	79%	9	13.6%	56%
South Africa	73%	10	14.0%	60%
Sri Lanka	55%	25	9.9%	68%
West Indies	78%	10	13.1%	60%
Zimbabwe	55%	6	20.3%	50%
Average	67%	13	14.4%	59%

8.4.3 Period 1997/98-2001

Using model (8.3) the standard deviation, σ is estimated to be 51.2, which gives a value of 72.4 for $\sqrt{2}\sigma$. The expected score for Team 1 is calculated as

$$s = \text{Average} + \text{Team 1 bat} - \text{Team 2 bowl} + \text{Home region effect} + \text{Toss effect}.$$

The expected score for Team 2 is

$$s = \text{Average} + \text{Team 2 bat} - \text{Team 1 bowl} - \text{Night bat} + \text{Night bowl} + \text{Toss effect}$$

Table 8.13 provides the subsequent probability estimates that Team 1 defeats Team 2. The bolded probabilities across the diagonal represent the average winning probability for each team (as Team 1) when playing in its home geographical region. The probability of 0.57 represents the average home regional winning probability of Team 1. The advantage for

Team 1 is notably less than the expected advantage it enjoyed during the previous study period but is still a modest one. The dominance of Australia and South Africa, when playing in their home regions is apparent, with their average winning probability, against all opposition, being greater than 50%. The column averages suggest that the average probability that both these teams would have been defeated, when playing in an away region (as Team 2), was substantially less than 50%. Conversely, the difficulties experienced by Zimbabwe on the International scene are manifest, with its chances of winning, in the main, being substantially below 50%. The subsequent estimated winning probabilities for all teams are provided in Table 8.14 together with the standard errors and the actual winning percentages. Note that the actual winning percentages represent wins by Team 1 when opposed to teams from a different region. Calculation of the standard errors suggests that teams, in general, performed as expected. However, England and South Africa performed significantly below expectations. The estimated probabilities highlight the substantial increase in the variability in the team quality effect, with the disparity in the winning probabilities for the top eight teams increasing to a sizeable 48%. As a consequence, there would have been less variability in the match outcomes during this period, with the stronger teams expected to defeat weaker opposition.

Table 8.13. Estimated probabilities that Team 1 defeats Team 2 in ODI cricket for the period 1997/98-2001

			Team 2 and Region									
			Aust	Eng	Ind	NZ	Pak	SA	SL	WI	Zim	
			4	1	3	4	3	5	3	2	5	*Ave.*
Team 1 and region	Aust	4	**0.56**	0.71	0.77	0.77	0.75	0.53	0.68	0.81	0.83	**0.73**
	Eng	1	0.49	**0.65**	0.72	0.72	0.69	0.46	0.62	0.76	0.78	**0.65**
	Ind	3	0.44	0.61	**0.68**	0.68	0.65	0.42	0.57	0.73	0.74	**0.60**
	NZ	4	0.32	0.48	0.56	**0.56**	0.53	0.30	0.45	0.61	0.63	**0.48**
	Pak	3	0.47	0.63	0.70	0.70	**0.68**	0.44	0.60	0.75	0.77	**0.63**
	SA	5	0.70	0.83	0.87	0.87	0.86	**0.68**	0.81	0.90	0.91	**0.84**
	SL	3	0.32	0.48	0.56	0.56	0.53	0.30	**0.45**	0.61	0.63	**0.50**
	WI	2	0.22	0.36	0.43	0.43	0.40	0.20	0.33	**0.49**	0.51	**0.36**
	Zim	5	0.18	0.30	0.37	0.37	0.35	0.16	0.27	0.43	**0.45**	**0.30**
	Average		**0.39**	**0.55**	**0.62**	**0.64**	**0.60**	**0.35**	**0.54**	**0.70**	**0.72**	**0.57**

Table 8.14. Estimated winning probabilities for Team 1 in ODI cricket for the period 1997/98-2001

Team	*Estimated home winning probability for Team 1*	*Number of home games played as Team 1*	*Standard error*	*Actual Team 1 home winning percentage*
Australia	73%	34	7.6%	74%
England	65%	20	10.7%	35%
India	60%	14	13.1%	64%
New Zealand	48%	18	11.8%	33%
Pakistan	63%	14	12.9%	43%
South Africa	84%	33	6.4%	64%
Sri Lanka	50%	16	12.5%	56%
West Indies	36%	22	10.2%	50%
Zimbabwe	30%	31	8.2%	13%
Average	57%	22	10.6%	48%

8.5 Comparison across study periods

Table 8.15 compares the combined team ratings across study periods. Figures 8.3 and 8.4 respectively provide boxplots of the distribution of the combined ratings and the estimated winning probabilities across periods. Clearly, the winning probabilities have, on average, decreased and become more variable. The non-parametric Mann-Whitney test, however, confirms that the ratings across study periods were not significantly different. $\left(W_8 = 70.5,\ p = 0.200\right)$. The probabilities tended to be lower because the team quality gap had markedly increased. This suggests that the majority of teams were inclined to struggle against the few stronger teams. Notably, teams such as Australia and South Africa were beginning to enjoy a significant advantage over its opposition.

The increased variability in the expected winning probabilities suggests that the winning chances of teams diminished as they were invariably more likely to play against a much stronger opponent. This gives rise to match outcomes being more deterministic during this period, with the stronger ranked teams more likely to defeat its lower ranked opponent. Australia, in particular, exhibited a dramatic improvement throughout the study. This perhaps was due in part to its selection policy to consciously select specialist teams for ODI and test cricket. Australia was also dominant as test-playing nation during this period. During the previous period, however, most teams were similarly rated and so the chances of most teams defeating an equally rated opponent were naturally higher.

Table 8.16 provides the percentage change in the ratings across study periods, with Figure 8.5 displaying boxplots of the distribution of the percentage change in ratings. This plot suggests that the change in bowling strength, across study periods, was less variable than the change in batting strength. Most notably, batting strength was a strong predictor of a winning match outcome during the first study period. However, for the ensuing period bowling strength more so than batting proficiency was a strong predictor of a win.

Table 8.15. Combined team ratings and the estimated winning probabilities based on the innings scores in ODI cricket across study periods

Team	*Period 1992/93-1997*		*Period 1997/98-2001*	
	Combined rating	*Estimated winning probability*	*Combined rating*	*Estimated winning probability*
Australia	119	50%	132	73%
England	101	83%	102	65%
India	83	81%	88	60%
New Zealand	113	52%	88	48%
Pakistan	93	79%	93	63%
South Africa	99	73%	137	84%
Sri Lanka	119	55%	108	50%
West Indies	105	78%	78	36%
Zimbabwe	67	55%	74	30%
Average		67%		57%

Table 8.16. Percentage change in ratings across periods

Team	*% change in Batting rating*	*% change in Bowling rating*	*% change in Combined rating*
Australia	0%	13%	11%
South Africa	-7%	8%	1%
Sri Lanka	15%	-8%	6%
Pakistan	-10%	-13%	-22%
England	-4%	4%	0%
India	34%	6%	38%
West Indies	-17%	9%	-9%
New Zealand	-13%	-14%	-26%
Zimbabwe	13%	-6%	10%

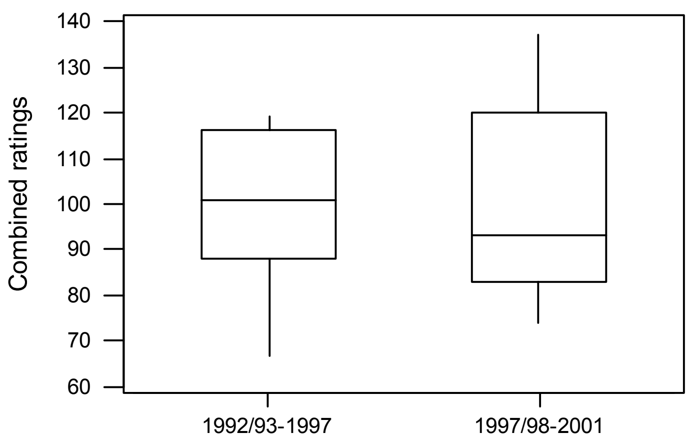

Figure 8.3. Boxplots of the of the distribution of combined team ratings in ODI cricket across the study periods 1992/93-1997 and 1997/98-2001

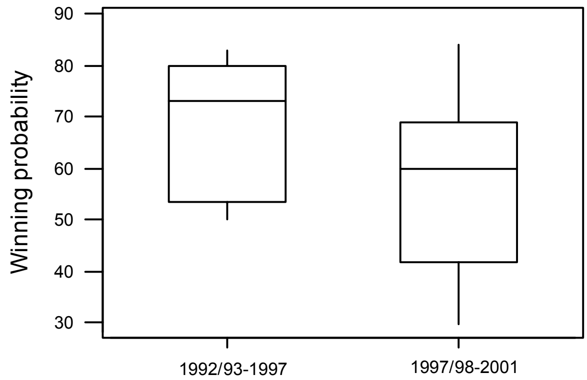

Figure 8.4. Boxplots of the of the distribution of the average winning probabilities in ODI cricket across the study periods 1992/93-1997 and 1997/98-2001

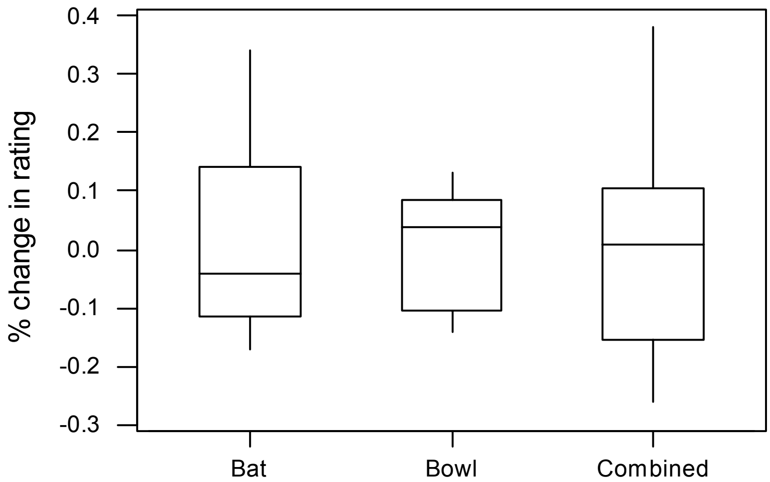

Figure 8.5. Boxplots of the of the distribution of the percentage change in ratings in ODI cricket across the study periods 1992/93-1997 and 1997/98-2001

8.6 Conclusions

By fitting a multiple linear regression model to the innings scores in ODI cricket a team's overall strength was able to be separated into its batting and bowling strength. In Chapter 6 the models used to fit the victory margins provided a measure of a team's overall strength but do not distinguish between batting and bowling strength. The least squares batting and bowling ratings, in essence, provide a measure of a team's attacking and defensive proficiency relative to the average rating of 100. In fitting the model to the innings scores location factors played a significant part in defining which model which provided the best fit of the data. For the first study period some teams gained a significant scoring advantage when playing at home. During the ensuing period a number of teams were significantly advantaged when playing in their home geographical region.

There was a greater disparity in batting and bowling strength during the second study period rather than the first, which suggests that match outcomes were more predictable during this period. Not surprisingly Australia and South Africa emerged as the dominant nations in both batting and bowling. For the first study period batting strength more so than bowling prowess was the stronger predictor of a winning match outcome. This supports the established orthodoxy that success in one-day cricket is commensurate with a team's batting proficiency. In contrast, during the second study period bowling strength rather than batting prowess was the stronger predictor of a winning result. This result contradicts conventional thinking.

CHAPTER 9
AN ATTACK AND DEFENCE MODEL FOR TEST CRICKET

9.1 Introduction

In modelling an attack and defence model for Test cricket attention will be focussed on the first innings only, where the primary team objective is to optimise performance levels in order to establish a substantial first innings lead. Since it can be assumed that teams go all out to establish a significant lead their first innings performance provides a reliable measure of their relative batting and bowling strength. Penultimate and final innings performances are not explicitly considered because teams tend to adopt a more calculated approach and accordingly adapt their style of play as a strategic response to what has occurred in the first innings. As a consequence, a team's penultimate and final innings batting and bowling performances are more reactionary and likely to lack the consistent approach that is more conspicuous in the first innings.

9.2 Fitting a linear attack and defence model to the first innings scores

9.2.1 Introduction

A team's expected first innings score in a Test match played between the batting team i and the bowling team j is modelled as

$$s_{ij} = A + a_i - b_j + f + t + \varepsilon_{ij} \tag{9.1}$$

where the indices $i, j = 1, \ldots, 9$ represent the nine ICC test-playing playing nations and s_{ij} signifies the expected first innings score. The intercept A represents the expected score between two average teams on a neutral ground and parameters a_i and b_j represent the respective batting and bowling ratings for teams i and j. The parameter f indicates whether or not team i batted first and the t parameter signifies whether or not team i won the coin toss. ε_{ij} is a zero-mean random error with constant variance. If we also take account of the HA effect in a match played on ground k then model (9.1) can be modified to

$$s_{ijk} = A + a_i - b_j + h_{ik} + f + t + \varepsilon_{ijk} \tag{9.2}$$

where the indices $i, j, k = 1, \ldots, 9$ represent the nine ICC test-playing playing nations and s_{ijk} signifies the expected first innings score. When $k = i$ the HA parameter can be modelled as either a common HA *h* (9.2a), or a team's individual batting HA h_i (9.2b) and is 0 otherwise. For model (9.2) it is assumed that all teams enjoy an advantage that is independent of all other teams irrespective of whether teams compete in the same geographical region or not. To account for any regional effects in a match played in home region m or away region l model (8.1) can be modified to

$$s_{ijlm} = A + a_i - b_j + r_{lm} + f + t + \varepsilon_{ijlm} \tag{9.3}$$

where the indices $l, m = 1, \ldots, 5$ represent the five geographical regions, with team i belonging to region l and team j belonging to region m. The parameter r_{lm} represents the resultant regional batting and bowling effect. When teams i and j belong to different regions $r_{lm} = r_l$ otherwise if $l = m$ $r_{lm} = 0$. Using a design matrix of indicator variables a least squares regression model is fitted to the scores. For convenience, $\sum_{i=1}^{9} a_i = 900$ and $\sum_{j=1}^{9} b_j = 900$.

9.2.2 Period 1992-1997

In fitting models (9.1), (9.2) and (9.3) to the first innings scores for the first five-year period all normality tests suggest that the normality assumption is seriously breached. It is thus necessary to transform the response variable. The innings scores are adequately transformed by using a square root transformation. Note that other transformation functions were tested such as a logarithmic function but in all cases the residuals were not normally distributed. Using the square root transformation, models (9.1) to (9.3) are thus modified to

$$\sqrt{s_{ij}} = A + a_i - b_j + f + t + \varepsilon_{ij} \tag{9.4}$$

$$\sqrt{s_{ijk}} = A + a_i - b_j + h_{ik} + f + t + \varepsilon_{ijk} \tag{9.5}$$

$$\sqrt{s_{ijlm}} = A + a_i - b_j + r_{lm} + f + t + \varepsilon_{ijlm} \tag{9.6}$$

where $\sum_{i=1}^{9} a_i = 9$ and $\sum_{j=1}^{9} b_j = 9$. This will ensure that the average team rating is one. The resulting least squares parameter estimates after fitting models (9.4), (9.5) and (9.6) to the scores are provided in Tables 9.1 and 9.2. As was the case with ODI cricket these in effect represent the respective batting and bowling ratings relative to the average rating of one. Table 9.3 uses analysis of variance techniques to compare the effectiveness of each of the models. With the addition of the single HA parameter, model (9.5a) provides the best fit of the innings scores. The respective estimates for the parameters A, h, f and t are 16.9743, 0.8570 ($p = 0.021$), -0.2674 ($p = 0.517$) and 0.3082 ($p = 0.449$). The home team clearly enjoyed a significant runs advantage during this period, which would have assisted the home team in establishing a substantial first innings lead. There is no evidence to suggest that teams benefited from batting first or winning the coin toss. Nonetheless, the negative coefficient for batting first suggests that there was a tendency for Team 2 to gain a runs advantage. Applying the inverse transformation to model (9.5a) gives

$$s_{ijk} = \left(A + a_i - b_j + h_{ik} + f + t + \varepsilon_{ijk}\right)^2 \tag{9.7}$$

The estimate for A converts to $16.9743^2 = 288$ runs. To convert the parameter coefficients attributed to HA, batting first and winning the coin toss into a runs advantage (or disadvantage) we initially assume that two equally rated teams are opposed to each other. Thus, the expected combined effect due to HA, batting first and winning the coin toss is $\left(16.9743 + 0.8570 - 0.2674 + 0.3082\right)^2 - 16.9743^2 = 31$ runs. In isolating the average effects, HA contributed a significant $\left(16.9743 + 0.8570\right)^2 - 16.9743^2 = 30$ runs, batting first disadvantaged teams by $16.9743^2 - \left(16.9743 - 0.2674\right)^2 = 9$ runs and winning the coin toss contributed $\left(16.9743+0.3082\right)^2-16.9743^2=11$ runs. To convert the batting and bowling coefficients into ratings we simply use the coefficients to determine the differential between the average expected team scores and the average score pro rated to an average team rating of 100. Tables 9.4 to 9.6 respectively display the transformed batting, bowling and combined ratings for each team. The dominance of Australia, South Africa and India during this period was substantial, with each of the teams respectively performing 30%, 19% and 23% better than average. This is reflected in their solid overall winning percentages of 50%, 47% and 48% respectively. Only Australia, India, South Africa and the West Indies performed better than average in both batting and bowling whereas New Zealand, Sri Lanka and Zimbabwe all underperformed in both the batting and bowling departments. For six of the nine teams their bowling strength outshone their batting strength. England, in particular, markedly underachieved as a bowling team relative to its batting performances. This has culminated in a relatively poor overall winning percentage of only 23% and a high losing percentage of 44%. There is a strong positive correlation of 0.91 between the combined ratings and the winning percentages ($p=0.001$). This suggests that during this period first innings combined batting and bowling strength was a strong predictor of a winning outcome. If batting and bowling strength are considered separately, the correlation coefficients are 0.83 ($p=0.006$) and 0.82 ($p=0.006$) respectively. This suggests that, in the main, both batting and bowling first innings strength were also strong predictors of a winning result.

