A Study of the Powerplay in One-Day Cricket

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Abstract

This paper investigates the powerplay in one-day cricket. The rules concerning the powerplay have been tinkered with over the years, and therefore the primary motivation of the paper is the assessment of the impact of the powerplay with respect to scoring. The form of the analysis takes a "what if" approach where powerplay outcomes are substituted with what might have happened had there been no powerplay. This leads to a paired comparisons setting consisting of actual matches and hypothetical parallel matches where outcomes are imputed during the powerplay period. Some of our findings include (a) the various forms of the powerplay which have been adopted over the years have different effects, (b) recent versions of the powerplay provide an advantage to the batting side, (c) more wickets also occur during the powerplay than had there been no powerplay and (d) there is some effect in run production due to the over where the powerplay is initiated. We also investigate individual batsmen and bowlers and their performances during the powerplay.

Keywords: Bayesian analysis, Cricket, Imputation, Paired comparisons, WinBUGS.

1 INTRODUCTION

In the major sports of the world, rule changes are typically considered with great care. For example, FIFA (Fédération Internationale de Football Association) has made very few significant rule changes in soccer over the last 44 years (www.fifa.com). In 1992, legislation was introduced whereby goalkeepers were henceforth forbidden from handling back-passes. The only other significant rule change in soccer during the period concerned the offside rule. The offside rule has been twice liberalized (1995 and 2005) whereby offsides are now less common. Similarly, baseball is a sport steeped in tradition where there is a reluctance to alter the way that the game is played. In Major League Baseball (MLB), one may point to the introduction of the designated hitter in 1973 as the most recent significant rule change (www.baseball-almanac.com/rulechng.shtml). Wright (2014) provides a survey of the analysis of sporting rules from the perspective of operational research (OR).

In contrast to the stability of rules (laws) involving many of the major sports, one-day cricket has tinkered continuously with its powerplay rule. One-day cricket was introduced in the 1960s as an alternative to traditional forms of cricket that can take up to five days to complete. With more aggressive batting, colorful uniforms and fewer matches ending in draws, one-day cricket has become very popular. In the early days of one-day cricket, fielding restrictions were introduced as an additional strategy for making the game more exciting and popular. In simple terms, the powerplay imposes fielding restrictions that encourages aggressive batting and the scoring of runs. More specifically, fielding restrictions on the bowling team are in place during the full 50 overs of an innings. During powerplay overs, the level of fielding restrictions is increased whereby there are fewer fielders allowed in the outfield which may encourage the batting team to play more attacking type shots.

Although fielding restrictions have existed in one-day cricket since the 1996 World Cup, the term "powerplay" was introduced by the International Cricket Council (ICC) in 2005. And since 2005, there have been four distinct implementations of the powerplay rule. This paper investigates the four versions with a specific focus on whether powerplays really do increase run production. Although it may appear self-evident that run scoring increases during the powerplay, it is conceivable that aggressive batting leads to more wickets which in turn results in fewer runs. This is the line of reasoning which has initiated our investigation.

There are various practical questions associated with our investigation. For example, is the run scoring and wicket taking properties associated with the powerplay in line with the desires of the ICC? Also, in-game wagering has become extremely popular with online sportsbooks (http://bleacherreport.com/articles/54254). Accordingly, are in-game wagering odds properly reflected by the onset of the powerplay? Other questions involve strategic implications of the powerplay. For example, in what over should a team invoke the powerplay? Moreover, is an individual's level of batting aggressiveness appropriate during the powerplay?

To our knowledge, there have not been any previous investigations on the effect of the powerplay. However, there are many data analytic studies concerning one-day cricket that have an OR focus. To get a sense of the variety of problems that have been addressed in one-day cricket, we mention a few recent papers. Most notably, Duckworth and Lewis (2004) developed the standard approach for the resetting of targets in rain interrupted matches. The approach known as the "Duckworth-Lewis method" has been adopted by all prominent cricketing boards and is based on the concept of resources which is a function of overs remaining and wickets taken. Following the seminal work of Duckworth and Lewis (2004), there have been various modifications and proposals for the resetting of targets (e.g. McHale and Asif 2013). Various authors including Allsopp and Clarke (2004) and Fernando, Manage and Scariano (2013) have investigated the effect of the home team advantage in one-day cricket. This is obviously important for match prediction. A topic of interest in every sport is player evaluation. Whereas in some sports, the measurement is straightforward, cricket performance involves a combination of batting, bowling and fielding contributions. In limited overs cricket, van Staden (2009) developed some simple and intuitive graphical displays to investigate batting and bowling performances. Valero and Swartz (2012) dispelled the myth that there are synergies in opening partnerships. It is argued that batsmen are not affected by the performance of their partners. Team selection is a problem of real interest to cricketing sides. Lemmer (2013) considered integer optimization methods for team selection. Swartz, Gill, Beaudoin and de Silva (2006) extended the problem to the determination of optimal batting orders using a simulated annealing algorithm. Norton and Phatarfod (2008) used dynamic programming to produce an optimal run scoring strategy for the batting team in both the first and second innings.

In section 2, the data are introduced and the four historical versions of the powerplay are

3

described. Section 3 is concerned with the construction of hypothetical parallel matches. We take a "what if" approach where powerplay outcomes are substituted with what might have happened had there been no powerplay. This leads to a paired comparisons setting consisting of actual matches and parallel matches where outcomes are imputed during the powerplay period. Section 4 carries out the powerplay analyses by comparing the actual matches with the parallel matches. We investigate the difference in run production and the number of wickets taken with respect to the various powerplay rules. We also investigate the difference in run production with respect to the over where the powerplay was initiated. Section 5 provides a Bayesian analysis of individual batsmen and their ability to take advantage of the powerplay. We then do likewise for bowlers. We conclude with a short discussion in section 6.

