‘How’s that?!’[1] Even the pros make mistakes

- an analysis of decision-making using the coin-toss in Cricket

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[1] ‘How’s that?!’ is also a phrase used in Cricket to get a batsman ‘out’

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Abstract

This paper seeks to understand how decision-making evolves as individuals make similar repeated decisions over time using the coin-toss in the sport of Cricket. At the start of all Cricket matches, teams are granted the decision rights to make a decision about which team bats or fields in which innings of the match via a coin-toss. This paper measures the impact of the coin-toss decisions on match outcome as teams play more matches, and make more decisions, over time. The paper finds that toss winners are less likely to win ‘Day’ matches (played only during the Day) and more likely to win ‘Day/Night’ matches (played partially in the evening) from 1971-2016. Within a ‘series of matches’, which are played between the same teams over a short time interval under similar playing conditions (even though these do change between matches), there is no significant improvement in decisions made. Moreover, the decision making trends over the whole sample point towards a diminishing ‘advantage’ from winning the toss. This might point towards consistently, and persistently, biased beliefs between teams as modelled in this study.

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1. Introduction

Decision making doesn't easily come to most, especially if the decision is of vital importance and there is significant uncertainty about payoffs. However, can an improvement in outcomes be observed if individuals make similar repeated decisions?

In Economics, there have been several studies that seek to test this. Theoretical frameworks in game theory, such as fictitious play, etc. propose that an improvement might be expected as individuals get familiarized with the environment by making choices more frequently.[1] Various empirical studies have also been conducted on this subject, but have had mixed findings. For instance, Thaler et al (1997) find that the subjects in their experiment who had the most data and opportunities to learn 'did the worst in terms of money earnt' although this was not the primary focus of their study. Barron and Erev (2003) find that giving 'immediate feedback does not lead toward expected value maximization' when subjects are making repeated similar 'small value' decisions. Another example can be found in Roth and Erev (1993) where observed behaviour matched the expected perfect equilibrium in just two out of the three games evaluated as players gained experience by making repeated decisions.

This paper also seeks to understand if such an improvement can be observed empirically by testing a strategic decision made at the beginning of every match in the sport of Cricket and how these decisions impact the match outcome as teams play more matches over time.

Cricket[2] is a bat and ball sport played between two teams and every match is played in two[3] distinct phases (henceforth 'innings'). In the first innings, one team bats and the other fields and in the second innings, these roles are reversed. The outcome of every match is

[1] See Fudenberg and Levine (1998) for a study on theoretical models of learning
[2] Section 2 gives further background on Cricket. Some photographs are also presented in Appendix I
[3] For the matches considered in this paper (Men's One-Day International) every match has two innings. Matches in other versions of the sport (not considered here) might contain four innings

determined by a large number of factors that can be segregated into three groups, viz. own team skill, opponent team skill and match conditions (weather, pitch conditions, etc.).

At the start of every match, one of these teams is granted the *decision rights* to decide whether they would prefer to bat or field in the first innings with the toss of a coin. In other words, the toss winner decides the ‘order of play’ for the match, i.e. which team bats or fields in the first and second innings (the team that bats in the first innings is referred to as ‘bats first’. Similarly, the team that ‘fields first’ is fielding in the first innings). There are only two permissible orders of play, viz. either the toss winner bats first (and the toss loser fields first) or the toss winner fields first (the toss loser bats first). Subsequently, these roles are swapped in the second innings.

During any given match, both teams would necessarily have to bat and field in one of the two innings. Consequently, the decision to bat or field first is expected to be taken in so far as it helps the team in some tangible way (and not just due to an inherent desire and/or external motivation to bat or to field). Matches are played competitively by all teams and their primary objective is to win the match. Hence, to the extent this is possible, teams are expected to make decisions that they believe would improve their chances of winning[4]. This leads to a related question, viz. if toss winners base their decision on improving their chances of winning, do toss winners win more matches than toss losers?