To illustrate how the first innings ratings work suppose Australia plays Zimbabwe at home with Australia electing to bat first after winning the coin toss. Australia's batting rating of 112 means that, on average it scored $\dfrac{112\times 288}{100}-288=35$ runs better than average. In contrast, Zimbabwe's bowling rating of 91 means that, on average, it conceded $288-\dfrac{91\times 288}{100}=26$ runs more than expected. Thus, with Australia batting at home, its advantage over Zimbabwe's bowling is $35+26+31=92$ runs. Now, with Zimbabwe batting and Australia bowling, Zimbabwe conceded $288-\dfrac{85\times 288}{100}=43$ runs more than expected whereas Australia scored $\frac{118 \times 288}{100} - 288 = 52$ runs more than expected. Thus, with Australia bowling, its advantage over Zimbabwe's batting is $52 + 43 = 95$ runs. Thus, Australia's expected lead is a substantial $92 + 95 = 187$ runs. The expected lead can also be easily computed by using the combined ratings. Australia's advantage over Zimbabwe is $\frac{(130 - 76) \times 288}{100} = 156$ runs, giving a lead of $156 + 31 = 187$ runs.

Table 9.7 provides the expected first innings leads for all teams. It is assumed that Team 1 is the home team and elects to bat first after winning the coin toss. The bolded values across the diagonal represent the expected runs advantage gained by the home team when batting first, having won the coin toss. The row averages represent the expected home team leads when the home team bats first, having won the coin toss. The column averages represent the expected opponent lead for each away team when batting second, having lost the coin toss. Table 9.7 provides a measure of relative team strength and highlights the overall strength of Australia, India and South Africa, and to a lesser extent, the West Indies, with each of these teams expected to establish a first innings lead both at home and away from home.

Table 9.1. Least squares parameter estimates for models (9.4), (9.5a) and (9.5b) in Test cricket for the period 1992-1997

Team		*Model (9.4)*	*Model (9.5a)*	*Model (9.5b)*	*Overall team HA*	*p-value*
Australia	Bat	1.7967	1.8289	1.8512	0.6768	0.345
England	Bat	1.3847	1.3003	1.5347	0.2609	0.712
India	Bat	2.2441	2.3223	1.6658	1.8526	0.048
New Zealand	Bat	-0.427	-0.4356	-0.4196	0.4199	0.603
Pakistan	Bat	0.6557	0.7828	1.0420	-0.4820	0.597
South Africa	Bat	1.5463	1.4612	1.7582	0.0468	0.960
Sri Lanka	Bat	0.0392	0.0683	-0.4947	1.6112	0.063
West Indies	Bat	1.8311	1.8451	2.6914	-1.1273	0.182
Zimbabwe	Bat	-0.1708	-0.1733	-0.6290	1.0880	0.333
Australia	Bowl	2.2875	2.3197	2.3399		
England	Bowl	-0.1216	-0.2060	0.0325		
India	Bowl	1.302	1.2802	0.6231		
New Zealand	Bowl	0.4212	0.4126	0.4269		
Pakistan	Bowl	1.1389	1.2660	1.5314		
South Africa	Bowl	2.2793	2.1942	2.4903		
Sri Lanka	Bowl	0.2914	0.3205	-0.2434		
West Indies	Bowl	1.1084	1.1224	1.9672		
Zimbabwe	Bowl	0.2929	0.2904	-0.1680		

Table 9.2. Least squares parameter estimates for model (9.6) in Test cricket for the period 1992-1997

Team		*Model (9.6)*	*Region*	*Overall regional advantage*	*p-value*
Australia	Bat	2.0938	Region 1	-1.1680	0.286
England	Bat	1.4414	Region 2	0.5633	0.547
India	Bat	2.0299	Region 3	1.6587	0.026
New Zealand	Bat	-0.0964	Region 4	0.0209	0.977
Pakistan	Bat	0.6260	Region 5	1.6564	0.077
South Africa	Bat	0.9439			
Sri Lanka	Bat	-0.0802			
West Indies	Bat	2.7941			
Zimbabwe	Bat	-0.7525			
Australia	Bowl	2.5190			
England	Bowl	-0.1291			
India	Bowl	1.2595			
New Zealand	Bowl	0.4673			
Pakistan	Bowl	1.0109			
South Africa	Bowl	2.2976			
Sri Lanka	Bowl	-0.0057			
West Indies	Bowl	1.0659			
Zimbabwe	Bowl	0.5146			

Table 9.3. Comparison of models (9.4), (9.5) and (9.6) for the innings scores in Test cricket for the period 1992-1997

Model	*Source*	*DF*	*SS*	R^2	*MS*	*F-ratio*	*p-value*
Model (9.4)	Regression	21	108985.4	0.15			
Model (9.5a) compared with model (9.4)	Regression	1	60.9		60.9	5.3	0.022
	Residual error	334	3803.7		11.4		
Model (9.5b) compared with model (9.4)	Regression	9	165.7		18.4	1.6	0.114
	Residual error	326	3698.9		11.3		
Model (9.6) compared with model (9.4)	Regression	5	108.4		21.7	1.9	0.094
	Residual error	330	3756.2		11.4		
	Total	356	112850.0				

Table 9.4. Transformed batting ratings in Test cricket for the period 1992-1997

Team and parameter estimates		*Aus*	*Eng*	*Ind*	*NZ*	*Pak*	*SA*	*SL*	*WI*	*Zim*	*Expected score*	*Rating*
		2.32	**-0.21**	**1.28**	**0.41**	**1.27**	**2.19**	**0.32**	**1.12**	**0.29**		
Aus	**1.83**		361	307	338	308	276	342	313	343	**323**	**112**
Eng	**1.30**	255		289	319	289	259	322	294	323	**294**	**101**
Ind	**2.32**	288	380		357	325	292	360	330	361	**337**	**116**
NZ	**-0.44**	202	280	233		233	206	263	238	264	**240**	**83**
Pak	**0.78**	238	323	271	301		242	304	277	305	**283**	**98**
SA	**1.46**	260	348	294	325	295		328	300	329	**310**	**107**
SL	**0.07**	217	298	248	277	249	220		253	281	**255**	**88**
WI	**1.85**	272	362	308	339	308	276	342		343	**319**	**110**
Zim	**-0.17**	210	289	241	269	241	213	272	246		**248**	**85**

Table 9.5. Transformed bowling ratings in Test cricket for the period 1992-1997

Team and parameter estimates		*Aus*	*Eng*	*Ind*	*NZ*	*Pak*	*SA*	*SL*	*WI*	*Zim*	*Expected score*	*Rating*
		1.83	**1.3**	**2.32**	**-0.44**	**0.78**	**1.46**	**0.07**	**1.85**	**-0.17**		
Aus	**2.32**		380	324	357	325	292	360	330	361	**341**	**118**
Eng	**-0.21**	209		240	268	240	212	271	245	272	**244**	**84**
Ind	**1.28**	254	341		318	289	258	322	294	323	**300**	**103**
NZ	**0.41**	227	310	259		260	231	291	265	292	**267**	**92**
Pak	**1.27**	253	340	288	318		257	321	293	322	**299**	**103**
SA	**2.19**	284	375	320	352	320		355	326	356	**336**	**116**
SL	**0.32**	224	306	256	285	257	228		262	289	**263**	**91**
WI	**1.12**	249	335	283	313	283	253	316		317	**294**	**101**
Zim	**0.29**	223	305	256	284	256	227	287	261		**262**	**91**

Table 9.6. Summary of transformed ratings in Test cricket for the period 1992-1997

Team	*Transformed batting rating*	*Transformed bowling rating*	*Combined rating*
Australia	112	118	130
England	101	84	85
India	116	103	119
New Zealand	83	92	75
Pakistan	98	103	101
South Africa	107	116	123
Sri Lanka	88	91	79
West Indies	110	101	111
Zimbabwe	85	91	76

Table 9.7. Expected first innings leads in Test cricket for the period 1992-1997

	Team	*Team 2*									
		Aust	*Eng*	*Ind*	*NZ*	*Pak*	*SA*	*SL*	*WI*	*Zim*	*Expected lead*
Team 1	Australia	**31**	161	63	189	115	51	178	86	187	**129**
	England	-99	**31**	-67	60	-15	-78	48	-44	57	**-17**
	India	-1	129	**31**	158	83	19	146	54	155	**93**
	New Zealand	-127	2	-96	**31**	-44	-107	19	-73	28	**-50**
	Pakistan	-53	77	-21	106	**31**	-32	94	2	103	**35**
	South Africa	11	140	43	169	94	**31**	158	66	166	**106**
	Sri Lanka	-116	14	-84	43	-32	-96	**31**	-61	40	**-37**
	West Indies	-24	106	8	135	60	-4	123	**31**	132	**67**
	Zimbabwe	-125	5	-93	34	-41	-104	22	-70	**31**	**-46**
	Average	**-67**	**79**	**-31**	**112**	**27**	**-44**	**99**	**-5**	**108**	**31**

9.2.3 Period 1997/98 to 2001

In fitting models (9.1), (9.2) and (9.3) to the first innings scores for the second five-year period the normality assumption is critically breached. Thus a square root transformation is used to transform the response variable. Note that other transformation functions were used but in all cases the residuals were not normally distributed. The subsequent fitting of models (9.4), (9.5) and (9.6) to the innings scores generates the least squares parameter estimates provided in Tables 9.8 and 9.9. Table 9.10 compares the statistical efficacy of fitting each of the models. With the addition of the single HA parameter, model (9.5a) provides the best fit of the innings scores. The respective estimates for the parameters A, h, f and t are 17.2429, 0.9057 ($p = 0.021$), -0.5351 ($p = 0.173$) and 0.0974 ($p = 0.814$). The results suggest that the home team has continued to enjoy a significant runs advantage. Team 2 has also continued to display a tendency to gain a runs advantage over Team 1 during this period.

The estimate for A converts to $17.2429^2 = 297$ runs. This suggests that the scoring capacity of teams has marginally increased across study periods. The expected combined effect due to HA, batting first and winning the coin toss is $(17.2429 + 0.9057 - 0.5351 + 0.0974)^2 - 17.2429^2 = 16$ runs. In isolating the average effects, HA contributed a significant $(17.2429 + 0.9057)^2 - 17.2429^2 = 32$ runs, batting first disadvantaged teams by a sizeable $17.2429^2 - (17.2429 - 0.5351)^2 = 18$ runs and winning the coin toss contributed $(17.2429 + 0.0974)^2 - 17.2429^2 = 3$ runs. Tables 9.11 to 9.13 display the respective ratings. Table 9.14 displays the expected first innings lead for each home team.

The combined ratings suggest that, overall, only three teams performed better than expected during this period, with Australia and South Africa rated substantially above average. Notably, Australia and South Africa were the only teams that were rated better than average in both batting and bowling. The West Indies enjoyed a solid bowling rating but in comparison underachieved with the bat. This is reflected in the fact that the West Indies won only 28% of its matches overall and was able to establish a first innings lead only 33% of the time. This is an interesting result given that during the period of the study West Indies had the game's premier batsman in Brian Lara playing for them. In general, the ratings reinforce the notion that the consistently successful teams tended to perform well in both the batting and bowling departments. Since the chances of winning are increased after a first innings lead has been established solid first innings performances in both batting and bowling tend to increase a team's chances of establishing a lead and thus increase its chances of winning. This is certainly the case with Australia and South Africa who won well over half their matches after establishing a first innings lead.

There is a very strong positive correlation of 0.93 between the combined ratings and the actual winning percentages ($p < 0.001$), which suggests that first innings strength was a strong predictor of a winning match outcome. In considering batting and bowling strength separately, batting strength, with a correlation coefficient of 0.92 ($p < 0.001$) formed a modestly stronger link with a winning result than did bowling strength with a correlation coefficient of 0.84 ($p = 0.005$). Nonetheless, both batting and bowling strength were strong predictors of a winning result during this period.

Table 9.14 provides the expected first innings leads for all teams and highlights the sustained dominance of Australia and South Africa with each of these teams expected to establish a substantial first innings lead both at home and away from home. All other teams were expected to trail on the first innings when playing away from home.

Table 9.8. Least squares parameter estimates for models (9.4), (9.5a) and (9.5b) in Test cricket for the period 1997/98-2001

Team		*Model (9.4)*	*Model (9.5a)*	*Model (9.5b)*	*Overall team HA*	*p-value*
Australia	Bat	3.0312	3.0066	3.0598	0.851	0.417
England	Bat	0.2992	0.2999	1.0045	-0.282	0.783
India	Bat	0.8196	0.7690	0.3252	1.736	0.190
New Zealand	Bat	1.1184	1.1601	0.9282	1.508	0.229
Pakistan	Bat	1.3969	1.3680	1.0082	1.621	0.194
South Africa	Bat	2.2012	2.3364	2.5273	0.475	0.676
Sri Lanka	Bat	1.5418	1.4206	1.0020	1.659	0.224
West Indies	Bat	-0.3306	-0.2679	-0.5237	1.602	0.138
Zimbabwe	Bat	-1.0775	-1.0927	-0.3316	-0.554	0.685
Australia	Bowl	2.1536	2.1291	2.1414		
England	Bowl	0.8389	0.8396	0.8862		
India	Bowl	0.0435	-0.0071	-0.0350		
New Zealand	Bowl	0.8052	0.8469	0.6568		
Pakistan	Bowl	0.6356	0.6067	0.7372		
South Africa	Bowl	2.3539	2.4891	2.5712		
Sri Lanka	Bowl	1.0474	0.9262	0.9214		
West Indies	Bowl	1.8297	1.8925	1.9215		
Zimbabwe	Bowl	-0.7077	-0.7229	-0.8007		

Table 9.9. Least squares parameter estimates for models (9.6) in Test cricket for the period 1997/98-2001

Team		*Model (9.6)*	*Region*	*Overall regional advantage*	*p-value*
Australia	Bat	2.8507	Region 1	1.626	0.130
England	Bat	0.9135	Region 2	-0.242	0.812
India	Bat	0.5316	Region 3	1.6034	0.048
New Zealand	Bat	1.1190	Region 4	1.2925	0.118
Pakistan	Bat	1.0984	Region 5	0.2965	0.736
South Africa	Bat	2.5189			
Sri Lanka	Bat	1.4094			
West Indies	Bat	-0.5485			
Zimbabwe	Bat	-0.8933			
Australia	Bowl	2.1725			
England	Bowl	0.9780			
India	Bowl	-0.1358			
New Zealand	Bowl	0.6385			
Pakistan	Bowl	0.6161			
South Africa	Bowl	2.6960			
Sri Lanka	Bowl	0.7044			
West Indies	Bowl	1.9670			
Zimbabwe	Bowl	-0.6368			

Table 9.10. Comparison of models (9.4), (9.5) and (9.6) for the innings scores in Test cricket for the period 1997/98-2001

Model	*Source*	*DF*	*SS*	R^2	*MS*	*F-ratio*	*p-value*
Model (9.4)	Regression	21	92438.9	0.23			
Model (9.5a) compared	Regression	1	59.1		59.1	5.4	0.021
with model (9.4)	Residual error	282	3110.8		11.0		
Model (9.5b) compared	Regression	9	106.5		11.8	1.1	0.363
with model (9.4)	Residual error	274	3063.4		11.2		
Model (9.6) compared	Regression	5	96.8		19.4	1.7	0.135
with model (9.4)	Residual error	278	3073.1		11.1		
	Total	304	95608.8				

Table 9.11. Transformed batting ratings in Test cricket for the period 1997/98-2001

Team and parameter estimates		*Aus*	*Eng*	*Ind*	*NZ*	*Pak*	*SA*	*SL*	*WI*	*Zim*	*Expected score*	*Rating*
		2.13	**0.84**	**-0.01**	**0.85**	**0.61**	**2.49**	**0.93**	**1.89**	**-0.72**		
Aus	**3.01**		377	410	376	386	315	373	337	440	**377**	**126**
Eng	**0.30**	238		308	279	287	227	276	245	334	**274**	**91**
Ind	**0.77**	252	295		295	303	241	292	260	351	**286**	**95**
NZ	**1.16**	265	308	339		317	253	305	273	366	**303**	**101**
Pak	**1.37**	272	316	347	316		260	313	280	374	**309**	**103**
SA	**2.34**	305	351	384	351	360		348	313	412	**353**	**118**
SL	**1.42**	273	318	349	317	326	262		281	376	**313**	**104**
WI	**-0.27**	220	260	288	260	268	210	258		313	**260**	**87**
Zim	**-1.09**	197	234	261	234	242	187	232	203		**224**	**75**

Table 9.12. Transformed bowling ratings in Test cricket for the period 1997/98-2001