2   DATA AND HISTORY OF THE POWERPLAY

For the analysis, we considered all ODI (one-day international) matches that took place from July 7, 2005 until the end of 2013 which involved full member nations of the International Cricket Council (ICC). Currently, the 10 full members of the ICC are Australia, Bangladesh, England, India, New Zealand, Pakistan, South Africa, Sri Lanka, West Indies and Zimbabwe. Details from these matches can be found via the Archive link at the CricInfo website (www.espncricinfo.com).

For these matches, only first innings data were considered. The rationale is that we want to study the powerplay under baseline circumstances. A team's batting behaviour (aggressive versus passive) in the second innings depends largely on the target score that was established in the first innings. We excluded matches that were discontinued or were shortened to less than 50 overs. We also excluded 197 matches where we were unsure about the starting and ending points of the powerplay. In total, we were left with 597 matches involving reliable full first innings data.

For the imputation methods of section 3, we require detailed batting results, at the level of balls bowled. This information does not appear to be generally available in a convenient format. Hence, a proprietary R-script was developed and used to parse and extract ball-by-ball information from the Match Commentaries. For each first innings, we have two rows of data with 300 columns. In the jth column of the first row, we record the number of runs scored on the jth ball bowled (with extras included). In the jth column of the second row, we record

4

either 0/1 according to whether a wicket was taken on the the jth ball bowled. Some additional columns were also recorded such as the match identifier, the batting team, the bowling team and the beginning and ending over for the batting powerplay. This results in a large dataset with $2(597) = 1194$ rows and 305 columns.

We now review the various historical implementations of the powerplay during the period of study, July 7, 2005 through 2013. We sometimes found it difficult to pin down details regarding the history of the powerplay. Some of our information was obtained from the following web sources:

- http://news.bbc.co.uk/sport2/hi/cricket/rules_and_equipment/4180026.stm

- http://voices.yahoo.com/cricket-power-play-rules-one-day-internationals-4720834.html

- http://www.espncricinfo.com/natwestchallenge/content/story/213010.html

- http://www.itsonlycricket/entry/106/

A: July 7/2005 - September 6/2008 - We have 239 observed matches where the match identifiers range from 2259 through 2762. During this period, there were three blocks of powerplays which imposed stricter fielding restrictions compared to the rest of the match. The first 10 overs of the innings imposed fielding restrictions which allowed only two fielders outside the 30-yard circle and two fielders within 15 yards of the on-strike batsman. This was known as the mandatory powerplay. The mandatory powerplay was followed by a five-over block known as powerplay 2 and a subsequent five-over block known as powerplay 3. The initiation of the two non-fixed powerplays were determined at the discretion of the bowling team. In both powerplays, the fielding restrictions allowed only three fielders outside of the 30-yard circle. If no powerplay had been initiated, then overs 41 through 50 automatically became powerplays. If only one powerplay had been initiated, then overs 46 through 50 automatically became powerplay 2.

B: October 9/2008 - September 20/2011 - We have 224 observed matches where the match identifiers range from 2763 through 3197. Rule B is the same as Rule A except that the start of one of the discretionary powerplays became the decision of the batting team. Hence the nomenclature for the two discretionary powerplays became the "bowling powerplay"

and the "batting powerplay" accordingly. Although it is technically possible for the batting powerplay to precede the bowling powerplay, this did not occur in any of the 224 matches. The rationale for the introduction of Rule B was based on the observation that under Rule A, the bowling team often employed powerplays 2 and 3 as soon as possible (i.e. in overs 11-15 and 16-20, respectively). With the decision to start one of the powerplays given to the batting team, the hope was to spread the powerplays throughout the innings.

C: October 13/2011 - September 5/2012 - We have 51 observed matches where the match identifiers range from 3198 through 3304. Rule C is similar to Rule B except that the bowling and batting powerplays were not allowed to take place during overs 11 through 14 nor during overs 41 through 50.

D: November 4/2012 - December 25/2013 - We have 83 observed matches where the match identifiers range from 3305 through 3448. Rule D is the current rule and again requires that the mandatory powerplay takes place during the first 10 overs with the same fielding restrictions that allow only two fielders outside the 30-yard circle. Under Rule D, the bowling powerplay has been dropped. The batting powerplay (a five-over block) must be completed by the 40th over. For the batting powerplay, the fielding restrictions allow only three fielders outside the 30-yard circle.

3 CONSTRUCTION OF PARALLEL MATCHES

The construction of hypothetical parallel matches is based on a "what if" approach where powerplay outcomes are substituted with what might have happened had there been no powerplay. Clearly, we want the imputations to be as realistic as possible, and this should take into account the nuances of the actual matches. For example, in a particular match, it is possible that pitch conditions are poor and batting is subsequently difficult. In this case, we impute overs that reflect the difficulty of scoring runs.

The study focuses on powerplay 3 under Rule A and the batting powerplays (for Rules B, C and D). Consequently, we construct parallel matches that only involve the imputation of powerplay 3 and the batting powerplays. The batting powerplays are of particular interest since most of the rule changes have involved the batting powerplay. Not only are we interested in the effect of

the batting powerplay, but we are also interested in the effect due to the over where the batting powerplay is initiated.

We now describe the imputation procedures. The procedures depend on what aspects of the parallel match need imputation and on the information that is available from the corresponding actual match. Table 1 provides a summary broken down according to the various powerplay rules and imputation procedures. Whereas Rules A, C and D mostly use imputation method (a), we observe that Rule B uses imputation method (b) roughly 50% of the time. This is because under Rule B, the batting team frequently chose its powerplay in the final overs of the match.