To test this, I use the basic methodology from Bhaskar (2009) where match-level data for 1,871 matches played between the top 9[5] Men’s One Day International Cricket teams during 1971-2003 is evaluated. Matches are further segregated into ‘Day’ (played only during the day) and ‘Day/Night’ (played partially in the evening) as conditions that affect the match

[4] Teams do recognize this advantage as well. See footnotes 16, 17 and 24
[5] These are: Australia, England, India, New Zealand, Pakistan, South Africa, Sri Lanka, the West Indies and Zimbabwe. Note that in the data for the present study, Zimbabwe has been omitted to make relative skill comparisons more comparable

outcome might be different in either format[6]. As the toss winner is assigned to the decision-making group at random (via the coin toss), ex ante toss winners are expected to do no worse than toss losers once decisions over a set of matches are aggregated to control for match-specific biases due to different relative skill levels, different match conditions, etc. Bhaskar (2009) finds that toss winners are more likely to win matches during ‘Day/Night’ conditions, as expected, but *less* likely to win matches during ‘Day’ conditions.

These findings are counter-intuitive as in any competitive sport, teams are expected to seek any advantage that they can get over their rivals, and to have a significantly *lesser* likelihood to win the match *after* giving a team the decision rights is a peculiar result. Bhaskar attributes his findings to teams ‘overweighting’ their own relative strengths while making decisions which might lead to biased decision-making. This is a particular example of teams possessing differing beliefs while making the toss decision that is explored further in the present paper.

As a first test for this study, I checked if trends change after updating the dataset to include the 696 matches played between 2003 (end of Bhaskar’s dataset) and 2016. My findings suggest persistence in the trends from before, i.e. toss winners are more likely to win the match during Day/Night conditions but less likely to win the match during Day conditions. These results are seen not only in the aggregate form (where the decisions of all teams combined) but also at the individual team level. That is, for every team winning the toss in Day/Night matches (except Australia and New Zealand) improves their chances of victory and winning the toss during Day matches (except England) worsens it. Figure 1 in section 3c shows these findings more clearly. These findings are more powerful than Bhaskar (2009) as I consider nearly 700 more matches and show that similar trends can be observed at the level of each team.

[6] Some examples include: the second innings of Day/Night matches are played under artificial lights which might make batting harder, dew on the field in the second innings of a Day/Night match might make it difficult for fielding players, etc.

The key assumption to running these tests has been that the granting of decision rights is strategically important and both teams believe it to be so. In a model with complete information sharing and agreement of the true state of the world, the granting of these decision rights is important as teams necessarily *disagree* about their respective optimal order of play (in the rest of this paper this is referred to as 'disagreement'). As before, there are only two possible orders of play for a given match, and if the optimal decision for one team is to pick one of these, then the opponent would be better off by picking the other order of play. This follows directly from Bhaskar (2009).

In practice, there isn't complete information sharing as teams make their decisions based on their *beliefs* over the true state. By incorporating beliefs into this model, the assumption of toss relevance is considerably weakened. Differing beliefs might also be a tangible explanation behind the trends, i.e. pre-existing beliefs might impact toss winners adversely during Day matches and advantageously during Day/Night matches. Unfortunately, as these factors are not observed in the evaluated data and I am unable to empirically test this.

However even if teams possess differing beliefs, they might be able to update their beliefs (and potentially reduce biases) over time depending on the actual match results and other factors not captured in the data (such as training sessions, watching teams play, etc.). This process is termed as 'learning' in this study. As this may exist along several aspects that may change across teams and over time, testing an explicit model might suffer from omitted variable bias. However, I can test if toss winners improve their chances of victory where 'learning' is expected to occur.

Firstly, 'learning' might be seen over a short time period where relative team skill and match-specific conditions are not very different. To test this, I measure if an improvement in outcomes is observed within a 'series of matches'[7]. All matches are played in the form of a

[7] A series is essentially a collection of matches played between the same teams. Teams win as many matches in a given series that help them win the series

series that typically last for around a month and are played in grounds that have *similar*[8] conditions with a cohort of players that does not change much either. Thus, an improvement in decision making in the latter end of a series might occur if teams are able to acquire more information that helps them reduce any pre-existing biases in their belief mechanisms. Empirically, I find that the matches at the latter end of a series tend to have improved decision making, but these findings are statistically insignificant. This does not support the hypothesis of learning within the context of a series as considered in this paper.