Team and parameter estimates		*Aus*	*Eng*	*Ind*	*NZ*	*Pak*	*SA*	*SL*	*WI*	*Zim*	*Expected score*	*Rating*
		3.01	**0.30**	**0.77**	**1.16**	**1.37**	**2.34**	**1.42**	**-0.27**	**-1.09**		
Aus	**2.13**		364	346	332	324	290	322	386	419	**348**	**116**
Eng	**0.84**	227		300	286	279	248	278	337	368	**290**	**97**
Ind	**-0.01**	202	287		258	252	222	250	306	336	**264**	**88**
NZ	**0.85**	228	316	300		280	248	278	337	368	**294**	**98**
Pak	**0.61**	220	308	292	279		241	270	328	359	**287**	**96**
SA	**2.49**	280	378	360	345	337		335	400	434	**359**	**120**
SL	**0.93**	230	319	303	289	282	251		340	371	**298**	**99**
WI	**1.89**	260	355	337	323	316	282	314		409	**325**	**108**
Zim	**-0.72**	183	263	248	236	230	201	228	282		**234**	**78**

Table 9.13. Summary of the transformed ratings in Test cricket for the period 1997/98-2001

Team	*Transformed batting rating*	*Transformed bowling rating*	*Combined rating*
Australia	126	116	142
England	91	97	88
India	95	88	83
New Zealand	101	98	99
Pakistan	103	96	99
South Africa	118	120	138
Sri Lanka	104	99	103
West Indies	87	108	95
Zimbabwe	75	78	53

Table 9.14. Expected first innings leads in Test cricket for the period 1997/98-2001

	Team	*Team 2*									
		Aust	*Eng*	*Ind*	*NZ*	*Pak*	*SA*	*SL*	*WI*	*Zim*	*Expected lead*
Team 1	Australia	**16**	70	75	59	59	20	55	63	105	**63**
	England	-38	**16**	21	5	5	-34	1	9	51	**3**
	India	-43	11	**16**	0	0	-39	-4	4	46	**-3**
	New Zealand	-27	27	32	**16**	16	-23	12	20	62	**15**
	Pakistan	-27	27	32	16	**16**	-23	12	20	62	**15**
	South Africa	12	66	71	55	55	**16**	51	59	101	**59**
	Sri Lanka	-23	31	36	20	20	-19	**16**	24	66	**19**
	West Indies	-31	23	28	12	12	-27	8	**16**	58	**10**
	Zimbabwe	-73	-19	-14	-30	-30	-69	-34	-26	**16**	**-37**
	Average	**-31**	**30**	**35**	**17**	**17**	**-27**	**13**	**22**	**69**	**16**

9.3 Comparison of first innings performances across study periods

Figures 9.1 to 9.3 display boxplots of the distribution of the transformed batting, bowling and combined ratings across periods. The boxplots suggest that both the team ratings and their level of variability were not substantially different across periods. Figure 9.4 displays the distributions of the first innings margins. An F-test confirms that the variability in the innings margins was not significantly different ($F_{1,\,654} = 0.926,\ p = 0.560$). Similarly, a two sample t-test (assuming equal variances) confirms that the margins were statistically equivalent ($T_{326} = 0.104,\ p = 0.298$). Apropos the combined ratings, Australia and South Africa maintained their overall dominance and were the top two ranked teams throughout both study periods. Notably, both Australia and South Africa increased their combined rating during the second study period. India markedly dropped in both the batting and bowling ratings whereas both New Zealand and Sri Lanka displayed a substantial overall improvement. It could be argued that Sri Lanka's general improvement was due, in part, to the emerging dominance of Muttiah Muralitheran, its record-breaking spin bowler.

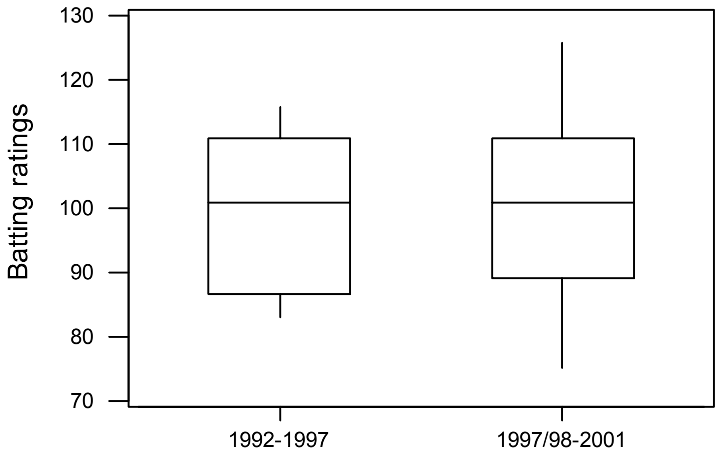

Figure 9.1. Boxplots of the of the distribution of the transformed batting ratings in Test cricket for the study periods 1992-1997 and 1997/98-2001

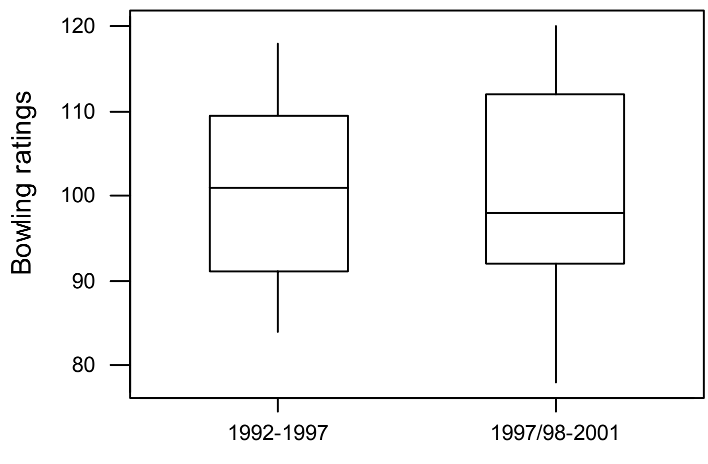

Figure 9.2. Boxplots of the of the distribution of the transformed bowling ratings in Test cricket for the study periods 1992-1997 and 1997/98-2001

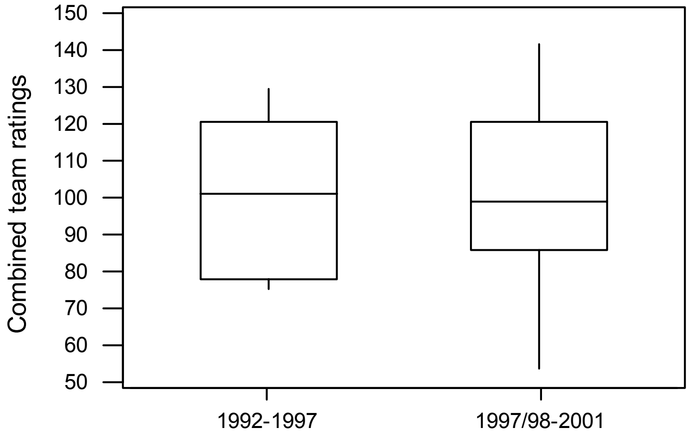

Figure 9.3. Boxplots of the of the distribution of the combined transformed ratings in Test cricket for the study periods 1992-1997 and 1997/98-2001

Figure 9.4. Boxplots of the of the distribution of first innings lead in Test cricket for the study periods 1992-1997 and 1997/98-2001

9.4 Fitting a multinomial (ordinal) logistic model to match outcomes

9.4.1 Introduction

A multinomial (ordinal) logistic regression model (with the use of the logit link function) can be fitted to match results in order to gauge the degree to which the observed variation in the match outcome of a win, draw and loss is critically affected by specific first innings performance measures. The observed variation in the match outcomes for Team i is modelled as a function of the common home team advantage, (signed) first innings lead, the result of the coin toss and the relative batting and bowling strength. In conducting the analysis it is assumed that the logit link function and the chosen co-variates are linearly related. Thus, if the cumulative probability of achieving a win, draw or loss is denoted by γ_{ijw}, for $i, j = 1, \ldots, 9$ where Team i is batting first in the third innings against Team j, the outcome of a match can be modelled as

$$\ln\left(\frac{\gamma_{ijw}}{1-\gamma_{ijw}}\right) = \beta_{0w} + \beta_1 h + \beta_2 r + \beta_3 x + \beta_4 t + \beta_5\left(a_i - b_j\right) + \beta_6\left(a_j - b_i\right) \qquad (9.8)$$

where $h = 1 \text{ or } 0$ signifies whether or not the HA rests with Team 1; $r = 1 \text{ or } 0$ indicates whether or not Team 1 was from a different geographical region than Team 2; x is the (signed) first innings lead of Team1 and $t = 1 \text{ or } 0$ indicates whether or not Team 1 won the coin toss. The $a_i - b_j$ and $a_j - b_i$ terms, for $i, j = 1, \ldots, 9$, represent the (signed) rating differentials between the batting and bowling teams during the first and second innings respectively. A common HA parameter is adopted because the least squares rating model (9.5a) was the better predictor of the transformed first innings score across both study periods.

To investigate the associated probabilities of Team 1 winning, drawing and losing a Test match model (9.8) can be transposed to give

$$\Pr\left(w=0\middle|h,\, r,\, x,\, t,\, a_i-b_j,\, a_j-b_i\right)=\frac{\exp\left\{\beta_{00}+\beta_1 h+\beta_2 r+\beta_2 x+\beta_3 t+\beta_4\left(a_i-b_j\right)+\beta_5\left(a_j-b_i\right)\right\}}{1+\exp\left\{\beta_{00}+\beta_1 h+\beta_2 r+\beta_2 x+\beta_3 t+\beta_4\left(a_i-b_j\right)+\beta_5\left(a_j-b_i\right)\right\}}$$

$$\Pr\left(w=1\middle|h,\, r,\, x,\, t,\, a_i-b_j,\, a_j-b_i\right)=\frac{\exp\left\{\beta_{01}+\beta_1 h+\beta_2 r+\beta_2 x+\beta_3 t+\beta_4\left(a_i-b_j\right)+\beta_5\left(a_j-b_i\right)\right\}}{1+\exp\left\{\beta_{01}+\beta_1 h+\beta_2 r+\beta_2 x+\beta_3 t+\beta_4\left(a_i-b_j\right)+\beta_5\left(a_j-b_i\right)\right\}}$$

The respective probabilities of Team i winning, drawing and losing are thus expressed as

$$\Pr\left(\text{Win}\middle|h,\, r,\, x,\, t,\, a_i-b_j,\, a_j-b_i\right)=\Pr\left(w=0\middle|h,\, r,\, x,\, t,\, a_i-b_j,\, a_j-b\right)$$

$$\begin{aligned}\Pr\left(\text{Draw}\middle|h,\, r,\, x,\, t,\, a_i-b_j,\, a_j-b\right)&=\Pr\left(w=1\middle|h,\, r,\, x,\, t,\, a_i-b_j,\, a_j-b\right)\\&\quad-\Pr\left(w=0\middle|h,\, r,\, x,\, t,\, a_i-b_j,\, a_j-b\right)\end{aligned}$$

$$\Pr\left(\text{Loss}\middle|h,\, r,\, x,\, t,\, a_i-b_j,\, a_j-b\right)=1-\Pr\left(w=1\middle|h,\, r,\, x,\, t,\, a_i-b_j,\, a_j-b\right)$$

Assuming that the home team (opposed to a team from a different region) bats first after winning the coin toss and if two equally rated teams are equal on runs after the completion of the first innings, the respective probabilities of the home team winning, drawing and losing are

$$\Pr\left(\text{Win}\middle|h=1,\, r=1,\, x=0,\, t=1,\, a_i-b_j=0,\, a_j-b_i=0\right)=\frac{\exp\left(\beta_{00}+\beta_1+\beta_2+\beta_4\right)}{1+\exp\left(\beta_{00}+\beta_1+\beta_2+\beta_4\right)}$$

$$\begin{aligned}\Pr\left(\text{Draw}\middle|h=1,\, r=1,\, x=0,\, t=1,\, a_i-b_j=0,\, a_j-b_i=0\right)&=\frac{\exp\left(\beta_{01}+\beta_1+\beta_2+\beta_4\right)}{1+\exp\left(\beta_{01}+\beta_1+\beta_2+\beta_4\right)}\\&\quad-\frac{\exp\left(\beta_{00}+\beta_1+\beta_2+\beta_4\right)}{1+\exp\left(\beta_{00}+\beta_1+\beta_2+\beta_4\right)}\end{aligned}$$

$$\Pr\left(\text{Loss}\middle|h=1,\, r=1,\, x=0,\, t=1,\, a_i-b_j=0,\, a_j-b_i=0\right)=1-\frac{\exp\left(\beta_{01}+\beta_1+\beta_2+\beta_4\right)}{1+\exp\left(\beta_{01}+\beta_1+\beta_2+\beta_4\right)}$$

9.4.2 Period 1992-1997

The parameter estimates for model (9.8) are provided in Table 9.15. The Pearson and Deviance goodness-of-fit tests confirm that model (9.8) provides an adequate fit of the data. Not surprisingly, the ability of teams to establish a first innings lead was a significant predictor of a winning match outcome. However, there was no evidence to suggest that teams gained a winning advantage from any of the other considered factors. Surprisingly, the relative strength parameters were not critical during this period, which suggests that either (a) batting or bowling strength alone in the penultimate and final innings were not influential in defining a winning outcome or (b) teams, in general, were evenly matched across innings and as a consequence undefined performance factors may have played a pivotal role.

It had been established previously that the home team gained a significant first innings runs advantage during this period; however, the home team was unable to consistently convert this advantage into a winning result. The respective probability estimates of the home and away teams (represented as Teams 1 and 2) winning, drawing and losing a Test match are provided in table 9.16. Note that it is assumed that Team 1 wins the coin toss and opposing teams come from different regions. Clearly, any differences between home and away performances (when represented as Team 1) were marginal; with the home team performing moderately better than the away team. Nonetheless, a draw was the most likely result during this period regardless of the order of innings. Figure 9.5 displays a plot comparing the winning probabilities for two equally rated home and away teams (when batting first) for leads of the order $x \in [-200, 200]$. The average leads needed by the home and away teams to have a better than 50% chance of winning, when batting first, were $x \geq 70$ and $x \geq 91$ runs respectively. This confirms that under similar circumstances the home team generally enjoyed a modest runs advantage over the away team. From a winning perspective, however, any advantage gained was marginal and statistically insignificant. If the home and away teams were represented as Team 2 (after losing the coin toss) they were not able to generally perform better than they did when represented as Team 1, with the home team performing marginally better than the away team. The average leads needed by the home and away teams to have a better than 50% chance of winning (when batting second) were $x \geq 122$ and $x \geq 142$ runs respectively. This confirms that the home team, on average, continued to enjoy a modest runs advantage over the away team. However, these results highlight the moderate advantage enjoyed by teams when batting first during this period, with teams in general being a sizeable 50 runs better off.

Table 9.15. Parameter estimates for the prediction of match outcomes for the team batting first in Test cricket for the period 1992-1997

Parameter	*Term*	*Coefficient*	*Standard error*	*p-value*	*Odds ratio*
β_{00}	Intercept (win)	-1.2490	0.6905	0.070	
β_{01}	Intercept (win and draw)	0.7950	0.6861	0.247	
β_1	Home	0.2009	0.3290	0.541	1.22
β_2	Region	0.3337	0.6193	0.590	1.40
β_3	Lead	0.009789	0.001402	<0.001	1.01
β_4	Coin toss	0.0626	0.3537	0.860	1.06
β_5	$a_i - b_j$	0.00613	0.01339	0.647	1.01
β_6	$a_j - b_i$	-0.01390	0.01380	0.314	0.99

Table 9.16. Probability estimates for the home and away teams represented as Teams 1 and 2 in Test cricket for the period 1992-1997

	Home team			*Away team*		
	Win	*Draw*	*Loss*	*Win*	*Draw*	*Loss*
Team 1	0.34	0.46	0.20	0.30	0.47	0.23
Team 2	0.23	0.47	0.30	0.20	0.46	0.34

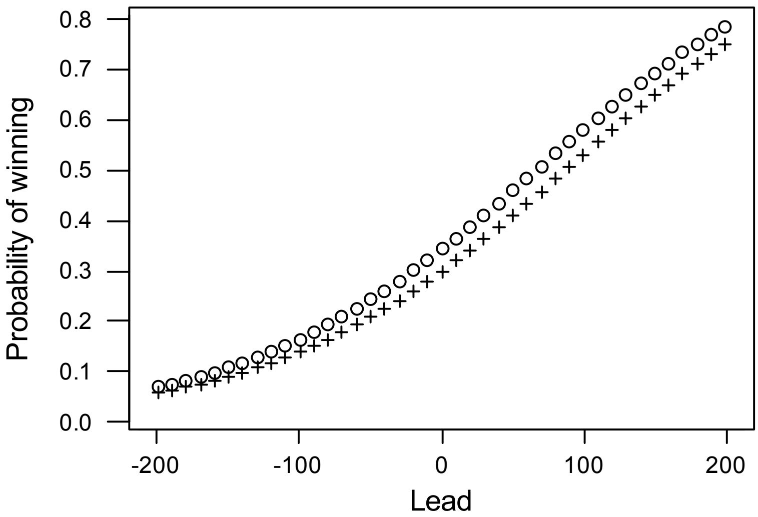

Figure 9.5. The probability of winning for the home (○) and away (+) teams for Test cricket during the period 1992-1997

9.4.3 Period 1997/98-2001

The parameter estimates for model (9.8) are provided in Table 9.17. The Pearson and Deviance goodness-of-fit tests confirm that model (9.8) provides an adequate fit of the data. There is strong evidence suggesting that both the establishment of a first innings lead and playing at home were significant predictors of a winning match outcome. Counter to the previous study period, the home team was able to effectively convert its first innings runs advantage into a winning outcome. Winning the coin toss was not significant; however, there was some suggestion that the team winning the coin toss displayed a modest losing tendency. Surprisingly, Team 1's batting strength (and thus usually Team 1's bowling strength in the penultimate innings) was not significant in shaping a winning outcome. In contrast, the moderate significance of the negative $a_j - b_i$ coefficient suggests that Team 2's bowling strength (and thus usually its batting strength in the final innings) was influential in defining a winning result. This suggests that Team 2 enjoyed a substantial advantage over Team 1. While it is not surprising that the rating differential in the final innings was moderately significant it was unexpected that the rating differential in the penultimate innings was highly insignificant. This advocates that teams were in the best position to force a win when they were able to exploit their superiority during the final rather than the penultimate innings. Note that this superiority could be in regard to batting or bowling since in a 'follow-on' scenario the batting order is reversed in the third and fourth innings (if needed). Consequently, it would be expected that the better rated teams were in a position of strength in the final innings. It may also explain the low percentage of draws for the West Indies during the study period since its excellent bowling rating but weak batting rating meant that it (or their opponents) consistently had the upper hand in the final innings. The analysis suggests that teams would have been better served during this period to expose their strength in the final rather than the penultimate innings. Thus, if a team was relatively strong at batting and it won the coin toss it would have been better served to bowl first whereas a strong bowling team would have been better served if it batted first. This may also explain the dominance of Australia and South Africa during this period, with their high batting and bowling ratings ensuring that they were regularly in a position of strength during the final innings.