Imputation Method (a): The simplest imputation procedure occurs when the actual batting powerplay is surrounded by 2.5 non-powerplay overs preceding the powerplay and 2.5 non-powerplay overs following the powerplay. For the parallel match, we substitute the powerplay results (both runs and wickets) with what happened during the surrounding overs. The surrounding overs are intended to be a fair representation of how the match would have proceeded had there been no powerplay. For the portion of the parallel match prior to the powerplay, we simply substitute what happened during the actual match. For the portion of the parallel match following the powerplay, we also substitute what happened during the actual match until the parallel innings terminate (i.e. 10 wickets lost or 50 overs consumed). Under these most basic conditions, Figure 1 provides a pictorial aid of the imputation procedure. However, if the actual match terminates earlier than the parallel match, there is no corresponding match history for imputation. In this case (which is rare - 68 out of 597 observed matches), the parallel match has $w < 10$ wickets taken at the point in time where the actual match terminated (i.e. the 10th wicket occurred). We then replicate the results from wicket w in the actual match until the end of the parallel match. We make sure that we skip (do not impute from) the powerplay; if the powerplay has x wickets, then our imputation begins from wicket $w - x$ in the actual match. There are only 18 such cases out of the 68.

Imputation Method (b): When the actual match does not have overs following the powerplay, Imputation Method (a) cannot be used. For example, this occurs when the powerplay takes place during overs 46 through 50. Our approach here is to take the ten overs preceding the powerplay and divide it into two blocks of 5 overs. Let R_1 be the number of runs scored
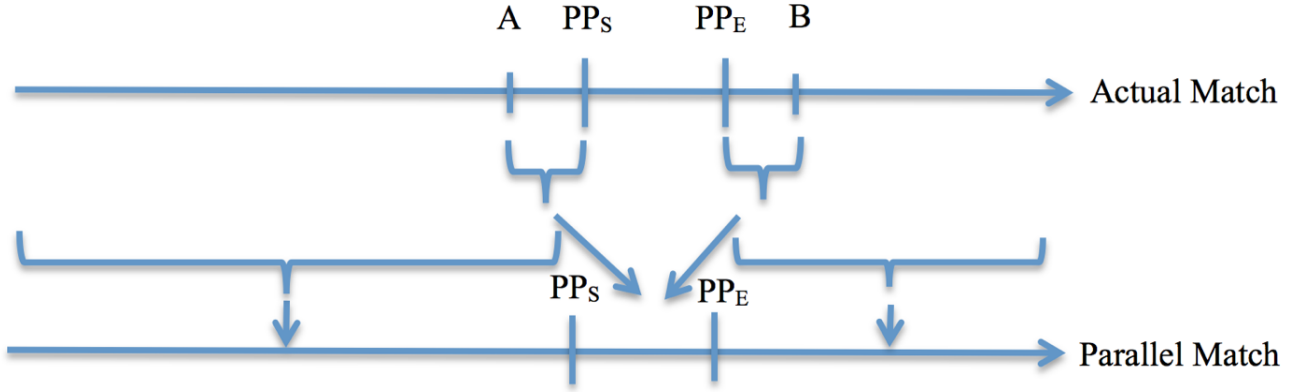
7

Figure 1: Imputation method (a) under the most basic conditions. The symbol A denotes 2.5 overs preceding the start of the powerplay (PP_S) and the symbol B denotes 2.5 overs following the end of the powerplay (PP_E).

in the first block and let R_2 be the number of runs scored in the second block. Then the ratio R_2/R_1 captures the change in scoring rate as the match progresses over the ten over interval. The number of imputed runs for the 2.5 overs following the powerplay is then set at $R_2(R_2/R_1)$ suggesting that the run scoring rate should change in this period by the same factor. Since we do not want R_2/R_1 to be unrealistically small or large, we do not permit the ratio to be less than 0.67 or greater than 1.5. We carry out the same procedure with the number of wickets. We experimented with values other than (0.67,1.5) and did not observe meaningful differences.

Powerplay Rule	Total Number of Matches	Imputation Method (a)	(b)
A	239	238	1
B	224	110	114
C	51	51	0
D	83	80	3

Table 1: Summary of the imputation procedures.

4 POWERPLAY ANALYSES

With the construction of the hypothetical parallel matches, we have a dataset satisfying a paired comparisons framework. For every match involving a batting powerplay, we have a parallel match

where batting outcomes are imputed as though there were no batting powerplay. This facilitates an analysis where we can look at the difference in run production between the actual match and its corresponding parallel match. Let $R_i^{(a)}$ be the number of first innings runs scored in the ith actual match and let $R_i^{(p)}$ be the number of first innings runs scored in the ith parallel match. Then the quantities of interest are the differences

$$D_i = R_i^{(a)} - R_i^{(p)}. \tag{1}$$

We also study the difference in the actual number of wickets lost during the powerplay and the number of wickets that were lost during the same window in the parallel match.

4.1 Powerplay Rule A

Figure 2 provides a histogram of the differences D_i in (1) corresponding to powerplay 3 under Rule A. The median and the mean of the dataset are 1.0 and 1.3 runs respectively suggesting that the powerplay had a minor influence on increasing the number of runs scored. A Wilcoxon test of the hypothesis of no effect (i.e. H_0 : median $= 0$ versus H_1 : median > 0) was carried out and the null hypothesis was not rejected with the p-value $= 0.08$. Therefore, the effect (i.e. the number of increased runs due to the powerplay) is insignificant.

In a comparison of wickets lost during powerplay 3 versus wickets lost during the corresponding period of the parallel match, a Wilcoxon test was also carried out. The p-value $= 0.45$ was obtained indicating that there was no increase in the number of wickets taken due to powerplay 3. There were 0.01 more wickets taken on average during powerplay 3.