Next, I converted the match-level dataset into a panel dataset to look at the relative performance of each team year-on-year. I measure the advantage that any team had on winning the toss in a specific year by comparing two conditional probabilities: the probability to win the match conditional on *winning* the toss and the probability to win the match conditional on *losing* the toss. I find that this 'Win Toss Advantage'[9] actually *decreases* over time across both formats (Day and Day/Night). This result is contrary to expectations if learning were to exist over time. It must be noted though that by looking at the probability of the team winning the match conditional on losing the toss, the biases of the rivals might affect the match outcome to a certain degree. However, these biases are not expected to be much different to that of the team as the identity of the rivals is not fixed when looking at any of the probabilities and that the long time horizon (45 years) considered here might allow for adjustment in these biases.

Cricket isn't the only sport in which a coin toss is utilised to make decisions that might impact gameplay. In Tennis, toss winners decide to serve/receive and in sports like hockey, soccer, rugby, etc. toss winners decide who 'kicks off' the match. A thorough literature review yielded no relevant academic interest on the coin-toss decisions in these other sports. This might be due to the limited significance attached to these decisions in other sports as unlike

[8] In a typical series, match conditions are expected to be similar in different matches as the grounds and the weather conditions are expected to behave similarly, especially if compared to matches played in another series at a different time

[9] Win Toss Advantage = P (Win | Win Toss) - P (Win | Lose Toss)

Cricket, matches typically last for a shorter timeframe[10] (so match conditions may not change as much over the course of a match) and all players of the team play together over the whole period of the match (in Cricket when a team bats, it is allowed to only have two players bat at any given time). This means that the coin-toss decision might be of greater strategic importance in Cricket than other sports. For these sports, other decisions (such as which side to choose during penalty kicks in soccer) have been discussed in various studies but the applicability of these frameworks to the question asked by this paper is limited.[11]

Apart from Bhaskar (2009) as mentioned earlier, there have been very few academic studies on the coin-toss in Cricket. Dawson, Morley, Paton and Thomas (2008) look at the 649 'Day/Night' matches played from 1979-2005 and find that toss winners improve their likelihood of victory if they elect to bat first, but there is no significant improvement if they choose to field first. These findings are consistent with the present paper. Silva and Swartz (1997) look at the decisions made in 427 matches played during the 1990s and find that there is no competitive advantage to the toss winner on match outcome after considering nine observed decision-making strategies. Clarke and Allsopp (2001) find that the toss offered no strategic advantage to teams during the 42 matches played during the 1999 Cricket World Cup, although this was not the focus of that paper. Note that the sample of matches considered in the latter two studies is much smaller compared to that from the present study.

Given the relative paucity of literature on this subject matter, this paper contributes to existing literature in three ways. Firstly, using Bhaskar (2009) for the base model, I find that toss winners are more likely to win 'Day/Night' matches but less likely to win 'Day' matches. I have 696 more matches in this dataset than Bhaskar (2009) which allows for greater precision in making inferences over the underlying trends.

[10] Matches in hockey, soccer and rugby typically last from 60-90 minutes depending on the format. Tennis matches last for approximately 90-120 minutes on average. One-Day International Cricket matches considered here last for 7-8 hours and are played outdoors with potentially greater variability in conditions during gameplay
[11] See McMorris and Colenso (1996) and Chiappori, Levitt and Groseclose (2002) on penalty kicks

Secondly, by departing from the models from Bhaskar (2009), I put forth a model of differing beliefs as an explanation for the observed trends. The existence of beliefs might induce teams to make decisions that they believe would help them win the match but might actually hinder them. As teams are expected to constantly update their beliefs over time, I also suggest a model of learning that allows for a belief updating mechanism. To the best of my knowledge, there hasn't been any other paper which has taken this particular viewpoint about the coin toss in Cricket.

Lastly, after testing for learning implicitly in the data, I do not find any significant improvement in the decisions made over the course of a series where learning over the match conditions, relative team skill, etc. might be expected to occur. In fact, the 'win toss advantage'[12] decreases year-on-year over the whole sample considered. This might suggest continued persistence of biased beliefs by teams. This finding is not dissimilar from the findings on learning from other studies in Behavioural Economics and those in other sports (eg. draft picks in the NFL studied in Massey and Thaler (2005)).