With all things being equal at the end of the first innings, the respective probability estimates for the home and away teams (represented as Teams 1 and 2) winning, drawing and losing a Test match are provided in Table 9.18. The home team has performed substantially better than the away team during this period even though the respective winning probabilities were quite low. However, when batting second both the home and away teams substantially increased their winning probabilities. Figure 9.6 displays a plot comparing the winning probabilities for the home team when it batted first and second for leads of the order $x \in [-200, 200]$. The average leads needed by the home team to have a better than 50% chance of winning was a sizeable $x \geq 178$ runs when it batted first but decreased markedly to $x \geq -67$ runs when it batted second, which suggests that the home team, when batting second, could afford to trail by 67 runs on the first innings. Batting second has in effect created a huge 245 run turnaround for the home team. If we also consider the improvement in the winning chances for the away team, the average lead required to have a better than 50% chance of winning when batting first was $x \geq 323$ runs. When batting second the average away team lead dropped markedly to $x \geq 67$ runs. This represents a sizeable 256 run turnaround for the away team. Figure 9.7 displays a plot comparing the winning probabilities for the away team when it batted first and second for leads of the order $x \in [-200, 200]$. These results underscore the substantial advantage enjoyed by the team batting second during this period and cannot be overstated.

To test the efficacy of model (9.8) for the first study period the successful classification rates for the training and test sets are 76% and 72% respectively. When the parameter estimates in Table 9.15 are used to predict the match outcomes for the entire data set the successful classification rate is 72%. For the second study period the respective successful classification rates for both sets are 78% and 71%. When the parameter estimates in Table 9.17 are used for the entire data set the successful classification rate is 74%. The consistency of the results across both study periods suggests that there is no evidence of any over-fitting. Note that the relatively high success rates suggest that model (9.8) was a moderately strong predictor of winning match outcome in Test cricket.

Table 9.17. Parameter estimates for the prediction of match outcomes for the team batting first in Test cricket for the period 1997/98-2001

Parameter	*Term*	*Coefficient*	*Standard error*	*p-value*	*Odds ratio*
β_{00}	Intercept (win)	-1.3434	0.5851	0.022	
β_{01}	Intercept (win and draw)	0.3179	0.5752	0.581	
β_1	Home	0.8641	0.3670	0.019	2.37
β_2	Region	-0.2354	0.5625	0.676	0.79
β_3	Lead	0.006475	0.001359	<0.001	1.01
β_4	Coin toss	-0.5132	0.3640	0.159	0.60
β_5	$a_i - b_j$	0.00011	0.01525	0.994	1.00
β_6	$a_j - b_i$	-0.02791	0.01599	0.081	0.97

Table 9.18. Probability estimates for the home and away teams represented as Teams 1 and 2 in Test cricket for the period 1997/98-2001

	Home team			*Away team*		
	Win	*Draw*	*Loss*	*Win*	*Draw*	*Loss*
Team 1	0.23	0.38	0.39	0.12	0.41	0.47
Team 2	0.47	0.41	0.12	0.39	0.38	0.23

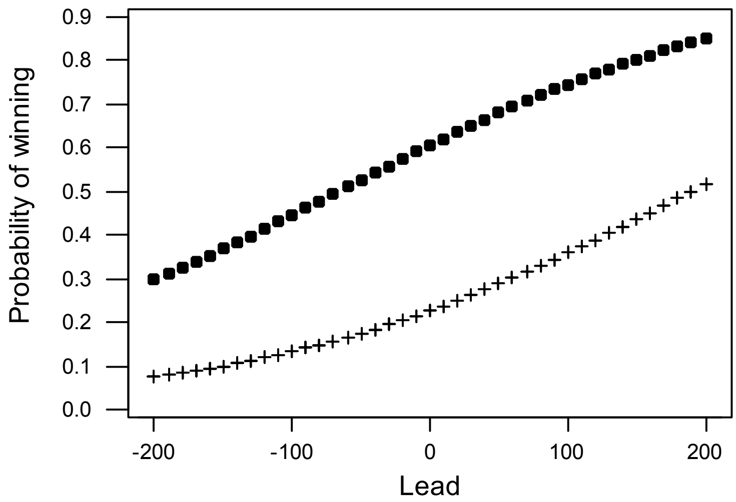

Figure 9.6. The probability of the home team winning when represented as Team 1 (+) and Team 2 (●) in Test cricket during the period 1997/98-2001

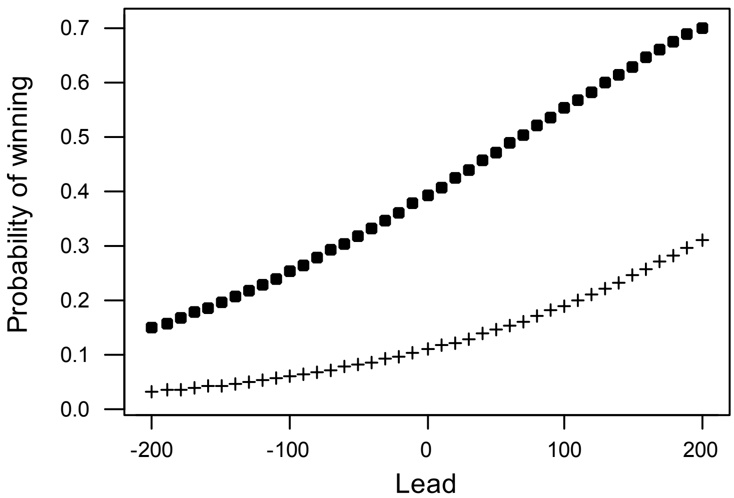

Figure 9.7. The probability of the away team winning when represented as Team 1 (+) and Team 2 (●) in Test cricket during the period 1997/98-2001

9.5 Quantifying the effect of batting second

To explore whether the winning trend enjoyed by Team 2 continued beyond the 2001 season the next 80 completed matches are considered, increasing the data set to 231 matches. This takes the study period up to the start of the 2002/03 season. In modelling the first innings scores, so as to gauge the batting and bowling ratings for the period, it was again necessary to transform the response variable employing the square root transformation. Models (9.4), (9.5) and (9.6) were subsequently fitted to the scores. Tables 9.19 and 9.20 provide the respective parameter estimates and Table 9.21 uses analysis of variance techniques to compare the statistical efficacy of each of the models. As a consequence, model (9.5a) provides the best fit of the data. The parameter estimates for the average score effect and effects associated with HA, the order of innings and winning the coin toss are 17.2748, 0.8661 ($p = 0.010$), -0.0278 ($p = 0.935$) and 0.2929 ($p = 0.392$) respectively. These transform to 298 runs, 31 runs, -1 run and 10 runs respectively.

Clearly, there was a significant HA effect during the extended study period. The transformed batting and bowling ratings are provided in Table 9.22.

In fitting model (9.8) to the match outcomes of a win, draw and loss for Team 1 for the extended study period the resulting parameter estimates are provided in Table 9.23. The relevant goodness-of-fit tests confirm that the model provides an adequate fit of the data. Not unexpectedly, the establishment of a first innings lead and the HA effect were highly significant predictors of a winning match outcome. Notably, the insignificance of the $a_i - b_j$ coefficient and the high significance of the negative $a_j - b_i$ coefficient are surprising results. These results confirm that (a) Team 2 has continued to enjoy a significant winning advantage and (b) relative strength during the final innings rather than during the penultimate innings has significantly contributed to a winning match outcome. The latter result also confirms that a team was clearly in the best position to force a win when it was able to exploit its dominance during the final innings rather than the penultimate innings. This possibly explains Australia's continued dominance since its very high batting and bowling ratings consistently puts it in a position of strength during the final innings.

In order to further quantify the order of innings effect we can fit a multinomial (ordinal) logistic model to the home results. Thus, if the cumulative conditional probability of a win, draw and loss is denoted by γ_{ijw} for the home team, the outcome of a match can be modelled as

$$\ln\left(\frac{\gamma_{ijw}}{1-\gamma_{ijw}}\right) = \beta_{0w} + \beta_1 s + \beta_2 r + \beta_3 x + \beta_4 t + \beta_5\left(m_i - n_j\right) + \beta_6\left(m_j - n_i\right) \qquad (9.9)$$

where $s = 1 \text{ or } 0$ signifies whether or not the home team batted second. The $m_i - n_j$ and $m_j - n_i$ terms, for $i, j = 1, \ldots, 9$, respectively represent the (signed) rating differentials between the home batting and away bowling teams during the first innings and the away batting and home bowling teams during the second innings. The parameter estimates generated by fitting model (9.9) to the match outcomes are provided in Table 9.24. The results confirm that there is strong evidence suggesting that Team 2 have continued to gain a substantial winning advantage during this extended period. To investigate this situation further, Team 2 respectively won, drew and lost 102, 58 and 71 matches during this extended period. A χ^2 goodness-of-fit test confirms that Team 2 was able to win significantly more matches than Team 1 $\left(\chi_1^2 = 13.3,\ p = 0.001\right)$. The region effect is highly significant but as outlined in Chapter 7 this result is confounded by the fact that the home team invariably plays in its home region. This result thus indirectly confirms that the home team enjoyed a significant winning advantage during this period. Surprisingly, the relative first innings batting and bowling strength of the home and away teams were highly insignificant in shaping a winning result. This suggests that location factors *per se* were possibly a major contributing factor. Table 9.25 provides the estimated probabilities of the home team winning, drawing and losing when electing to bat first and second upon winning the coin toss, and opposed to an equally rated team. The results suggest that the winning probability of the home team (when batting second) increased by a substantial 63% whereas the home team's losing probability decreased by a sizeable 43%.

Table 9.19. Least squares parameter estimates for models (9.4), (9.5a) and (9.5b) in Test cricket for the period 1997/98-2002/03

Team		*Model (9.4)*	*Model (9.5a)*	*Model (9.5b)*	*Overall team HA*	*p-value*
Australia	Bat	5.8531	5.8262	5.8149	0.9431	0.289
England	Bat	3.0451	3.0132	3.0058	0.9715	0.260
India	Bat	3.2293	3.2564	2.9408	1.6650	0.101
New Zealand	Bat	2.8071	2.8644	3.6444	-0.8040	0.456
Pakistan	Bat	3.5282	3.4707	3.2372	1.4080	0.219
South Africa	Bat	4.4534	4.5356	5.1888	-0.6251	0.519
Sri Lanka	Bat	3.9390	3.8365	3.0737	2.1440	0.064
West Indies	Bat	2.2744	2.2951	1.8844	1.8268	0.046
Zimbabwe	Bat	0.8704	0.9019	1.2101	0.2210	0.849
Australia	Bowl	4.8326	4.8056	4.8878		
England	Bowl	3.3751	3.3432	3.3814		
India	Bowl	2.1044	2.1315	2.1302		
New Zealand	Bowl	3.6517	3.7090	3.6951		
Pakistan	Bowl	3.7348	3.8365	3.5750		
South Africa	Bowl	4.2839	3.6772	4.3168		
Sri Lanka	Bowl	3.0236	4.3662	2.8517		
West Indies	Bowl	3.7586	3.7793	3.7793		
Zimbabwe	Bowl	1.2354	1.2669	1.3828		

Table 9.20. Least squares parameter estimates for models (9.6) in Test cricket for the period 1997/98-2002/03

Team		*Model (9.6)*	*Region*	*Overall regional advantage*	*p-value*
Australia	Bat	6.2108	Region 1	0.9839	0.252
England	Bat	2.9076	Region 2	1.8599	0.042
India	Bat	2.9357	Region 3	1.8437	0.005
New Zealand	Bat	3.1808	Region 4	0.1154	0.869
Pakistan	Bat	3.0549	Region 5	-0.4899	0.518
South Africa	Bat	5.0424			
Sri Lanka	Bat	3.5160			
West Indies	Bat	1.7877			
Zimbabwe	Bat	1.3640			
Australia	Bowl	4.9256			
England	Bowl	3.4415			
India	Bowl	1.9995			
New Zealand	Bowl	3.6806			
Pakistan	Bowl	3.5126			
South Africa	Bowl	4.3980			
Sri Lanka	Bowl	2.6791			
West Indies	Bowl	3.8918			
Zimbabwe	Bowl	1.4714			

Table 9.21. Comparison of models (9.4), (9.5) and (9.6) for the innings scores in Test cricket for the period 1997/98-2002/03

Model	*Source*	*DF*	*SS*	R^2	*MS*	*F-ratio*	*p-value*
Model (9.4)	Regression	21	150011.7	0.22			
Model (9.5a) compared	Regression	1	83.3		83.3	6.7	0.010
with model (9.4)	Residual error	442	5472.0		12.4		
Model (9.5a)	Regression	22	150095.0	0.24			
Model (9.5b) compared	Regression	8	101.8		12.7	1.0	0.435
with model (9.5a)	Residual error	434	5370.2		12.4		
Model (9.6) compared	Regression	4	85.7		21.4	1.7	0.149
with model (9.4)	Residual error	438	5386.3		12.3		
	Total	464	155567.0				

Table 9.22. Summary of transformed ratings in Test cricket for the period 1997/98-2002/03

Team	*Transformed batting rating*	*Transformed bowling rating*	*Combined rating*
Australia	132	119	152
England	96	98	94
India	97	85	82
New Zealand	94	102	97
Pakistan	102	104	106
South Africa	114	104	118
Sri Lanka	107	111	118
West Indies	88	102	90
Zimbabwe	70	73	44

Table 9.23. Parameter estimates for the prediction of match outcomes for the team batting first in Test cricket for the period 1997/98-2002/03

Parameter	*Term*	*Coefficient*	*Standard error*	*p-value*	*Odds ratio*
β_{00}	Intercept (win)	-1.6060	0.5115	0.002	
β_{01}	Intercept (win and draw)	0.1781	0.4990	0.721	
β_1	Home	0.7234	0.2952	0.014	2.06
β_2	Region	0.0705	0.4671	0.880	1.07
β_3	Lead	0.008246	0.001123	<0.001	1.01
β_4	Coin toss	-0.2288	0.3018	0.448	0.80
β_5	$a_i - b_j$	-0.01557	0.01376	0.258	0.98
β_6	$a_j - b_i$	-0.03402	0.01417	0.016	0.97

Table 9.24. Parameter estimates for the prediction of match outcomes for the home team in Test cricket for the period 1997/98-2002/03

Parameter	*Term*	*Coefficient*	*Standard error*	*p-value*	*Odds ratio*
β_{00}	Intercept (win)	-1.7212	0.4893	<0.001	
β_{01}	Intercept (win and draw)	0.0831	0.4712	0.860	
β_1	Second	0.7461	0.3014	0.013	2.11
β_2	Region	1.1088	0.4650	0.017	3.03
β_3	Lead	0.008215	0.001125	<0.001	1.01
β_4	Coin toss	-0.3626	0.2984	0.224	0.70
β_5	$m_i - n_j$	0.01227	0.01227	0.381	1.01
β_6	$m_j - n_i$	-0.00596	0.01359	0.661	0.99

Table 9.25. Probability estimates for the home team when represented as Team 1 and 2 in Test cricket for the period 1997/98-2002/03

	Win	*Draw*	*Loss*
Team 1	0.27	0.43	0.30
Team 2	0.44	0.39	0.17

9.6 Conclusions

By fitting a multiple linear regression model to the first innings scores in Test cricket the resulting least squares ratings provided an accurate gauge of a team's batting and bowling strength. This in turn provided a relative measure of a team's attacking and defensive proficiency. The analysis suggests that there was essentially no difference in the average performance across periods. Nonetheless, performances tended to be more variable during the second study period. Australia was a dominant force and its striking ascendancy in both batting and bowling goes a long way in explaining why it has reigned supreme as a cricket playing nation.

It was established that there was a strong HA effect with the home team displaying a strong winning tendency particularly during the second study period. There was also strong evidence suggesting that Team 2 was consistently in a position of strength and was able to win considerably more often than Team 1. This contradicts conventional thinking which posits that teams should elect to bat first in order to (a) exploit early favourable playing conditions and (b) avoid batting last on an unpredictable wicket.