4.2 Powerplay Rules B, C and D

In this subsection, powerplay rules B, C and D are combined since they only differ in terms of when the batting powerplay is allowed to take place. This provides us with a dataset of 358 matches. Having seen that powerplay 3 under Rule A conferred no advantage to the batting team, it is interesting to investigate the revised Rules B, C and D. Recall that Rules B, C and D put the determination of the batting powerplay into the hands of the batting team. Perhaps the ICC had observed that Rule A was not accomplishing much in terms of increased run production, and that tinkering with the powerplay rule was required.
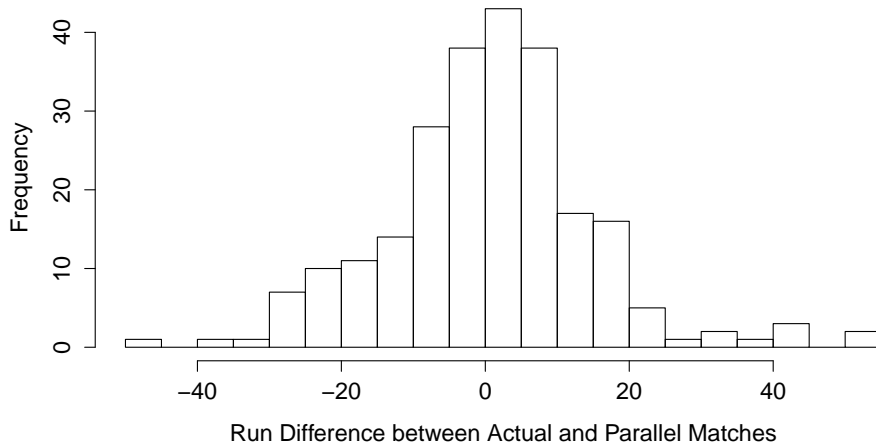
Figure 2: Histogram of the 239 differences D_i corresponding to Rule A.

Figure 3 provides a histogram of the differences D_i in (1) corresponding to the batting powerplay under Rules B, C and D. The median and the mean of the dataset are 6.0 and 6.5 runs respectively suggesting that the powerplay provides increased run production. A Wilcoxon test of the hypothesis of no effect (i.e. H_0 : median = 0 versus H_1 : median > 0) was carried out and the null hypothesis was strongly rejected with the p-value = $6.7 * 10^{-12}$. So it appears that the powerplay changes implemented by the ICC had the effect of increased run production.

In a comparison of wickets lost during the batting powerplay versus wickets lost during the corresponding period of the parallel match, a Wilcoxon test was also carried out. The p-value = 0.007 was obtained indicating that the number of wickets taken during the battng powerplay was greater than had there been no powerplay. There were 0.17 more wickets taken on average during the batting powerplay.

If we compare Figure 2 with Figure 3, we see that the run difference under Rules B, C and D is greater but is also more variable than under Rule A. This implies that the newer powerplay rules create more runs but also introduce greater uncertainty in the match. The new versions of the powerplay provide more runs for the batting team if they can avoid losing wickets. However, if their aggressiveness during the powerplay leads to an increased number of lost wickets, then the powerplay is detrimental to the batting team.

Recall that the imputation procedure for a parallel match was based on the assumption that
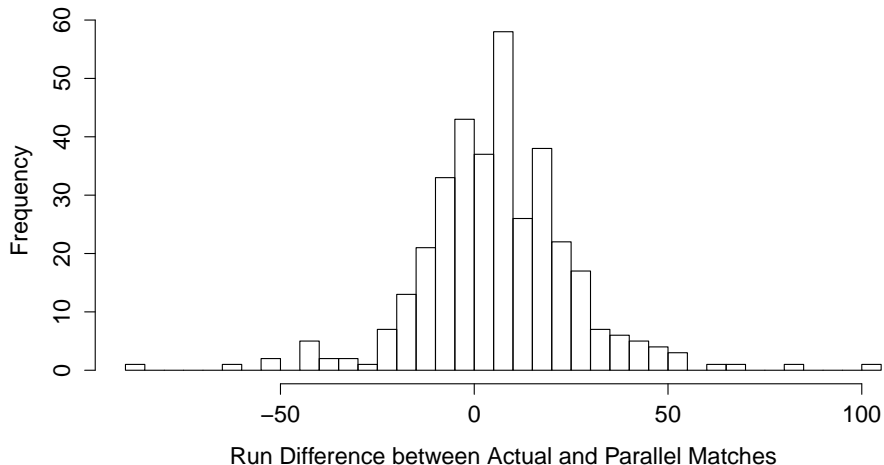
Figure 3: Histogram of the 358 differences D_i corresponding to Rules B, C and D.

had there not been a batting powerplay, then the results during these overs would resemble the surrounding overs. Although apparently reasonable, it is good to check the sensitivity of the assumption. In the imputation procedure, the surrounding overs of a 5-over batting powerplay were defined as the 2.5 overs (i.e. 15 balls) preceding the powerplay and the 2.5 overs (i.e. 15 balls) following the powerplay. We now modify the assumption and instead consider the surrounding 8 balls preceding the powerplay and the 7 balls following the powerplay. Then the number of runs observed during these $8 + 7 = 15$ balls are scaled and imputed where the powerplay occurred. This provides us with a comparison set of 358 parallel matches. Under this alternative imputation procedure, we observed a mean difference of 6.3 more runs during the actual matches than the parallel matches. This is comparable to the 6.5 mean run difference under the original imputation procedure. This suggests a robustness of the proposed imputation procedure.