This paper is structured as follows. After giving a brief background on Cricket in Section 2, Section 3 looks at the toss decision more closely. Section 4 builds the baseline model from Bhaskar (2009) and shows the persistence of trends. Section 5 introduces beliefs into this framework and builds a theoretical claim for learning. Section 6 discusses the hypotheses and findings on learning. Section 7 concludes.

2. Background on Cricket[13]

Cricket is a sport played between two teams. Every cricket match is divided into two distinct phases called 'innings', and both teams bat or field alternatively in each innings. In the first innings, the team that is batting (henceforth 'bats first') aims to score as many 'runs' as

[12] See footnote 9
[13] Appendix I has a few photographs on Cricket

possible while the team that is fielding (‘fields first’) aims to reduce the number of ‘runs’ scored by the batting team.

In the second innings, these roles are reversed, but the aim of the teams is slightly altered. In this innings, the team that is batting (‘bats second’) aims to outscore the team that batted first (fielding team in the second innings). If the team that batted second scores more runs than the team that batted first then it wins the match. If it fails to do so, then the team that batted first wins the match.

Matches are played as part of a bilateral series (a series of matches between two teams, with the winner of the series being the team that has won more matches than its opponent) or multi-team series (a classic example of this is the World Cup. These typically have an initial round-robin format and teams that perform well in this initial stage progress to a ‘Knockout’ stage that eventually determines the winner of the series). Ultimately, teams seek to win as many matches that helps them win the series, but note that the exact number of matches required to win the series are different from one series to the other. All matches are played in two different types of conditions, viz. matches played entirely in the day time (referred to as ‘Day’ matches) and those played in the evening (‘Day/Night’ matches).

3. Decision at the toss

At the toss, the decision is made by the toss winner to choose the order of play. The order of play essentially refers to which team bats/fields in which of the two innings. Over the course of the whole match, both teams must necessarily bat and field in one of the two innings. Thus, an inherent preference to bat (or field) purely for the love of doing it might not be considered while making the decision as over the course of the whole match that team will necessarily get to both bat and field. Similarly, no known external motivation exists that restricts a team to make a certain decision.

Like all competitive sports, winning is the ultimate objective[14] for teams in Cricket. As teams are expected to be utility maximizers, improving their chances of winning is expected to be the primary dimension that toss winners seek to maximize. In practice, teams also recognize that the decision made at the toss might affect the outcome of the match. For instance M.S. Dhoni, then captain of India, after the loss of a match in a (T20[15]) World Cup semi-final stated that losing the toss was a critical factor that affected the match outcome as the order of play chosen by the toss winner meant that his players had to perform in 'worse' match conditions[16]. In fact, Nasser Hussain, then captain of England, labelled the decision to field first in a match the 'biggest mistake (he) made as England captain'[17].

Although winning is the primary objective for teams, it is possible that toss winners might consider other factors, apart from winning, while making the decision. These might include:

1. Gaining more experience about playing in a certain order of play, especially if they have relatively less experienced players
2. Satisfying their risk appetite, for eg. risk-loving teams may gain some utility by making 'riskier' decisions

Note that even though these factors might affect the decision, they might not *change* their ultimate objective to win the match. For instance, a team may want to gain experience in an order of play *and* win the match. A risk-loving team may choose to make a 'cautious' decision if making a 'riskier' choice significantly reduces their ex ante chances of winning. The focus of this paper is on the impact of toss decisions on winning, but section 6c discusses the findings from this paper with respect to these other factors as well.

[14] Some matches might become 'inconsequential' if their result does not affect the outcome of a given series. If this is the case, winning might not be the primary maximizing factor which teams consider, but winning is still important for other intangible reasons such as pride, team morale, etc. Note, that for this paper I estimate that about 15.6% of the matches are 'inconsequential' and the results are robust even after taking these matches out of the sample

[15] T20 is a shorter format of International Cricket, which has not been considered in the paper, but is at a similar standard in terms of the level of competition to that which has been considered here.

[16] Krishnaswamy (2016), article from ESPNCricinfo

[17] John (2006), article from The Guardian

4. Updating Bhaskar (2009)

This section aims to build on the findings from Bhaskar (2009) and to test how the observed trends have evolved since the last match considered in that paper from 2003. Bhaskar's findings were that toss winners were more likely to win the match during 'Day/Night' matches and less likely to win during 'Day' matches.