During the second study period there was solid evidence suggesting that a team's superiority in the final rather than the penultimate innings was critical in setting up a win. Notably, Team 2's bowling strength was decisive in defining a winning match outcome which supports the notion of Team 2 having the upper hand during this period. In the extended 1997/98-2992/03 period further analysis confirms that (a) Team 2 continued to enjoy a significant winning advantage and (b) a team's relative superiority during the final innings continued to be highly significant in defining a winning result. This confirms that a team was clearly in the best position to force a win when it was able to exploit its dominance during the final rather than the penultimate innings. The dominance of the team batting second cannot be overestimated and the results clearly describe a trend that has emerged in Test cricket. The results clearly advocate that to improve their winning chances, teams should expose their particular strength, whether that be batting or bowling, in the final rather than the penultimate innings. This puts paid to the mythical notion, often spruiked by cricket pundits, that when given the opportunity teams to bat first teams should do so. Clearly, the analysis has shown that this has approach has been detrimental to the team batting first.

Unexpectedly, during the first study period there was no evidence to suggest that the differential in a team's first innings batting and bowling ratings contributed significantly to a winning outcome. Given that a first innings lead was shown be a very strong predictor of a winning result during this period this is a surprising result. One would expect the establishment of a lead and a team's relative strength to be dependent on each other since the stronger teams would be expected to forge the larger leads. This result suggests that (a) relative strength alone in the penultimate and final innings were not significant in defining a winning outcome or (b) teams, in general, were evenly matched across innings and as a result undefined performance factors may have played a key role.

CHAPTER 10
A MODEL FOR PREDICTING MATCH OUTCOMES IN TEST CRICKET

10.1 Introduction

Betting on sport is a burgeoning industry and with a plethora of betting options now available it is fast becoming the staple of the keen punter. And with the advent of new technologies it is not uncommon for punters to bet on the outcome of sporting contests while they are in progress. However, the vagaries of Test cricket and the length of time over which it is played make it a difficult proposition to accurately predict match outcomes in a two-horse race. To overcome this difficulty a simple two-stage prediction model is introduced. The model allows predictions to be made at four stages of a Test match: before the coin toss; after the coin toss; at the completion of Team 1's first innings and after both teams have completed their first innings. The model is presented as a simple application of a team's batting and bowling ratings introduced in Chapter 9 and is supplemented by a HA performance effect.

10.2 Setting up a prediction algorithm

In developing the algorithm, the attack and defence model is firstly fitted to the first innings scores in order to gauge the batting and bowling ratings for each team and to quantify the extent of the HA effect (in runs). Subsequently, the expected first innings lead is then estimated. Secondly, a multinomial (ordinal) logistic regression model is fitted to the match outcomes (with the co-variates being the average lead and the home team indicator) in order to estimate the probability that a team wins, draws or loses a Test match. Note that the model does not include a 'time to finish' variable and so it is assumed that match outcomes are independent of the time remaining in a match. This creates an anomaly in a Test match, for example, when the duration of the match has been dramatically reduced due to rain. It was shown in earlier chapters that a team's first innings lead is a very strong predictor of a winning match outcome. In this in stance, however, the most likely outcome is a drawn result regardless of the size of a team's first innings lead.

Since the first innings ratings are being used for predictive purposes the more recent test performances need to be weighted more heavily than past performances. This is achieved by employing an exponential smoothing technique, which weights past observations with exponentially decreasing weights. It follows that for any defined time period, t for $t = 1, 2, \ldots, n$ the predicted rating can be found by calculating the respective smoothed ratings, R_t such that

$$R_t = R_{t-1} + \alpha\left(y_t - R_{t-1}\right) \tag{10.1}$$

where y_t represents the actual team rating at time t and α is the smoothing constant applied to ratings such that $0 < \alpha_1 \leq 1$. To put simply, 10.1 can be expressed as

$$\text{New team rating} = \text{ Old team rating } + \ \alpha \times \left(\text{Actual rating} - \text{Predicted rating}\right)$$

The optimal smoothing constant is considered to be the value which minimises the mean absolute error between the actual and predicted ratings. The team batting and bowling ratings are determined using the linear modelling methods similar to those outlined in Chapter 9. Three models are contrasted. The first model presumes that the variability in team scores is dependent on the differential in team strength. The second and third models presume that the variability in team scores is dependent on both team quality and a HA effect. In particular, the second model assumes that the HA effect is common to all teams whereas the third model assume that the HA effect is unique to each team. In formally presenting these models, a team's first innings score in a Test match played between the batting team i and the bowling team j is modelled as

$$s_{ij} = A + a_i - b_j \tag{10.2}$$

where the indices $i, j = 1, \ldots, 9$ represent the nine ICC Test-playing nations and s_{ij} signifies the expected first innings score. The intercept A represents the expected score between two average teams on a neutral ground and the parameters a_i and b_j represent the smoothed batting and bowling ratings for teams i and j respectively. If we also take account of a HA effect, 10.2 can be re-expressed as

$$s_{ijk} = A + a_i - b_j + h_{ik} \tag{10.3}$$

where the indices $i, j, k = 1, \ldots, 9$ represent the nine ICC test-playing playing nations and s_{ijk} signifies the expected first innings score. When $k = i$, the HA parameter can be modelled as either a common HA, h (10.3a) or a team's individual batting HA, h_i (10.3b) and is 0 otherwise.

10.3 Fitting a linear model to the first innings run differentials

To illustrate how the predictive process works we will consider the 231 matches conducted during the period 1997/98-2002/03. The batting and bowling ratings are each initialised at 100 runs and the HA ratings are initialised at 10 runs.

To gauge the effectiveness of the models employed, the actual (signed) differential between the first innings scores will be compared with the predicted (signed) differential. Subsequent to this, three measures of efficacy will be adopted. Firstly, as a crude measure, a correct prediction will be one whereby the signs of the actual and predicted differential are the same. The model which generates the highest percentage of correct predictions will be the preferred model. For example, if the actual (signed) differential was $+10$ runs and the predicted (signed) differential was $+150$ runs this would count as a correct prediction since both differentials are positive. The measure is only rudimentary, however, since it does not take in to account the size of the differential. This exposes an anomaly created by this measure. Suppose for example that the actual (signed) differential was $+1$ run and the predicted (signed) differential was -1 run. This counts as an incorrect prediction even though the difference is a marginal two runs. On the other hand, from the previous example, a sizeable differential of $+150-(+10)=140$ runs counts as a correct prediction. A second and improved measure of model efficacy takes account of the mean absolute error. Under this scheme, the model generating the smallest mean absolute error is deemed to be the preferred model. A third measure takes in to account the logarithmic likelihood of whether a team leads or trails on the first innings. Assuming that the leads predicted by models (10.2) and (10.3) are normally distributed such that Lead ~ N(0,121^2), the probability estimate of Team 1 leading on the first innings is computed as $\Pr(\text{Lead} > 0)$. One would prefer a set of predictions that attaches the highest probability estimates to the situations that actually occur. This will be gauged by the maximum logarithmic likelihood for each version of models employed at the end of the study period. It is assumed that the model that generates the maximum logarithmic likelihood has, on average, been more effective at predicting which team actually led on the first innings. The subsequent diagnostic results that arise from fitting each of the models, via application of the 'Solver' facility in Microsoft Excel, are provided in Table 10.1. The low values for the smoothing constants suggests that both batting and bowling strength and the HA effect varied marginally throughout this period. The common HA model, with the application of the two smoothing constants is the preferred model. Two simple control measures can also be set up to gauge the effectiveness of the preferred model. The first control measure assumes that both Teams 1 and 2 have an equal chance of establishing a first innings lead. The second control measure assumes that the chances of Teams 1 and 2 establishing a first innings lead are the respective long term proportions (based on the 231 Test matches for the period 1997/98-2002/03). The proportion of matches in which Teams 1 and 2 led on the first innings during this period were 48% and 52% respectively. The maximum logarithmic likelihood is generated by model (10.3a).

The respective smoothed batting and bowling ratings, as generated by model (10.2a) are provided in Table 10.2. At the end of the set period the smoothed average first innings score (for an average team on a neutral ground) and the HA effect are predicted to be 302 runs and 88 runs respectively.

Table 10.1. Diagnostic results arising from the fitting of models (10.2) and (10.3) to Test innings scores for the period 1997/98-2002/03

Model	*Type*	*Overall smoothing constant*	*Twofold smoothing constants*		*Testing model efficacy*		
			Team ratings	*HA*	*% correct*	*Mean absolute error*	*Log likelihood*
Equal chances of Teams 1 and 2 setting up a first innings lead							-160.13
Long term proportions associated with the establishment of a first innings lead							-159.95
10.2	No HA	$\alpha_1 = 0.036$			68%	110	-169.48
10.3a	Common HA	$\alpha_1 = 0.052$			68%	108	-147.11
10.3a	Common HA		$\alpha_1 = 0.052$	$\alpha_2 = 0.129$	70%	108	-145.51
10.3b	Team HA	$\alpha_1 = 0.037$			68%	109	-201.53
10.3b	Team HA		$\alpha_1 = 0.039$	$\alpha_2 = 0.026$	68%	109	-202.35

Table 10.2. Smoothed team ratings in Test cricket at the completion of the 1997/98-2002/03 study period

Team	*Batting rating*	*Bowling rating*	*Combined rating*
Australia	201	133	234
England	135	79	114
India	111	40	51
New Zealand	73	86	59
Pakistan	123	87	110
South Africa	155	106	161
Sri Lanka	148	73	121
West Indies	110	80	90
Zimbabwe	45	14	-41
Average	122	78	100

10.4 Fitting a multinomial (ordinal) logistic model to the match outcomes

If the cumulative probability of achieving a win, draw or loss is denoted by γ_{ijw}, for $i, j = 1,\ldots,9$ where Team i is batting first in the third innings against Team j. The outcome of a match can be modelled as

$$\ln\left(\frac{\gamma_{ijw}}{1-\gamma_{ijw}}\right) = \beta_{0w} + \beta_1 h + \beta_2 x \tag{10.4}$$

where $h = 1$ or 0 signifies whether or not the HA rests with Team 1 and x is the (signed) first innings lead of Team1. The resulting parameter estimates are provided in Table 10.3. Application of the Pearson and Deviation goodness-of-fit tests suggests that the model provides an adequate fit of the data.

Table 10.3. Parameter estimates for the prediction of match outcomes for the team batting first in Test cricket at the completion of the 1997/98-2002/03 study period

Parameter	*Term*	*Coefficient*	*Standard error*	*p-value*	*Odds ratio*
β_{00}	Intercept (win)	-1.6565		0.000	
β_{01}	Intercept (win and draw)	0.0723	0.2425	0.732	
β_1	Home	0.6974	0.2109	0.015	2.01
β_2	Lead	0.008956	0.001010	0.000	1.01

To demonstrate how the prediction model can be applied, assume that Australia plays South Africa at home at the completion of the 2002/03 season and elects to bat first. From Table 10.2 Australia's home lead was expected to be $234+88-161=161$ runs. Now, using the parameter estimates in Table 10.3 the expected probability of Australia winning, drawing and losing (after leading by 161 runs on the first innings) are 0.62, 0.28 and 0.10 respectively. Thus, it can be deduced that South Africa's predicted chances of winning, drawing and losing when batting second and playing away from home are 0.10, 0.28 and 0.62 respectively. Conversely, if South Africa plays away from home and elects to bat first it is expected to trail by 161 runs on the first innings. South Africa's predicted chances of winning, drawing and losing under this circumstance are computed as 0.04, 0.16 and 0.80. Australia's respective chances of winning, drawing and losing when playing at home and batting second are thus 0.80, 0.16 and 0.04.

The range of probability estimates for an Australia versus South Africa Test match, covering all the possible scenarios, are summarised in Table 10.4. The results highlight the predicted advantage gained by playing at home, with the predicted home winning chances for Australia, playing as Team 1 and 2, for example, increasing by 343% and 176% respectively. The results also highlight the advantage of batting second, with South Africa's home and away winning chances, on average, increasing by 73% and 150% respectively. Tables 10.5 and 10.6 provide the winning probabilities for the home and away teams represented as Team 1 (Table 10.5) and Team 2 (Table 10.6). The probabilities across the diagonals represent the probability estimates of the home and away teams winning against an equally rated team when represented as Team 1. Interestingly, the predicted 88-run HA has increased the winning probability for Team 1 by a substantial 475%. The row percentages in Tables 10.5 and 10.6 represent the average probability estimates of the respective home and away teams defeating their opponents. The column percentages in represent the average probability estimates of the respective away and home teams defeating their opponents.

To test the efficacy of the above prediction algorithm we can contrast the logarithmic likelihood of the algorithm's match predictions with the logarithmic likelihoods of the match outcomes predicted by two control measures. For comparative purposes, the two control measures are considered to be the logarithmic likelihood of an equal chance attached to winning, drawing and losing and the logarithmic likelihood of the chances attached to winning, drawing and losing being the actual long term proportions over 231 previous Test matches. The long term proportions associated with winning, drawing and losing were 31%, 25% and 44% respectively. Table 10.7 provides the log likelihoods for each of the three measures. Since the prediction algorithm provided the maximum logarithmic likelihood at the end of the study period, on average it was clearly more effective at predicting the correct match outcomes than the two control measures.

Table 10.4. Probability estimates for an Australia versus South Africa Test match covering all match scenarios at the completion of the 1997/98-2002/03 study period

Team	*Location*	*Order of innings*	*Win*	*Draw*	*Loss*
Australia	Home	Team 1	0.62	0.28	0.10
South Africa	Away	Team 2	0.10	0.28	0.62
Australia	Home	Team 2	0.80	0.16	0.04
South Africa	Away	Team 1	0.04	0.16	0.80
Australia	Away	Team 1	0.14	0.34	0.52
South Africa	Home	Team 2	0.52	0.34	0.14
Australia	Away	Team 2	0.29	0.41	0.30
South Africa	Home	Team 1	0.30	0.41	0.29

Table 10.5. Estimates of the winning probabilities for the home team at the completion of the 1997/98-2002/03 study period

	Team	*Away team*									
		Aust	*Eng*	*Ind*	*NZ*	*Pak*	*SA*	*SL*	*WI*	*Zim*	*Ave.*
Home team	Australia	**0.46**	0.71	0.81	0.80	0.72	0.62	0.70	0.75	0.91	**0.75**
	England	0.22	**0.46**	0.60	0.58	0.47	0.36	0.44	0.51	0.77	**0.49**
	India	0.14	0.32	**0.46**	0.44	0.33	0.24	0.31	0.37	0.66	**0.35**
	New Zealand	0.15	0.34	0.48	**0.46**	0.35	0.25	0.33	0.39	0.67	**0.37**
	Pakistan	0.22	0.45	0.59	0.57	**0.46**	0.35	0.43	0.50	0.77	**0.48**
	South Africa	0.30	0.56	0.69	0.68	0.57	**0.46**	0.55	0.61	0.84	**0.60**
	Sri Lanka	0.23	0.47	0.61	0.59	0.48	0.37	**0.46**	0.53	0.78	**0.51**
	West Indies	0.19	0.40	0.54	0.53	0.41	0.31	0.39	**0.46**	0.73	**0.44**
	Zimbabwe	0.07	0.17	0.27	0.26	0.18	0.12	0.16	0.21	**0.46**	**0.18**
	Average	**0.19**	**0.43**	**0.57**	**0.56**	**0.44**	**0.33**	**0.41**	**0.48**	**0.77**	**0.46**

Table 10.6. Estimates of the winning probabilities for the away team based at the completion of the 1997/98-2002/03 study period

	Team	*Home team*									
		Aust	*Eng*	*Ind*	*NZ*	*Pak*	*SA*	*SL*	*WI*	*Zim*	*Ave.*
Away team	Australia	**0.08**	0.20	0.31	0.29	0.21	0.14	0.19	0.24	0.50	**0.26**
	England	0.03	**0.08**	0.13	0.12	0.08	0.05	0.08	0.10	0.26	**0.11**
	India	0.02	0.05	**0.08**	0.07	0.05	0.03	0.04	0.06	0.17	**0.06**
	New Zealand	0.02	0.05	0.09	**0.08**	0.05	0.03	0.05	0.06	0.18	**0.07**
	Pakistan	0.03	0.08	0.13	0.12	**0.08**	0.05	0.07	0.09	0.25	**0.10**
	South Africa	0.04	0.12	0.19	0.18	0.12	**0.08**	0.11	0.14	0.35	**0.16**
	Sri Lanka	0.03	0.08	0.14	0.13	0.09	0.06	**0.08**	0.10	0.27	**0.11**
	West Indies	0.02	0.07	0.11	0.10	0.07	0.04	0.06	**0.08**	0.22	**0.09**
	Zimbabwe	0.01	0.02	0.04	0.03	0.02	0.01	0.02	0.03	**0.08**	**0.02**
	Average	**0.02**	**0.08**	**0.14**	**0.13**	**0.09**	**0.05**	**0.08**	**0.10**	**0.27**	**0.11**

Table 10.7. Logarithmic likelihoods for three methods of estimating a match outcome in Test cricket at the completion of the 1997/98-2002/03 study period

Measure	*Logarithmic likelihood*
Prediction algorithm	-244.78
Equal chances attached to each match outcome	-253.78
Long term proportions attached to each match outcome	-247.30

10.5 Applying the prediction algorithm

To gauge the effectiveness of the prediction algorithm we will apply it to the Test-series which immediately followed the last match in the 2002/03 season. This saw Sri Lanka opposed to England at home in a three-Test series. The actual first innings results and match outcomes are provided in Table 10.8. Note that this example is used for illustrative purposes only. Ideally, the algorithm would be applied to a large number of matches over an extended period of time, with the batting and bowling ratings constantly updated.