It is also worth asking whether what happens in the surrounding overs is affected by them being just before or just after the powerplay. To investigate this to some extent, we obtained the mean number of runs scored in the third over prior to the powerplay (4.9), the second over prior to the powerplay (5.6) and the over immediately prior to the powerplay (5.3). The run scoring pattern provides no indication of a change in tactics prior to the powerplay.

We now investigate the effect of the powerplay with respect to the over where the powerplay was initiated. We aggregate all 597 matches. The corresponding plot is given in Figure 4 along

11

with a smoothed lowess curve to assess general features. We observe that most of the powerplays in our dataset were initiated in the vicinity of three time points: the 16th over, the 36th over and the 46th over. We also observe that the batting powerplay under Rule B was invoked near the end of the innings in the majority of matches.
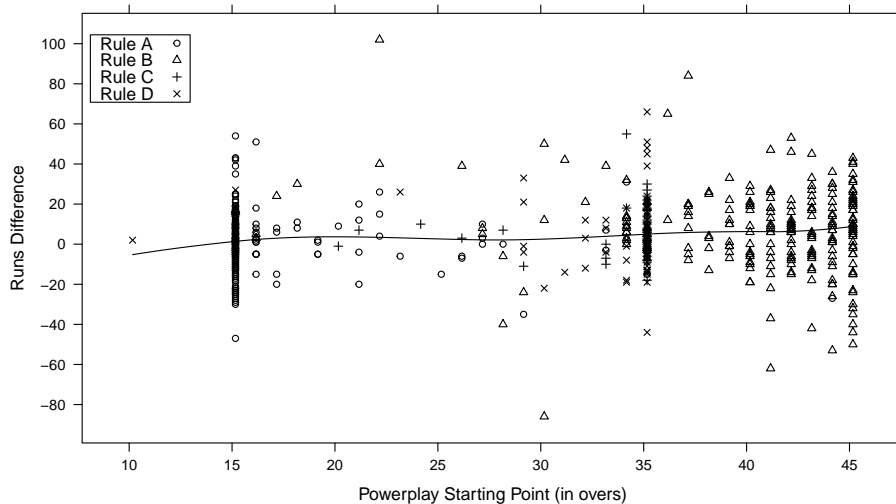

Figure 4: The run differences D_i for all rules A, B, C and D plotted against the over where the powerplay was initiated. A lowess curve with parameters span=0.5 and degree=2.0 is superimposed.

Further investigation of Figure 4 reveals that under Rule A, powerplay 3 was typically initiated early in the innings. Specifically, powerplay 3 was initiated in the 16th over in 193 of the 239 matches. We hypothesize that the reason why the powerplay was ineffective at this stage was because it was early in the match and the batting team did not want to take the risk of batting aggressively and losing wickets. Recall that the timing of powerplay 3 was at the discretion of the bowling team.

Under Rules B, C and D, the initiation of the batting powerplay was at the discretion of the batting team, and this appears to have made a positive difference in run production. A very close inspection of the smoothed curve suggests that it may not have been advantageous to initiate the powerplay late in the match, say beyond the 41st over. Our intuition here is that when the batting powerplay begins late, the batsmen involved in the powerplay are typically weaker batsmen in the lineup and are unable to take advantage of the situation. Of course, under the current Rule D, it is no longer possible to initiate the batting powerplay beyond the 36th over.

In Figure 4, there is also some evidence that initiating the powerplay near the 36th over may be optimal. This stage of the match provides a compromise; it is sufficiently late in the match that the batsmen are free to bat aggressively, and it is sufficiently early in the match so that good batsmen (i.e. mid-order batsmen) are typically available for batting. The smoothed curve also suggests that it may also be beneficial to begin the batting powerplay around the 21st over. However, we are not convinced of this due to the sparsity of data at this stage of the match.

5 INDIVIDUAL BATSMEN AND BOWLERS

We have seen that the current implementation of the powerplay contributes on average 6.5 additional runs of scoring had there not been a powerplay. It is interesting to investigate whether some batsmen take a greater advantage of the powerplay conditions than other batsmen.

We therefore considered 45 batsmen during the study period (i.e. rules B, C and D) who faced a minimum of 600 balls. Details on these batsmen are provided in Table 2. The number of balls faced during the powerplay varies greatly among batsmen where Kumar Sangakkara of Sri Lanka faced 416 balls and Alastair Cook of England faced 53 balls. All of the batsmen faced many more balls (typically about ten times as many) during non-powerplay conditions.

With many balls faced, we appeal to the Central Limit Theorem and define

$$X_i^{(1)} \equiv \text{ run rate per over for the } i\text{th batsmen during PP} \sim \text{Normal}(\mu_i^{(1)}, \sigma^2/n_{1i})$$
$$X_i^{(2)} \equiv \text{ run rate per over for the } i\text{th batsmen during non-PP} \sim \text{Normal}(\mu_i^{(2)}, \sigma^2/n_{2i})$$

where n_{1i} and n_{2i} are the number of balls faced by the ith batsman during powerplay conditions and non-powerplay conditions respectively. In a Bayesian analysis, we further define prior distributions

$$\begin{aligned}
\mu_i^{(1)} &\sim \text{ Normal}(\mu_0^{(1)}, \sigma_\mu^2) \\
\mu_i^{(2)} &\sim \text{ Normal}(\mu_0^{(2)}, \sigma_\mu^2) \\
\sigma^2 &\sim \text{ Inverse Gamma}(1, 1) \\
\sigma_\mu^2 &\sim \text{ Inverse Gamma}(1, 1)
\end{aligned}$$

where $\mu_0^{(1)}$ and $\mu_0^{(2)}$ are set according to the sample means of the dataset (i.e. an empirical Bayes approach). The hyperparameters of the Inverse Gamma distributions provide standard reference

13

priors. The non-constant values n_{1i} and n_{2i} provide a twist that prevents a straightforward classical analysis.