In applying the prediction algorithm, a number of scenarios can be considered, each of which pertains to a progressive stage of the match. In essence, this means that the odds of winning for each team can be re-computed at the completion of each stage. In a climate where bets are received while competitions are in progress this provides an informed account of a team's progressive winning chances. The four scenarios that will be considered are:

- The time before the coin is tossed and Team 1 is not known
- The time after the coin toss has been won and Team 1 is known
- The time after Team 1 has completed its first innings
- The time after Team 2 has completed its first innings and the actual lead is known

In the first scenario there is a 50% chance that either Sri Lanka or England will be Team 1. In the second case Team 1 is known. In the third case we can adjust the (signed) first innings differential by replacing Team 1's predicted score with its actual score. In the final scenario we can employ the actual (signed) first innings differential by replacing the predicted leads of Teams 1 and 2 with their actual leads. The six steps in the process are summarised below. The smoothed HA and team ratings, updated upon completion of each of the three Test matches are provided in Table 10.9. The updated parameter estimates when model (10.4) is fitted to the match outcomes are provided in Table 10.10. The expected first innings scores for each team are provided in Table 10.11.

Step 1 The most recent batting and bowling ratings are used to compute the probability that both teams win, lose or draw the first Test match. Since Team 1 is unknown prior to the coin toss;

$$\Pr(\text{Sri Lanka wins}) = 0.5 \times \Pr(\text{Sri Lanka wins} + \text{England loses})$$

$$\Pr(\text{England wins}) = 0.5 \times \Pr(\text{Sri Lanka loses} + \text{England wins})$$

$$\Pr(\text{Draw}) = 0.5 \times \Pr(\text{Sri Lanka draws} + \text{England draws})$$

Step 2 Probabilities of winning, drawing and losing the first Test match are computed after the coin toss once Team 1 is known

Step 3 At the end of Team 1's innings, the predicted lead is adjusted so that

$$\text{Predicted lead} = \text{Team 1's actual score} - \text{Team 2's predicted score}.$$

Then the probability of winning, drawing and losing the first Test match are computed

Step 4 At the end of Team 2's innings, the probability of winning, drawing and losing the first Test match are computed based on the actual first innings lead

Step 5 The ratings and logistic regression parameter estimates are updated once each innings score in the first Test match is known, then Steps 1 to 4 are repeated for the second Test match

Step 6 The ratings and logistic regression parameter estimates are updated once each innings score in the second Test is known, then Steps 1 to 4 are repeated for the third Test match

To test the efficacy of the prediction algorithm, when applied to an actual series of results, we compute the logarithmic likelihood for each scenario so as to gauge which model best predicts the outcomes that actually occurred. For further comparison, two additional control measures are also introduced. The control measures are an equal chance of winning, drawing and losing and the actual long term proportions of winning, drawing and losing (over 231 previous Test matches). For the latter the proportion of wins, draws and losses were 31%, 25% and 44% respectively. The diagnostic results are provided in Table 10.12. Not surprisingly, the best model predictors arose in the latter two scenarios when first innings details were known. Notably in all scenarios where the prediction algorithm was applied the model clearly provided the best predictors of the actual match outcomes. The prediction algorithm also performed significantly better than the control measures. Clearly, as more information became available, not unexpectedly, the logarithmic likelihood steadily improved.

Table 10.8. First innings results and match outcomes in a Sri Lanka versus England Test series

Test	*Home team*	*Team 1*	*Team 2*	*Team 1 score*	*Team 2 score*	*Actual Team 1 (signed) lead*	*Match outcome*
1	Sri Lanka	Sri Lanka	England	331	235	96	Draw
2	Sri Lanka	Sri Lanka	England	382	294	88	Draw
3	Sri Lanka	England	Sri Lanka	265	628	-363	Sri Lanka

Table 10.9. Updated HA and team ratings upon completion of each Test match in a Sri Lanka versus England Test series

Completion of Test match	*Smoothing constants*		*New Average score*	*New HA rating*	*New batting rating*		*New bowling rating*	
	α_1	α_2			*Sri Lanka*	*England*	*Sri Lanka*	*England*
1	0.050	0.129	292	66	148	134	74	79
2	0.050	0.129	286	66	148	128	80	79
3	0.050	0.129	284	66	148	126	82	79

Table 10.10. Updated parameter estimates for the prediction of match outcomes for the team batting first in Test cricket for the period 1997/98-2002/03

Parameter	*Term*	*Coefficient*	*Standard error*	*p-value*	*Odds ratio*
At the completion of the first Test					
β_{00}	Intercept (win)	-1.6700	0.2428	0.000	
β_{01}	Intercept (win and draw)	0.0799	0.2109	0.705	
β_1	Home	0.6881	0.2866	0.016	1.99
β_2	Lead	0.008980	0.00101	0.000	1.01
At the completion of the second Test					
β_{00}	Intercept (win)	-1.6837	0.2431	0.000	
β_{01}	Intercept (win and draw)	0.0874	0.2109	0.678	
β_1	Home	0.6801	0.2857	0.017	1.97
β_2	Lead	0.009008	0.001011	0.000	1.01

Table 10.11. Expected first innings scores in a Sri Lanka versus England Test match with Sri Lanka being the home team

Test	*Home team*	*Team 1*	*Team 2*	*Expected Team 1 score*	*Expected Team 2 score*	*Expected (signed) home lead*
1	Sri Lanka	Sri Lanka	England	459	364	95
2	Sri Lanka	Sri Lanka	England	427	352	75
3	Sri Lanka	England	Sri Lanka	421	332	89

Table 10.12. Predicted results for each match played in a Sri Lanka versus England Test series

Test	*Team 1*	*Team 2*	*Predicted Team 1 (signed) lead*	*Predicted home probabilities for Sri Lanka*			*Actual outcome*
				Win	*Draw*	*Loss*	
Control measures							
			Equal chances attached to each match outcome: Logarithmic likelihood				-3.94
			Long term proportions attached to each match outcome: Logarithmic likelihood				-3.10
Model applied before the coin toss							
1	Sri Lanka	England	95	0.47	0.36	0.17	
2	Sri Lanka	England	75	0.42	0.39	0.19	
3	Sri Lanka	England	89	0.45	0.38	0.17	
1	England	Sri Lanka	-95	0.52	0.34	0.14	
2	England	Sri Lanka	-75	0.48	0.36	0.16	
3	England	Sri Lanka	-89	0.51	0.35	0.14	
1				0.50	**0.35**	0.16	Draw
2				0.45	**0.38**	0.18	Draw
3				**0.48**	0.37	0.16	SL win
					Logarithmic likelihood		-2.75
Model applied after the coin toss							
1	Sri Lanka	England	95	0.47	**0.36**	0.17	Draw
2	Sri Lanka	England	75	0.42	**0.39**	0.19	Draw
3	England	Sri Lanka	-89	**0.51**	0.35	0.14	SL win
					Logarithmic likelihood		-2.64
Model applied after Team 1 has completed its innings							
1	Sri Lanka	England	-33	0.22	**0.39**	0.38	Draw
2	Sri Lanka	England	30	0.33	**0.41**	0.26	Draw
3	England	Sri Lanka	-67	**0.46**	0.22	0.17	SL win
					Logarithmic likelihood		-2.61

Table 10.12. (Continued) Predicted results for each match played in a Sri Lanka versus England Test series

Model applied after Team 2 has completed its innings							
Test	*Team 1*	*Team 2*	*Actual Team 1 (signed) lead*	*Predicted home probabilities for Sri Lanka*			*Actual outcome*
				Win	*Draw*	*Loss*	
1	Sri Lanka	England	96	0.48	**0.36**	0.16	Draw
2	Sri Lanka	England	88	0.45	**0.37**	0.17	Draw
3	England	Sri Lanka	-363	**0.92**	0.06	0.01	SL win
					Logarithmic likelihood		-2.10

10.6 Conclusions

It was established that a simple prediction algorithm model can be applied in order to predict match outcomes in a Test match series and set appropriate odds for winning, losing and drawing. Firstly, with the application of exponential smoothing techniques a team's first innings attack and defence ratings and a team HA rating can be determined. These can then used to predict a team's first innings lead. Secondly, a multinomial (ordinal) logistic model, with the explanatory variables being a team's first innings lead and a home team indicator, can be applied in order to estimate a team's match outcome probabilities. The prediction model was applied to the three-match Sri Lanka versus England Test series immediately following the last match in the study period. The home and team batting and bowling ratings were updated at the completion of each match. A number of scenarios, outlining the progressive stages of each match, were considered. These were predictions (1) before the coin is tossed and Team 1 is not known; (2) after the coin toss has been won and Team 1 is known; (3) after Team 1 has completed its first innings and (4) after Team 2 has completed its first innings and the actual lead is known. Calculation of the logarithmic likelihood confirmed that the prediction algorithm, in all cases, was clearly more effective than other control measures at attaching appropriate predictive weights to the match outcomes which actually occurred. Not surprisingly, the logarithmic likelihood steadily improved as more information became available.

CHAPTER 11
FINAL CONCLUSIONS

11.1 Introduction

Cricket generates a plethora of statistics but for the most part has escaped rigorous examination. By employing a range of linear and logistic modelling methods the thesis examined three ICC-sanctioned cricket competitions. These were ODI cricket, Test cricket and domestic cricket. The thesis measured the extent to which team performance effects such as HA, batting and bowling strength and the order of innings play a pivotal role in defining winning match outcomes and quantified the degree to which these effects contributed to (a) a team's victory margin in ODI cricket; (b) a team's first innings runs differential in Test and domestic cricket and (c) a team's innings score in ODI and Test cricket. As a consequence, the thesis formulated alternative ways of defining and measuring team strength (in all forms of cricket) and challenged the methodologies currently employed by cricket administrators to quantify and rate team performance.

Cricket contrasts with many team sports in that it is not generally played within easily definable constraints. In particular, constraints associated with time, playing surface and match conditions are not easily characterised in cricket. In Test and domestic-based cricket, for example, the length of innings can vary markedly and are rarely the same length. It is also not uncommon for the playing surface to deteriorate significantly throughout the duration of a match, making batting an increasingly difficult exercise. Similarly, in ODI cricket it is not easy to gauge the extent of a Team 2 victory since matches involving a Team victory are truncated once the target score has been reached. As a result, team performances are not readily compared.

In examining team performance in all forms of cricket the conventional approach has been to simply deem a team's win/loss ratio as the foremost indicator of team success. This orthodoxy espouses that the higher a team's winning percentage the stronger the team and vice versa. This provides a worthwhile account of a team's overall ability but does not quantify the degree to which specific factors such as HA and batting and bowling strength may have contributed to a team's level of performance. In a similar vein, in analysing a home team's superiority in a balanced home and away competition, many authors such as Schwartz and Barsky (1977) and Courneya and Carron (1992) interpret the HA effect as the ability of a team to win more than 50% of its matches at home. This provides an overall rudimentary measure of the HA effect but fails to take into account the relative abilities of the competing teams. Under this system, the only teams enjoying a HA would be those that win on a consistent basis at home. In effect, it presupposes that any HA and team quality effects are dependent on each other. It precludes the notion that (a) HA and team quality can act independently and (b) the capacity of the home team to restrict the winning potential of a superior opponent is also a measure of HA. In contrast, the application of statistical modelling methods provides the tools necessary to move beyond simply using match outcomes as the only measure of a team's performance credibility. Broadly speaking, these techniques can be used to effectively measure the extent to which specific performance factors contribute to a team's run-scoring potential and its ability to orchestrate a winning result.

Domestic and Test cricket both represent the long form of the game, with a maximum of two innings allowed for each team. However, the games are structured differently. In a Test match a team can only win by securing an outright result otherwise the match is drawn or very rarely tied. Domestic cricket competitions are points-based, with the team accruing the most points being declared the winner. Points are generally awarded in both innings, with an outright result attracting the most points. The protocols for the allocation points are unique to the region in which the competition is conducted. Nonetheless, since an outright result attracts the most points the securing of an outright victory is the modus operandi of the competing teams. In ODI cricket, teams are afforded fifty overs (in a single innings) to score as many runs as possible. The team with the higher innings score wins. If teams finish on the same score the match is tied. Test and domestic cricket are based on the same structural premise; however, the manner in which a team wins is manifestly different. In a Test match a team only wins if it can secure an outright result.

Note that in analysing domestic and Test cricket the principal focus is the first innings and not the second because in the former case it can be safely assumed that teams go all out to maximise their first innings advantage. Consequently, this provides an accurate gauge of team strength. On the other hand, there is a propensity for second innings performances to be more reactionary, with teams choosing to adopt a more measured approach. As a result, teams often adjust their style of play as a strategic response to the situation of the match. Pitch conditions also tend to deteriorate over time, which often stifles a team's natural style of play.

Results for Test and ODI cricket are considered in five-year periods because it is assumed that for the majority of teams the composition of the core playing group has essentially remained the same over this period of time. Consequently, it would be expected that any team quality effects would be consistent within each of the five-year periods but not necessarily across periods. Over longer time periods the core playing group may change dramatically, which suggests that the team quality effect may also dramatically change. Accordingly, this may lead to a misinterpretation of the findings. As a result, the analysis of team performance may not accurately account for the inherent variability in team quality and thus provide only an average measure of a team's relative strength.

11.2 Domestic cricket

The thesis confirmed that in both the Australian and English domestic cricket competitions, namely the Pura Cup and the Frizzell County Championship there was a significant HA effect. In both cases the home team was able to secure significantly more overall wins, more outright results and more points than the away team. However, there was no evidence of a seasonal effect, with the overall HA effect remaining consistent across study periods. Comparison of the variability of the points-margins across competitions suggests that the overall HA enjoyed by teams in the Pura Cup was more substantial than in the Frizzell County Championship.

Logistic modelling techniques were used to quantify the degree to which effects such as HA, a lead on the first innings and winning the coin toss contributed to a winning result. The thesis ascertained that both HA and a team's first innings lead were very strong predictors of a winning match outcome in the Pura Cup. However, only the first innings lead was a strong predictor of a winning result in the Frizzell County Championship. It is most likely that the HA effect is not as prevalent in the County Championship because teams are expected to play at a diverse number of locations thus preventing them from developing innate knowledge of localised conditions. It is well documented that vocal home crowd support can be an influential factor in the shaping of a home victory, with the larger the crowd the more influential the support. However, with the crowds for both the Pura Cup and the Frizzell County being very small it can be argued that any advantage gained from a vocal home crowd would be negligible. This suggests that travel factors in the Frizzell County Championship and familiarity with local conditions in the Pura Cup were possibly more influential in determining the HA effect. There was no evidence to suggest that teams were advantaged by winning the coin toss in either competition. There was also no evidence to suggest that the accumulation of bonus points in the Frizzell County Championship was a strong predictor of a winning outcome. Nonetheless, it appears that the point allocation system in the County Championship has been (either consciously or unconsciously) engineered so as to dissuade teams from forcing a drawn result after establishing a first innings lead on points. In essence, the points system employed in the County Championship discourages teams from relying solely on first innings bonus points as an avenue to a winning result.

Linear modelling methods were employed to measure the degree to which effects such as team quality and HA contributed to the observed variation in the runs differential. The resulting least squares parameter estimates provided a measure of a team's overall batting and bowling strength (recorded as a team rating relative to the average rating of 100) and quantified the advantage (in runs) attributed to effects such as HA and the order of innings. A rating above 100 signifies that a team has performed better than average. The converse is true for a team rating less than 100. One would expect a team rated above 100 to be in a winning position more often than not. Team ratings provide an effective method for contrasting team performances in cricket competitions and allow comparisons to be drawn that are not confounded by other effects such as HA. Since the ratings take account of the size of a victory they provide an accurate gauge of a team's performance relative to both the average performance and the strength of its opponents. They ultimately reward teams for strong performances and recognise that a dominant victory is worth more than a marginal victory.

Not surprisingly, team strength in the first innings was a strong predictor of a winning result in the Pura Cup, with the highest rated teams displaying a tendency to win more matches and earn more points than their opponents. In the County Championship, however, first innings strength was only a moderate predictor of a winning outcome. This suggests that other factors such as HA possibly played a pivotal role in defining outcomes in this competition. In fact, it was established that there was a significant HA (runs) effect, with the home team gaining a significant first innings runs advantage in both competitions.