We implemented the model using WinBUGS software (Spiegelhalter, Thomas and Best 2003) where our primary interest concerns the parameters $\mu_i^{(1)}$ and $\mu_i^{(2)}$ for $i = 1, \ldots, 45$. A WinBUGS implementation is straightforward as the generation of parameters from the posterior distribution is done in the background. A user is only required to specify the statistical distributions. We ran 15,000 iterations of the Markov chain where 5,000 iterations were used as burn-in. Standard diagnostics provide evidence that the Markov chain has adequately converged.

In Figure 5, we provide boxplots of the differences $\mu_i^{(1)} - \mu_i^{(2)}$ generated from the Markov chain where the boxplots are sorted in ascending order of mean difference. We observe that nearly all of the mean differences exceed zero which implies that batsmen score runs at a higher rate during the powerplay. The only exceptions to this are T. Iqbal of Bangladesh where $E(\mu_i^{(1)} - \mu_i^{(2)}) = -0.26$ and M. Guptill of New Zealand where $E(\mu_i^{(1)} - \mu_i^{(2)}) = -0.05$. At the other end of the plot, the greatest value of $E(\mu_i^{(1)} - \mu_i^{(2)})$ is attributed to M. Mahmudullah of Bangladesh for whom $E(\mu_i^{(1)} - \mu_i^{(2)}) = 2.35$. This difference translates to $5(2.35) = 11.75$ extra runs during the five-over powerplay block than during non-powerplay conditions. Also notable among the exceptional powerplay batsmen are M. Hussey of Australia where $E(\mu_i^{(1)} - \mu_i^{(2)}) = 2.28$ and S. Marsh of Australia where $E(\mu_i^{(1)} - \mu_i^{(2)}) = 2.19$. The batsman with the highest mean value of $\mu^{(1)}$ is V. Sehwag of India where $E(\mu_i^{(1)}) = 7.96$. Not only is Sehwag great during the powerplay but he is great at all times with $E(\mu_i^{(2)}) = 7.19$ and therefore his mean difference is only $E(\mu_i^{(1)} - \mu_i^{(2)}) = 0.77$.

For bowlers, we carry out a similar analysis to investigate individual powerplay performances. Here we have obtained data on 28 bowlers during the study period (i.e. rules B, C and D) who have bowled at least 1000 balls. Details on these bowlers are provided in Table 3. The inferential quantities of interest for the ith bowler are the mean run rate per over during the powerplay $\mu_i^{(1)}$ and the mean run rate per over $\mu_i^{(2)}$ during non-powerplay conditions. In cricket parlance, $\mu_i^{(1)}$ and $\mu_i^{(2)}$ are referred to as the mean economy rates. The economy rate is often regarded as more important than both the bowling strike rate and the bowling average in one-day cricket. The bowling strike rate is defined as the average number of balls bowled per wicket and the bowling average is defined as the average number of runs conceded per wicket.
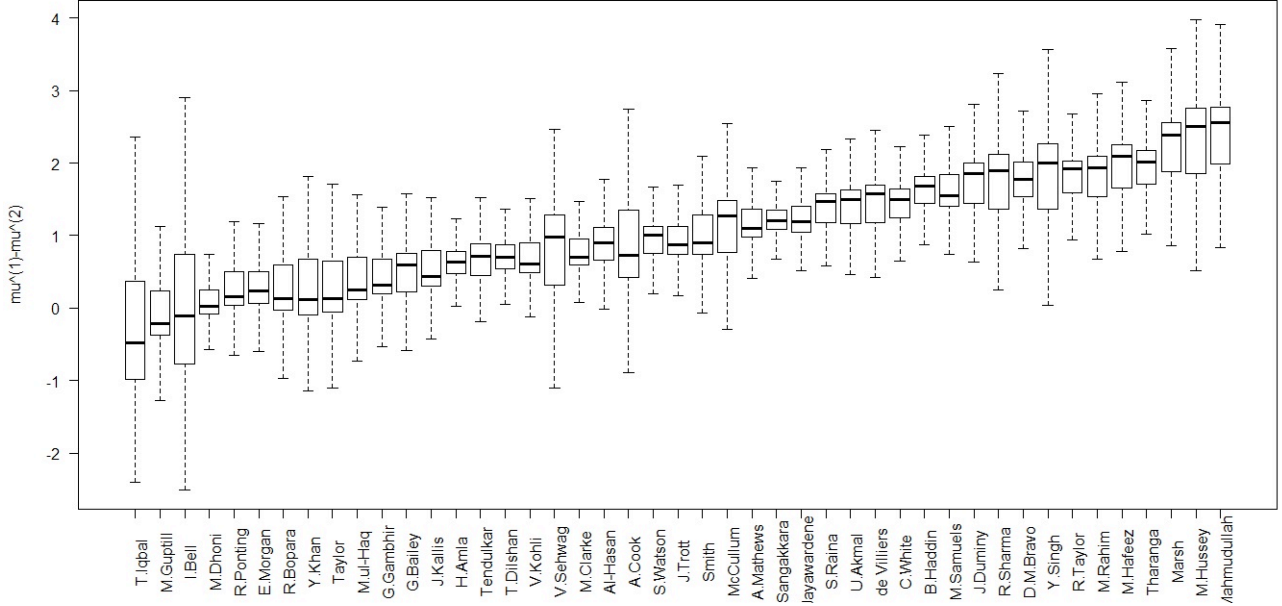
14

Figure 5: Boxplots of the differences $\mu_i^{(1)} - \mu_i^{(2)}$ for the 45 batsmen based on output from the Markov chain corresponding to the hierarchical model of section 5.