There is an interesting parallel between Test cricket, the Frizzell County Championship and the Pura Cup competition. All of these forms of cricket are essentially based on the same playing format; however, the chances of winning for the team trailing on the first innings vary markedly. This anomaly rises because the probability of winning in Test cricket and the Frizzell County Championship are continuous across all possible innings differentials. In the Pura Cup, however, a discontinuity is evident, with the probabilities of winning and losing 'on points' distinctly different for the leading and trailing teams. Authors such as Preston and Thomas (2002) and Carter and Guthrie (2004) have addressed similar issues in interrupted ODI matches and argue that for a system to be fair to both teams the winning and losing probabilities must be continuous across any breaks in play. In effect, the trailing team in the Pura Cup competition can be severely penalised by the point-allocation system if they trail by relatively few runs. The Frizzell County Championship is also a points-based competition but since both teams can earn first innings bonus points the discontinuity is effectively removed. As a consequence, it is not uncommon for the trailing team to be actually ahead 'on points' at the completion of the first innings. This confirms that in both Test cricket and the Frizzell County Championship the probability of winning for a team trailing by one run is essentially the same as the probability of winning after leading by one run because the winning and losing probabilities are continuous across the break in innings. Not surprisingly, a marginal difference of two runs between the two teams results in a marginal difference the winning probabilities. In the Pura Cup, however, the leading team needs to only secure a draw in order to win the match 'on points'. In contrast, the trailing team has no choice but to conjure an outright result regardless of the first innings deficit. The securing of an outright win in the Pura Cup has proven to be a perennially more difficult task than playing out a draw, especially for the trailing team. Even if the deficit is a paltry run, the trailing team has no option but to orchestrate an outright result in order to establish a win 'on points'. Accordingly, a marginal difference of only two runs creates a critical difference in the winning probabilities. Thus the winning probabilities are not continuous across the break in innings and a discontinuity occurs. In effect, the discontinuity arises because it is a far more challenging task for the trailing team to orchestrate an eight-point turnaround and win outright than it is for the leading team to play out a draw and preserve a two-point buffer. Under these circumstances the leading team in the Pura Cup competition has a stronger winning chance than the leading team in the Frizzell County Championship. As a consequence, it was established that the respective predictions for a winning match outcome were more highly variable in the Frizzell County Championship than in the Pura Cup competition.

Since the match winner in domestic competitions is solely dependent on the allocation of points this highlights an incongruity associated with schemes of this nature. This arises because, by default, some matches end up being worth more points than others. In the Pura Cup competition, for example, if the team trailing on the first innings wins outright the match is worth eight points; i.e. two points are awarded to the team leading on the first innings and six points are awarded to the trailing team for winning outright. In contrast, if the team leading on the first innings wins outright the match is worth only six points; i.e. two points are awarded for establishing a first innings lead and an additional four points are earned for securing an outright result. In the case of a draw, the match is worth only two points; i.e. two points are awarded to the team leading on the first innings. This is exacerbated by another problem associated with domestic cricket competitions in that some grounds (or pitches), by their very nature, are more conducive to a particular match outcome than others. This problem is outlined by Clarke (1986) in his analysis of a season of Australian domestic cricket. Accordingly, if a team's home ground produces a high proportion of draws it is more often than not competing for relatively fewer points. In contrast, if a team's home ground is conducive to outright results, teams are customarily competing for relatively more points. Since the rules that underpin the Pura Cup competition must be fair to all teams this discrepancy must be adequately addressed. This is a difficult state of affairs to regulate because the nature of playing surfaces is commensurate with local conditions. This also underscores the implicit HA enjoyed by teams who predominantly play at venues that are more favourable to producing outright results and highlights the need for administrators to take these inequities into account when implementing playing conditions. Currently, at venues that are conducive to producing outright results, teams are essentially playing for a potential pool of eight points; i.e. six points for an outright result and two points for a draw. In contrast, at venues favourable to drawn results, teams are competing for a pool of only two points; i.e. the two points earned for establishing a first innings lead. There is a call for a 'points' system, especially in the Pura Cup competition that addresses this situation and ensures that all matches are worth the same number of points.

11.3 ODI cricket

Teams in ODI cricket generally improved significantly in their run-scoring capacity throughout both study periods. This underscores the attitudinal change which accompanied ODI cricket in the mid-1990s whereby teams restructured their teams in order to expose more free-flowing batsmen higher in the batting order. Up until the mid-1990s the composition of ODI cricket teams mirrored those of Test cricket.

The thesis established that there was a significant overall HA effect, with the home team able to consistently score more runs and win significantly more matches than its opponents. The probabilities of the home team winning (in either innings) were found to be similar across study periods. Notably, team quality factors became less pronounced over time and there was some evidence of a day/night effect during the first study period, with the team batting first (in daylight) able to score significantly more runs than the team batting second (at night). The variability of the scores in day/night matches increased markedly (in both innings) across study periods. There was some strong evidence supporting a regional effect during the first study period with teams tending to lose when opposed to teams from different geographical regions. During the second study period there was also some evidence of a regional scoring effect. In particular, the sub-continental and Australasian regions displayed a capacity to produce generally higher scores. This possibly arose because the stronger batting nations during this time resided in these regions. There was also some evidence suggesting that during the second study period teams in the

Australasian region displayed a solid winning advantage over their opponents. However, there was no evidence to suggest that teams were significantly advantaged by either winning the coin toss or the order of innings.

It is evident that the current methods used to record a Team 2 victory in ODI cricket are inconsistent and misleading. At present, Team 1 and 2 victories are recorded differently. The method that is employed to record a Team 1 victory makes sense because the level of dominance exercised by the winning team, in effect, is commensurate with the margin of victory. A 100-run victory is clearly more dominant than a one-run victory. There is a need for a similar method to document a Team 2 victory. Currently, the method used to record a Team 2 victory sheds little light on the strength of the win. For example, a 10 wicket victory could have been achieved on the last ball of the day or with 20 overs to spare. The introduction of a revised system for recording a Team 2 victory needs to be investigated which (a) is consistent across innings; (b) provides a mechanism for all Team 2 victories to be ranked accordingly and (c) allows Team 1 and Team 2 victories to be easily compared. In establishing a system that allows the extent of a Team 2 victory to be compared with a Team 1 victory the Duckworth and Lewis (1998) (D/L) rain interruption rules, with the modifications suggested by de Silva, Pond and Swartz (2001), can be employed. The D/L methodology sets a revised target score for Team 2 when a match has been delayed. The method takes into account the residual run scoring resources (in the form of the number of wickets lost and the number of overs remaining) a team has at its disposal at the time of the stoppage. It is based on an exponential decay model that calculates the expected number of runs to be scored in the remainder of an innings as a function of the number of overs remaining and the number of wickets lost. In effect, the D/L methodology contends that a team that has, for example, lost only two wickets at the time of a stoppage is potentially in a stronger position than a team that has lost nine wickets. The D/L rain interruption rules have been sanctioned by the ICC and are formally used in all ICC-recognised ODI cricket matches.

The thesis demonstrated that the D/L rain interruption rules methodology can be used to scale up the actual winning Team 2 scores in proportion to its unused run scoring resources to estimate a projected score. In effect, this creates a projected victory margin for Team 2 when it wins with unused run scoring resources (in the form of overs and wickets) at its disposal and, as a result, provides a more realistic measure of Team 2's relative superiority at the point of victory than the current wickets-in-hand method. This approach ensures that all victories (across innings) can be measured on a consistent scale and contrasted after both teams have theoretically expended their available quota of run scoring resources. It is incumbent on cricket authorities to consider introducing this system of recording Team 2 victories because it is consistent with methods employed to record Team 1 victories and is clearly more effective at gauging the actual strength gap between opponents.

Following the work undertaken by Clarke and Allsopp (2001) in their analysis of the 1999 Cricket World Cup, authors such as de Silva, Pond and Swartz (2001) have also employed the D/L rain interruption rules methodology to estimate the magnitude of victory in ODI cricket matches. They characterize this by the effective run differential between opposing teams. When comparing the distributions of the actual and effective run differentials they discern that the distribution of the effective run differentials has a longer tail than the actual run differentials. They conjecture that this discrepancy arises because the D/L methodology tends to overestimate a team's potential when a large number of unused run scoring resources are available and conversely, underestimates a team's potential when a limited number of run scoring resources are available. As a consequence, they propose a modification to the D/L procedure to account for these discrepancies. To some degree Duckworth and Lewis (2004) have addressed these anomalies and subsequently updated their model parameters. Under the revised D/L scheme any revised target set for Team 2 is not deemed improbable, even under extreme circumstances.

By fitting a range of multiple linear regression models to the victory margins the thesis established that during the first study period the model that included a common HA parameter was more effective than the other models at explaining the observed variation in the victory margins. During the second study period, however, the most proficient model included an individual parameter for each of the five geographical regions. During the first study period both the home team and Team 1 enjoyed a significant runs advantage over their opponents. In the main, the team quality effect remained constant across study periods. Its variability, however, was more pronounced during the second study period.

There was also some evidence suggesting that a team's scoring potential was influenced by regional effects during the second study period but not the first.

By modelling the innings scores in ODI cricket (instead of the victory margins) a team's overall strength was separated into its batting and bowling strength. The resulting least squares parameter estimates provided team ratings for both batting and bowling. These give an accurate measure of a team's attacking (batting) and defensive (bowling) proficiency (relative to the average rating of 100) and provide a more accurate account than the team ratings derived from modelling the victory margins. For example, a strong overall rating may disguise the fact that a team is consistently underachieving with the ball. For example, suppose a team's overall rating is 120 and its batting rating is 140. This hides the fact that its bowling rating of 80 is significantly below par. For the first study period, a model that included nine individual HA parameters provided the best fit of the data whereas a model that included the five regional parameters provided the best fit of the data for the ensuing study period. Some teams gained a significant scoring advantage when playing at home during the first study period whereas a number of teams were significantly advantaged when playing in their local geographical region during the following period. There was also strong evidence suggesting that there was a greater disparity in batting and bowling strength during the second study period rather than the first. This suggests that match outcomes were more predictable during this period. For the first study period batting strength rather than bowling prowess was the stronger predictor of a winning match outcome. This supports the established orthodoxy that success in ODI cricket is commensurate with a team's batting proficiency. During the second study period, however, bowling strength was the stronger predictor of a winning result. This contradicts conventional thinking.

The ICC Cricket World Cup is an ODI cricket competition contested between seeded teams, divided into two groups. There are four distinct phases of the competition: the preliminary phase, involving the Group Matches; the Super-Six phase; the Semi-finals stage and the Final. The competition uses a seemingly ad hoc set of matches to define the world champion, the structure of which raises many questions. In the 1999 and 2003 World Cups, for example, to eliminate half the teams a highly disproportionate number of matches were devoted to the preliminary stage of the competition, a number of which were heavily one-sided contests. Conversely, only a few matches were used to split the top teams in the finals phase of the competitions. In order to give the greatest chance to the better teams, it makes more sense to play fewer matches during the early phases of the competition, when the variability in team strength is high and more matches in the later stages when teams are more evenly matched. Many other considerations also come into play, such as giving all teams a minimum number of matches and giving the weaker countries experience against the stronger teams. In any event, whatever structure is ultimately used it should not compromise nor lose sight of its primary goal of determining the best team in the competition. The ICC Cricket World Cup understandably must prescribe a set of rules under which the tournament operates. Consequently, a team can do no more than win under the prescribed conditions. Conversely, it should be recognised that there is a large element of luck in matches that pit equally matched ODI teams against each other.

The outcome of an ODI match can be unduly influenced by random factors, especially if the competing teams are evenly matched. This may ultimately seal the fate of a team's chances of winning a major cricket tournament (such as the ICC Cricket World Cup) and overshadow a team's overall standing throughout the tournament. Linear modelling methods, that take account of the size of a victory, can be used to generate team ratings. The ratings are calculated independently of effects such as HA and quantify team performance relative to both the average rating and the ratings of competing teams. Under this scheme teams are duly rewarded for a strong victory and penalised for a large loss. They provide a robust measure of team quality and are not sensitive to the extraneous effects that may decide the ultimate winner of a cricket tournament.

Another issue associated with tournaments such as the ICC Cricket World Cup is how to effectively separate teams that, upon completion of the qualifying stages of a tournament, are tied on the same number of wins. Two methods could be investigated to handle this situation. Firstly, after application of the D/L methodology and the scores for Team 2 (when winning) have been scaled up the victory margins for Teams 1 and 2 can be computed. The average of the victory margins (across all matches) can then be compared. The team with the lowest average would progress to the next stage of the tournament.

Secondly, team ratings can be generated and updated as the tournament progresses. Under this scheme the team with the highest rating would progress. This would confirm that the team advancing to the next stage has, on average, enjoyed the stronger victories.

11.4 Test cricket

In Test cricket the fortunes of a team may ebb and flow over a four or five-day period. This makes the analysis of performance effects, such as those associated with HA and the order of innings a complex task. In his analysis of Test cricket statistics, Clarke (1998) particularly lamented the fact that the analysis of HA in cricket has not been extensively investigated.

A preliminary analysis of Test cricket established that there is a significant HA effect, with the home team more effectual than its opponents at establishing a first innings lead. This strongly contributed to the home team's distinct winning advantage. Not surprisingly, the thesis determined that the establishment of a first innings lead, in general, provided teams with a strong winning advantage in Test matches. There was some evidence of a regional effect during the second study period, with the sub-continental and Australasian regions, in particular, tending to score more heavily than its opponents. However, teams from the Australasian region were generally more effective than teams from other regions at converting this advantage into a winning result.

By fitting a range of multiple linear regression models to the innings differentials the thesis established that during both study periods the model that included a common HA parameter was the more effective at explaining the observed variation in the first innings run differentials. The resulting least squares parameter estimates provide an accurate gauge of a team's overall strength relative to the average team rating of 100. It was established that there was a significant HA effect across both study periods with the home team enjoying a sizeable first innings runs advantage over its opponents and displaying a strong propensity to win. This underlines the benefit in being able to effectively exploit local conditions over an extended period of time. Teams from the sub-continental regions in general enjoyed a significant first innings runs advantage. It can be argued that teams from these regions were in the best position to exploit playing conditions unique to these regions. Logistic modelling techniques also confirmed that a team's first innings lead, not surprisingly, was a very strong predictor of a winning match outcome, especially during the second study period.

By modelling the first innings scores in Test cricket a team's overall strength can be separated into its batting and bowling strength. The subsequent least squares parameter estimates provide a rating of a team's attacking (batting) and defensive (bowling) proficiency relative to the average rating of 100. It was ascertained that there was essentially no difference in the average (batting and bowling) performance across study periods. Nonetheless, performances tended to be more variable during the second period of the study. Surprisingly, during the first study period there was no evidence to suggest that a team's batting or bowling strength significantly contributed to a winning result. This intimates that either (a) relative batting bowling strength alone were not influential in defining match outcomes or (b) due to the evenness of team quality, undefined factors may have played a crucial role in influencing a winning outcome. During the second study period Team 2 was consistently in a position of strength and was able to win considerably more often than Team 1. This contradicts conventional thinking which posits that teams should elect to bat first in order to (a) exploit early favourable playing conditions and (b) avoid batting last on an unpredictable wicket. There was solid evidence during the second study period suggesting that a team's relative strength in the final rather than the penultimate innings was critical in setting up a win. Notably, Team 2's bowling strength was decisive in defining a winning match outcome which supports the notion of Team 2 having the upper hand during this period. In the extended 1997/98-2992/03 study period further analysis confirms that (a) Team 2 continued to enjoy a significant winning advantage and (b) relative superiority in the final innings continued to be highly significant in defining a winning result. This confirms that a team was clearly in the best position to force a win when it was able to exploit its dominance during the final rather than the penultimate innings. The dominance of the team batting second cannot be overestimated and the results clearly describe an unexpected trend that has emerged in Test cricket. The results strongly advocate that to improve their winning chances, teams should expose their particular strength, whether that be batting or bowling, in the final rather than the penultimate innings. This puts paid to the mythical notion, often spruiked by cricket pundits, that when given the opportunity, teams should elect to bat first. Clearly, there is strong evidence to suggest that, in the main, this approach has been detrimental to the team batting first.

Betting on sport is a burgeoning industry and with a wealth of betting options now available is fast becoming the staple of the keen punter. Added to this, the advent of new technologies has meant that punters can now bet on match outcomes while games are in progress. However, the vagaries of Test cricket and the length of time over which it is played make it a difficult proposition to accurately predict match outcomes. To overcome this difficulty the thesis introduces a simple prediction model that can be used to predict match outcomes in Test cricket. The model incorporates team batting and bowling ratings as a gauge of team strength and is augmented by the inclusion of a HA performance effect. The algorithm is initially applied to first innings scores to ascertain a team's batting and bowling ratings. These are then used to predict the possible match outcomes of a win, loss and draw. Appropriate odds can then be set for winning, losing and drawing. Firstly, with the application of exponential smoothing techniques, a team's first innings attack and defence ratings and a team HA rating are determined. These are then used to predict a team's first innings lead. Secondly, a multinomial (ordinal) logistic model, with the explanatory variables being a team's first innings lead and a home team indicator, is applied in order to estimate a team's match outcome probabilities of winning, losing and drawing. The batting and bowling ratings are updated at the completion of each match and the model re-applied to make predictions in the following Test match. A number of scenarios, outlining the progressive stages of each match, are considered. These included, before and after the coin toss; at the completion of Team 1's innings and at the completion of both first innings. It follows that as more information becomes available at the various stages of a match the better the predictions.

11.5 Team ratings in ODI, Test and domestic cricket

Upon completion of ICC sanctioned international cricket matches teams are awarded rating points. This system has been introduced so that team performances can be compared over an extended period of time. Points are allocated at the completion of all ODI and Test matches and are used to update a team's overall ranking. However, they are not used to determine a match or series winner as is the case with domestic cricket competitions.

The systems the ICC employs for rating teams in ODI and Test cricket use seemingly ad hoc point-allocation protocols. In ODI cricket, for example, if the gap between competing teams is less than 40 points, the winning team scores 50 points more than its opponent's rating. Why use these values? A similar situation occurs in Test cricket. The thesis contends that for a range of reasons, any system that apportions points as a performance measure is inherently problematic. For example, the point allocations are rarely commensurate with the state of a match and unavoidable discontinuities occur at the point-allocation boundaries.

The rating system used for ODI cricket provides a crude measure of a team's relative standing. However, it is ultimately unsuccessful because the rating of team performance is not commensurate with the strength of a victory. For example, Team 1 could have won by 150 runs with 10 overs to spare or by one run off the last ball of its innings. Similarly, Team 2 could have won by ten wickets with 10 overs to spare or with one ball to spare. In all of these instances the size of the victory is radically different. The ICC rating system, though recognising the value of a lowly ranked team defeating a much higher ranked opponent, would effectively rate the strength of all these victories equally. Accordingly, the extent of a team's victory is not reflected in the existing ICC system. It makes better sense to rate and ultimately rank team performances using a system that takes account of the magnitude of a victory. Another inherent problem associated with the current system is that the allocation of points is arbitrary in nature and cannot avoid discontinuities at the point-allocation boundaries. Under the current ICC rules incremental changes in the rating gap between competing teams leads to disproportionate changes in the allocation of match points. This suggests that the allocation of points is not continuous across all point-allocation boundaries. For example, if the rating gap between teams is 39 points the ICC employs a markedly different system than if the difference is 40 points. In this case, a marginal difference of one rating point results in a sizeable difference in the allocation of match points. Furthermore, application of the ICC rules means that some matches end up being worth more points than others. This clearly disadvantages teams that, for example, play a disproportionate number of matches away from home. It has been well documented by authors such as Allsopp and Clarke (1999) and de Silva, Pond and Swartz (2001) that the home team in ODI cricket enjoys a significant advantage in both runs and a capacity to win. Accordingly, under the ICC rules the away team, on average, is playing for fewer points than the home team. The system, in effect, also penalises the stronger teams by ensuring that wins against weaker opposition are worth less than a weaker team's victory against a stronger opponent. Ostensibly, this appears to be a fair system but it could be deemed unfair for a perennially dominant team that, for a period, plays a majority of its games in an away location that strongly favours the home team.

The thesis recommends that the introduction of a revised system for rating teams in ODI cricket be investigated that (a) removes the discontinuities inherent in the ICC system; (b) recognises that some wins, in essence, are more significant than others; (c) uses team rating measures that accurately reflect the magnitude of a victory; (d) allows Team 1 and Team 2 victories to be compared on a consistent scale; (e) ensures that team ratings are continuous across all boundaries; (f) takes account of the up-to-date effects associated with HA and the relative difference in the competing team's batting and bowling strength and (g) ensures that teams are competing for the same pool of rating points.

In Test cricket, teams compete for the ICC Test championship. Teams earn rating points at the completion of a series. These are then used to update the team ratings. Using a rating regime of this type is intrinsically problematic because it neglects to take into account crucial match or series characteristics. For example, the current system fails to differentiate between the lengths of a series. Under the existing regime, a team winning a two match series one win to nil is rated equally with a team winning a five-match series five wins to nil. In the latter case the series win is far more conclusive than in the former case and should be reflected in the rating system. Also, no distinction is made between the magnitudes of a victory. For example, a team winning a five-Test series may have crushed its equally rated opponent, winning each match by a huge margin. Conversely, it may have marginally won each match or marginally won the series. In each of these scenarios, however, under the ICC rules the winning team is awarded the same number of rating points (i.e. for winning the series) even though the extent and nature of each victory are radically different. In a similar vein, the ICC system implies that in a drawn match the competing teams are equally matched. This could be far from the truth. For example, due to enforced breaks in play, the available playing time in a match could be dramatically reduced so that one team, though in position of strength, is unable to enforce a deserved victory. Furthermore, the ICC rules for Test cricket suffer the same problem as does its rules for ODI cricket, in that discontinuity problems arise at the point-allocation boundaries. For example, if the rating gap between competing teams is 39 points a markedly different system is used if the rating gap is 40 points. Thus, a marginal one-point rating gap results in a highly disproportionate point allocation.

The thesis recommends that the introduction of a revised rating system for Test cricket be investigated that (a) ensures that teams are rated after the completion of each match and so are not unduly influenced by the varying lengths of series; (b) avoids the discontinuities at the point-allocation boundaries that are present under the current system, thus a marginal difference in the rating gap between teams will not necessarily produce a sizeable difference in the allocation of points; (c) recognises that a team's overall strength is derived from its batting and bowling strength; (d) doesn't severely penalise a team if it establishes a substantial first innings lead but ends up losing the match; (e) reflects the state of a match and so rewards teams that either forge a likely win after leading on the first innings or fashion an unlikely win after trailing on the first innings; (f) does not unduly penalise teams that have been ranked highly over an extended period of time and (g) ensures that all matches are worth the same number of total rating points.

With reference to domestic cricket, to overcome some of the inherent anomalies of the Pura Cup competition the thesis recommends that the introduction of a new system be investigated. One scheme could operate in a similar manner as the Frizzell County Championship. This system would (a) abolish the allocation of points to the team leading on the first innings; (b) introduce a first innings bonus point system that allocates points for the achievement of specific batting and bowling performances; and (c) encourage teams to play for outright results. Note that with regards to the latter situation, in order to dissuade teams from relying solely on first innings bonus points to contrive a win 'on points' and thus forcing a drawn result, the points system could be engineered so that any advantage gained by securing bonus points is outweighed by the advantage gained by winning outright. The advantage of this approach over the current system is that the allocation of points (a) is not arbitrary in nature; (b) reflects the state of the match at different stages; (c) recognises the relative differences in team quality during the first innings and (d) ensures that the probabilities of winning and losing remain continuous across the break in innings. However, this approach suffers the same fate as the ICC rating systems for Test and ODI cricket in that unavoidable discontinuities occur at the point-allocation boundaries. Accordingly, marginal variations in performance give rise to disproportionate variations in the allocation of points. A second approach could be to preserve the current system but with points allocated as a proportion of a set constant. For example, suppose the constant is 100 and suppose a team wins six points to two. Under this scenario, the winning team receives $\frac{6}{8}\times 100 = 75$ points and the losing team receives 25 points. An added benefit of this system is that all matches end up being worth the same number of points regardless of where matches are played. Accordingly, teams are not disadvantaged if their home grounds are not conducive to producing outright results.

A critical problem associated with the Pura Cup competition (under the current rules) is that the team leading on the first innings is awarded an arbitrary two points regardless of the size of the lead. In effect, if a match is drawn, the system decrees that a marginal lead of one run is commensurate with a lead of 300 runs. This clearly confirms that under the current system the leading team is not rewarded for its first innings superiority, especially if the lead is a substantial one. To further underscore this inequity, suppose a match is truncated due to inclement weather. Under this scenario, the leading team, though in a position of strength is ultimately denied the opportunity to secure a probable outright result and so can only earn two points for a drawn result. Any system that is introduced must avoid this injustice and ensure that the leading team, if it goes on to win outright, is generously rewarded for its first innings superiority.

11.6 Quantifying the home advantage effect across team sports

One of the focal points of this thesis has been to develop quantitative methods to definitively measure the HA effect as an independent source of potential runs for the home team. Many authors such as Courneya and Carron (1992) have speculated on the possible qualitative sources of the HA effect in a broad range of organised team sports. These include (a) game location factors such as crowd support, travel fatigue, familiarity of the physical playing conditions and game rules (b) critical psychological and behavioural states of competitors, coaches and officials and (c) performance outcomes such as skill implementation, scoring capabilities and match outcome measures. In their analysis of Australian Rules football Stefani and Clarke (1992) suggest that one point in 21 can be attributed to a team's HA, which they advocate is not as large as in other sports. For example, in European Cup soccer, a sizeable one goal in three can be attributed to the HA effect.

In ODI cricket, for the period 1992/93-1997, HA contributed one run in 31 overall. In a typical score of 250 runs, this would lead, on average, to a marginal advantage of eight runs. The home team winning percentage for this period was 61%. This is also commensurate with the overall HA evident in many team sports. The advantage improved markedly to one run in 13 for the period 1997/98-2001. In a score of 250 runs this, on average, corresponds to a 19-runs advantage. Nevertheless, the 60% winning percentage for the home team was similar to the previous study period. This suggests that the home team, though more proficient than its opponents at scoring runs, was unable to consistently capitalise on this advantage.

In Test cricket, for the 1992-1997 study period, HA contributed one run in 13 for the first innings. In a typical score of 350 runs, this corresponds to a sizeable advantage of 27 runs. This culminated in a considerable home winning percentage of 71% during this period (i.e. calculated as home wins plus half draws). The home runs advantage marginally improved to one run in 11 for the period 1997/98-2001 or 32 runs in a score of 350 runs. The home winning percentage for this period was a sizeable 79%. Clearly, the home team became more proficient at capitalising on its advantage.

The HA effect in Test cricket appears more profitable than in ODI cricket. With Test cricket generally attracting smaller crowds than ODI cricket this result suggests that game location factors such as travel fatigue and the knowledge of local conditions, more so than effects due to partisan crowds, have impacted on the longer form of the game. With Test matches lasting up to five days pitch conditions can deteriorate considerably over time and vary markedly from region to region. This would favour the local team the longer the match progressed. With ODI cricket matches being relatively short and with crowds being generally larger it can be speculated that crowd effects would have the greater influence on HA in this form of the game. It is well documented that vocal home crowd support can be an influential factor in the shaping of a home victory, with the larger the crowd the more influential the support. Pitch conditions are designed to be more homogenous in ODI cricket and so team performances are not influenced the effects of a deteriorating pitch or the knowledge of localised conditions.

In the Pura Cup competition and the Frizzell County Championship, HA for the first innings respectively contributed, on average, a considerable one run in 10 (or 35 runs in a typical score of 350 runs) and one run in 25 (or 14 runs in a score of 350 runs). This advantage is reflected in a solid home winning percentage of 61% in the Pura Cup but a moderate 52% in the Frizzell County Championship. In the latter case, the home team was unable to consistently capitalise on its first innings runs advantage. This underlines the fact that in the Frizzell County Championship, teams are expected to play at a diverse range of venues. Thus, no one team can claim tenure of a home venue. With the crowds for both the Pura Cup and the Frizzell County being very small it can be argued that any advantage gained from a vocal home crowd would be non-existent. This suggests that travel factors in the Frizzell County Championship and familiarity with local conditions in the Pura Cup were possibly more influential in shaping a HA than any effects attributed to partisan crowd.

To quantify the overall HA effect (in runs) since the mid-1990s (across all forms of cricket) we can compute the average HA. This was measured as a sizeable one run in 17.

11.7 Limitations of the investigation and recommendations for further research

It is well documented that a significant HA effect exists in many team sports. The thesis has demonstrated that this also extends to cricket, both as an advantage in runs and a propensity to win. Authors such as Courneya and Carron (1992) have thoroughly investigated the qualitative sources of HA in a range of team sports but their treatise did not include cricket. As a result, the sources of the HA effect in cricket needs further investigation. One would envisage that partisan crowd support, travel fatigue and the familiarity of local playing conditions would play critical roles in defining the HA effect in cricket. One could speculate that in Test cricket, where crowd size is relatively small but playing conditions are unpredictable, travel factors would define the HA effect. Test cricket, in the main, is played under contrasting local conditions in a diverse range of geographical regions. Visiting national teams are often expected to quickly acclimatise to physical and cultural conditions that are in deep contrast to their customary life experiences. As a consequence, one would imagine that regional effects would play a pivotal role in defining match outcomes. In ODI cricket, however, where playing conditions are predictable and crowd size is generally large, one would imagine that the influence of a partisan crowd would be the definitive source of the HA effect.

In applying logistic regression methods to model match outcomes in Test cricket the thesis did not consider the effects associated with time constraints. Specifically, the thesis did not include the 'length of time remaining' to complete a match (after the completion of the first innings) nor the current second innings scores as key explanatory variables when modelling match outcomes. In contrast, when calculating the probability of a team winning, the analysis assumes that matches are played until a result ensues. Note that this does not create a problem *per se* for domestic cricket because a team can still win (on points) if a match is drawn. However, one would foresee that this could have a critical affect on differentiating between a team winning, losing or drawing a Test match. The thesis established that a substantial first innings lead is a very strong predictor of a winning match outcome in Test cricket. However, if a match is truncated due to inclement weather or if severe time constraints diminish the likelihood of a team securing an outright result then a draw is the most likely outcome regardless of the size of the first innings lead. As a consequence, one would expect that the 'length of time remaining' variable to be a strong predictor of a draw when the time available is limited. In the context of Test cricket the 'length of time remaining' variable could be represented by the number of overs remaining rather than the actual time left since the latter is highly dependent on a team's over rate. For example, if the requisite 90 over daily minimum is bowled play continues until the set daily playing time of six hours expires. Otherwise, play continues until 90 overs have been bowled. Accordingly, the actual daily playing time may vary markedly depending on how quickly teams can complete their overs. It makes more sense to use the overs remaining as the relevant time variable since, in the main, this is fixed.

The thesis presented a prediction model that can be used to estimate probabilities and subsequently set the odds of winning, drawing and losing a Test match. However, in its present form the model is encumbered by the same problem outlined above. The thesis has demonstrated that a substantial first innings lead is a very strong predictor of a winning match outcome in Test cricket. As a consequence, one would expect the model to predict a win if the estimated lead is a considerable one. However, this discounts the situation whereby there is only a limited time remaining to complete a match. Whereas it is likely that a team will win if it has established a substantial lead and the time remaining is considerable, it is highly unlikely that a team would win a severely truncated match regardless of the magnitude of the lead. In refining the model, it makes more sense, when modelling match outcomes, to include the 'length of time remaining' and the current second innings scores as key explanatory variables. This would ensure that the estimated odds of winning, losing and drawing adequately reflect the state of the match. A related situation involves declarations, especially when they occur during the penultimate innings of a match. A declaration generally occurs when the batting team is in a dominant position and its captain elects to truncate the innings, inviting the opposing team to bat. However, he must get the timing right and make a decision that maximises his team's winning chances. On the one hand, he needs to establish a competitive second innings lead whereas on the other hand he must ensure that he has allowed enough time to dismiss the opposition. This suggests that declarations are highly dependent on the time remaining in a match. This creates an anomalous situation when applying the prediction model because it presupposes that matches are played for an unlimited period of time. By *reductio ad absurdum* this eliminates the possibility of a declaration occurring. The model also discounted any regional effects and assumed that the HA effect was common to all teams. In a revised version of the model it would be more appropriate to respectively take account of any regional and individual HA effects.

The models presented throughout the thesis, in the main, assume that the only variables affecting match outcomes are home advantage, first innings lead (not ODI cricket), winning the coin toss, the day/night effect (not Test cricket) and regional effects (not domestic cricket). The affects of other variables such as travel, team composition, pitch and climatic conditions, rule constraints, and game strategies etc were not considered. Any future study may take account of these effects and quantify the extent to which they impact on team performance. Also, the thesis assumes that all teams from the same geographical region enjoyed the same regional advantage. It may make more sense to assume that the advantage varies within regions. A parallel would be the situation whereby a venue is shared by different home teams. In this instance, it would be expected that the HA between teams would vary.

Throughout the thesis the analysis has primarily quantified team performance at the completion of a team innings. In contrast, there has not been a focus on what has occurred during an innings. For example, are there any possible trends in (a) the runs scored per over; (b) the fall of wickets or (c) the manner in which various teams score runs? Similarly, there was no examination of the effect that individuals have on team performance. For example, do the performances by individual players follow a trend in consecutive innings? Any future examination may take account of these considerations.

Contrary to the systems currently employed by (a) the ICC, to rate teams in Test and ODI cricket and (b) Cricket Australia, to allocate match points in the Pura Cup competition, the thesis proposes that revised rating schemes, based on established linear and logistic modelling techniques, be investigated for each of the three forms of cricket. Though the proposed rating systems are founded on sound analytical methods the thesis does not set the systems up to test their operational efficacy. An effort needs to be made to scrutinise how the systems function over extended periods of time, incorporating a range of possible scenarios. This will determine whether the systems are fair to all teams and are not sensitive to systemic anomalies. The thesis also makes no attempt to contrast the effectiveness of the instituted schemes with the current schemes. It is well and good to discard a system and replace it with a radically different scheme but if the outcomes are similar there seems little point in changing. Also, an effort needs to be made to not only compare systems but to contrast the degree to which the intra-related differences are preserved. For example, if Australia is an 80% better Test team overall than Zimbabwe then this should be reflected in both schemes. Note that one of the distinct advantages of the proposed schemes is that a team is rated on both its batting and bowling prowess. This ultimately provides a more precise measure of a team's all-round capabilities.

In rating teams in Test and domestic cricket the thesis considered first innings performances only since it was assumed that this provided a more accurate appraisal of the relative differences in team strength. In contrast, the thesis does not model second innings performances to rate team strength since it was assumed that these were not commensurate with first innings performances and thus did not reflect comparative differences in team quality. This presupposed that during the second innings teams tended to be more reactionary in their approach and thus usually adopted an especially cautious and measured response. In essence, this means that in modelling team quality the thesis has accounted for only half a team's performance. A method that dually models both first and second innings performances needs further consideration, especially when gauging the effect of team quality factors. Note that in applying logistic regression techniques to model match outcomes the thesis modelled second innings performances since these directly impact on match results. A more direct and all encompassing modelling approach is required, however.

11.8 Closing statement

In one of the first statistical analyses of cricket Elderton and Elderton (1909) used cricket data to demonstrate some of the fundamental aspects of statistics. Further work was undertaken by Elderton (1927) who demonstrated how cricket data can be used to model the exponential distribution and Wood (1941, 1945) who examined performance consistency in cricket and applied the geometrical distribution to model cricket scores. Strangely, there was a research hiatus for many years. Research was re-ignited in the 1980s which stimulated a steady stream of studies in a diverse range of contexts. This thesis adds to the compendium of research by using linear and logistic modelling techniques to measure team performance and quantify the HA effect in Test, ODI and domestic cricket.

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