In Figure 6, we provide boxplots of the differences $\mu_i^{(1)} - \mu_i^{(2)}$ where the boxplots are sorted in ascending order of mean difference. In this case, it is bowlers on the left side of the plot who have performed exceptionally during the powerplay. We observe that the only bowler with a negative value of $\mu_i^{(1)} - \mu_i^{(2)}$ is A. Mathews of Sri Lanka with $\mu_i^{(1)} - \mu_i^{(2)} = -0.07$. This implies that he bowls better during the powerplay than during non-powerplay overs. Of course, this may simply be a case of small sample size as Matthews has bowled only 116 powerplay balls. The median value of the $\mu_i^{(1)} - \mu_i^{(2)}$ values amongst the 28 bowlers is 1.15 which says that the median bowler allows $5(1.15) = 5.75$ more runs on average during the five-over powerplay block than during non-powerplay overs. At the right end of the plot is P. Kumar of India for whom $\mu_i^{(1)} - \mu_i^{(2)} = 2.03$. This implies that Kumar allows on average $5(2.03) = 10.15$ more runs during the five-over powerplay block than during non-powerplay overs.

In Table 3, we have distinguished the bowlers as either fast or spin bowlers. A cursory inspection of Figure 6 indicates that fast bowlers tend to be situated in the rightmost boxplots. This suggests that spin bowlers adjust better to the powerplay overs than do fast bowlers. To test this formally, we divide the 28 bowlers according to 10 spinners and 18 fast bowlers. We then

15

carry out a two-sample t-test on the null hypothesis of no difference between the two types of bowlers where our observations are the posterior means of $\mu_i^{(1)} - \mu_i^{(2)}$. With the p-value $= 0.045$, we reject the hypothesis using a two-tailed test. This shows that there is a significant difference between the economy rates of the fast bowlers and the spin bowlers during the powerplay.
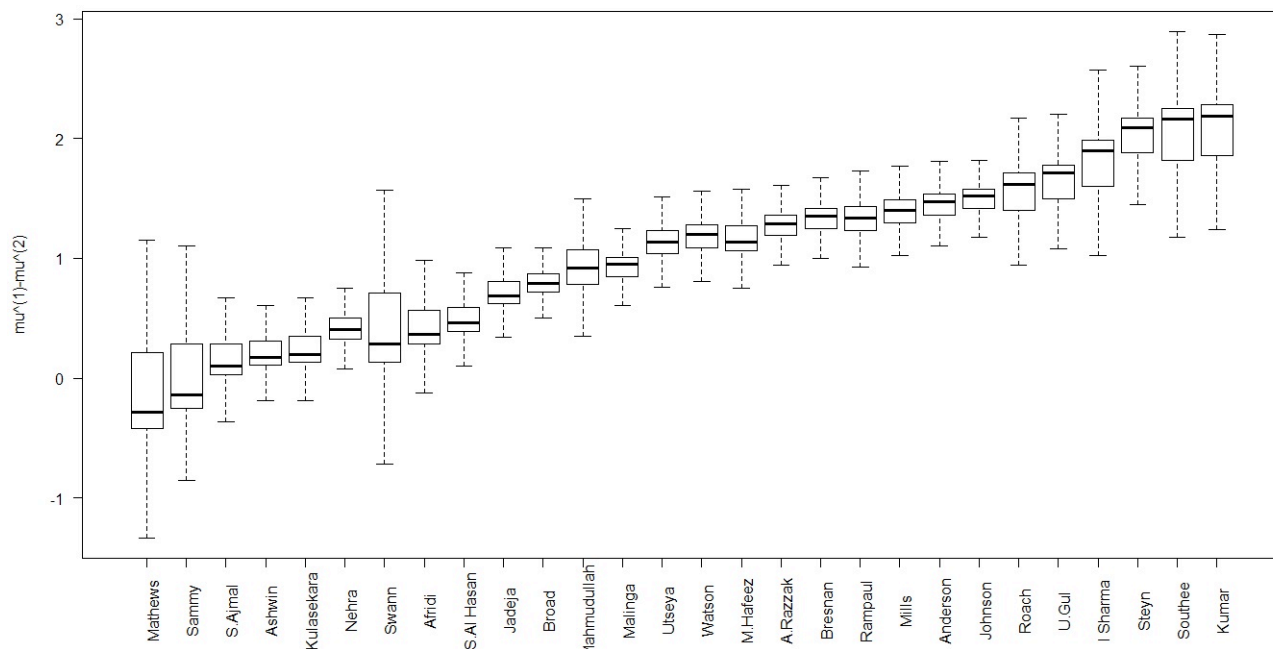
Figure 6: Boxplots of the differences $\mu_i^{(1)} - \mu_i^{(2)}$ for the 28 bowlers based on output from the Markov chain corresponding to the hierarchical model of section 5.

6   DISCUSSION

This paper appears to be the first quantitative investigation on the effect of the powerplay in one-day cricket. The main result is that recent versions of the powerplay rule contribute an average of 6.5 additional runs. However, the contribution of increased runs is countered by an increase in the number of lost wickets which adds uncertainty to the match. Furthermore, the choice of over where the powerplay is initiated has some effect on the number of runs scored. It appears that initiating the batting powerplay in the 36th over is roughly optimal.

Based on the above findings, there are possible implications for the game:

1. The ICC may want to again revisit the powerplay with a focus on the intention of the

powerplay. If the intention is to create more runs, we have now quantified the average number of increased runs. Is 6.5 runs adequate? Altering the fielding restrictions may further modify run scoring. Of course, the ICC may be wary of changing the powerplay rule once again. If a goal of the batting powerplay is to introduce more uncertainty into the game, then this appears to have been accomplished since the average number of wickets lost during the powerplay is greater than had there been no powerplay. When the batting team loses large numbers of wickets during the powerplay, then their run production decreases.

2. There may be strategic implications for the powerplay. Although invoking the powerplay around the 36th over appears to be roughly optimal, teams may want to consider their batting style (i.e. aggressive versus passive) during the powerplay. They may be able to invoke the powerplay earlier if they tone down their level of aggressiveness. The advantage of initiating the powerplay earlier is that early-order batsmen may be able to take better advantage of the powerplay opportunity.

3. One might ask "what are the implications of this study for Twenty20 cricket?" In Twenty20 cricket, the powerplay is mandated to take place during the first six overs of each innings when the best batsmen are typically batting. At the end of the 6th over, there are 14 overs remaining since Twenty20 matches are allotted 20 overs. In one-day cricket, the optimal completion of the powerplay occurs roughly at the end of the 40th over (i.e. 10 overs remaining). Also, in Twenty20, losing wickets is less of a concern for the batting side than in one-day cricket. Therefore, there is some suggestion that the timing of the powerplay in Twenty20 may be optimal in terms of creating additional runs.

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Name	Runs(non-PP)	Balls Faced(non-PP)	Runs(PP)	Balls Faced(PP)
K. Sangakkara (SL)	1358	1804	395	416
Misbah-ul-Haq(PAK)	1172	1631	257	347
M. Clarke (AUS)	1373	1737	310	345
R.Ponting (AUS)	1039	1222	277	321
A.B. de Villiers (SA)	1705	1782	384	311
H. Amla (SA)	1793	1868	325	304
M.S. Dhoni(IND)	1795	1800	297	298
R. Taylor (NZ)	1035	1274	311	272
A. Mathews (SL)	940	1295	235	260
S. Raina (IND)	1044	1184	286	252
J.P. Duminy (SA)	992	1127	301	249
M.Hussey (AUS)	1181	1314	325	239
S. Watson (AUS)	1338	1420	261	234
T.M. Dilshan (SL)	1482	1607	239	230
V. Kohli (IND)	1005	1233	204	225
Y. Khan (PAK)	909	1227	161	222
J. Trott (ENG)	1012	1260	208	221
M. Jayawardene (SL)	834	1097	210	220
M. Guptill (NZ)	1128	1238	186	218
B. Haddin (AUS)	637	857	223	217
M. Hafeez (PAK)	1268	1559	237	200
Y. Singh (IND)	801	804	268	195
G. Gambhir (IND)	890	1010	179	194
M. Mahmudullah (BAN)	662	864	237	193
B. Taylor (ZIM)	709	893	146	186
J. Kallis (SA)	587	693	164	181
R. Bopara (ENG)	433	504	153	178
U. Akmal (PAK)	712	838	184	166
V. Sehwag (IND)	1121	903	241	165
S.E. Marsh (AUS)	561	762	191	165
U. Tharanga (SL)	736	1045	170	162
C. White (AUS)	850	1065	161	153
M. Samuels (WI)	511	833	132	153
S. Tendulkar (IND)	609	587	171	147
E. Morgan (ENG)	680	665	143	135
G. Smith (SA)	670	913	117	135
B.B. McCullum (NZ)	728	716	155	123
T. Iqbal (BAN)	812	989	72	111
G. Bailey (AUS)	733	669	133	110
Shakib-Al-Hasan (BAN)	732	821	100	96
M. Rahim (BAN)	823	1094	99	91
D.M. Bravo (WI)	421	639	85	89
I. Bell (ENG)	635	802	44	68
R.G. Sharma (IND)	433	550	68	60
A. Cook (ENG)	618	831	43	53

Table 2: Summary data on the 45 batsmen considered in section 5.

Name	Style	Runs (non-PP)	Balls Bowled (non-PP)	Runs (PP)	Balls Bowled (PP)
M. Johnson (AUS)	Fast	829	1129	496	501
R. Ashwin (IND)	Spin	1075	1344	408	496
S. Ajmal (PAK)	Spin	1160	1592	360	489
S. Broad (ENG)	Fast	827	978	446	457
L. Malinga (SL)	Fast	1057	1175	423	399
Shakib-Al-Hasan (BAN)	Spin	738	963	328	391
T. Bresnan (ENG)	Fast	886	1097	391	377
J. Anderson (ENG)	Fast	1085	1414	326	321
A. Nehra (IND)	Fast	830	845	336	320
U. Gul (PAK)	Fast	828	953	368	317
R. Jadeja (IND)	Spin	1526	2012	272	313
A. Razzak (BAN)	Spin	787	1009	311	312
S. Watson (AUS)	Fast	610	774	299	302
N. Kulasekara (SL)	Fast	1131	1307	252	282
D. Steyn (SA)	Fast	706	984	276	257
S. Afridi (PAK)	Spin	1566	2023	210	254
I. Sharma (IND)	Fast	674	773	298	248
P. Utseya (ZIM)	Spin	958	1209	240	244
P. Kumar (IND)	Fast	1219	1522	280	237
K. Mills (NZ)	Fast	769	1093	222	237
T. Southee (NZ)	Fast	925	1164	270	231
M. Hafeez (PAK)	Spin	969	1399	197	224
R. Rampaul (WI)	Fast	692	952	210	221
D. Sammy (WI)	Fast	773	1022	133	186
K. Roach (WI)	Fast	664	853	168	159
A. Mathews (SL)	Fast	954	1161	87	116
M. Mahmudullah (BAN)	Spin	838	1032	55	57
G. Swann (ENG)	Spin	948	1206	46	57

Table 3: Summary data on the 28 bowlers considered in section 5.