In section 4a, I build the model of toss relevance central to undertaking this study showing that under the assumption of complete information sharing, the toss necessarily impacts the outcome for every match. This model has been adapted from Bhaskar (2009) with minor cosmetic changes such as changing variable names, etc. In section 4b, I present the empirical data to be used for the rest of the paper. Section 4c illustrates the results of updating the data to 2016, showing the persistence of trends from before.

a. Toss relevance under complete information-sharing[18]

Let's assume that the match is played between two teams, team 1 and team 2. Before making the toss decision, both teams consider three aspects about the match, viz.

- The skill and strategies for team 1: Contains information about players, team dynamics, etc. for team 1
- The skill and strategies for team 2: Contains information about players, team dynamics, etc. for team 2
- The match conditions: Includes information on weather, pitch conditions[19], etc. that lie outside the control of either team. Moreover, these may change as the match progresses[20]

[18] For the sake of brevity, I have assumed that the decision at the coin toss is made by a 'team'. In reality, the decision is made by the captain, the key decision maker within the team

In all that follows, these three factors are combined into the state of the world, ω, coming from a super-set Ω which contains all possible states of the world. To consider the underlying relevance of the toss, it is assumed that there is no uncertainty about ω from either team. This assumption is relaxed in section 5a.

To make the toss decision once the ω has been drawn, the teams consider two counterfactual 'orders of play':

1. Order B: Team 1 bats first and team 2 fields first

   Or

2. Order F: Team 1 fields first and team 2 bats first

The strategies, relative team performance and match conditions are expected to interact differently in the two counterfactuals and both teams are aware of this. It is assumed that the intention of the toss winner is to pick either of the two counterfactuals that might improve its likelihood of victory.

From the perspective of team 1, if it wins the toss it computes the winning probabilities[21] under either 'order of play', comparing:

$$P\ (Team\ 1\ Win\ |\ Order\ B) = b\ (\omega)$$

$$P\ (Team\ 1\ Win\ |\ Order\ F) = f\ (\omega)$$

Note that once the ω is drawn, b (ω) and f (ω) may yield different outcomes.

Team 2 looks at the same probabilities, and as there are only two possibilities (either team 1 wins or team 2 wins), the probabilities it compares are:

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[19] Different pitch conditions might help certain players and inhibit others

[20] For instance, the pitch could deteriorate over the course of a match, which helps different kinds of fielding players. The weather might be overcast in one section of the match and a team might seek to avoid that, etc.

[21] For simplicity, this paper looks at the orders as considered from Team 1's perspective, but team 2 can also be used without changing the result

$$P\ (Team\ 2\ Win\ |\ Order\ B) = 1 - b\ (\omega)$$

$$P\ (Team\ 2\ Win\ |\ Order\ F) = 1 - f\ (\omega)$$

Both teams make the decision based on which distribution they prefer. Thus, their respective decision rules are:

Team 1: If b (ω) > f (ω), pick order B. Else pick order F

Team 2: If 1 – f (ω) > 1 – b (ω), pick order F. Else pick Order B.

- Note, $1 - f(\omega) > 1 - b(\omega) \Rightarrow b(\omega) > f(\omega)$

If both teams pick optimally and b (ω) > f (ω), then team 1 would pick order B and team 2 would pick order F. More generally, it can be established that for any values of b (ω) and f(ω), both teams should necessarily *disagree* over their optimal choices (if team 1's optimal order is order B, team 2's optimal order would be order F and vice versa).

This 'disagreement' about the order of the play shows why the toss is relevant. In the counterfactuals where team 1 and team 2 are the toss winners and both pick optimally, then the orders of play selected will necessarily be different. Thus, by winning the toss, the toss winner gets to choose the play order that gives it an advantage and the toss loser an identical disadvantage. Henceforth, 'disagreement' is referred to as this critical condition that helps establish the relevance of the toss.

Following from Bhaskar (2009), an identifying assumption has been made that $b \neq f$ as the probability of this event is negligible.

b. Data

The data considered in this paper is on the toss decisions made in the Men's One-Day International Cricket from 1971-2016. This data is publically available and was sourced from the ESPNCricinfo website. Officially, there is a hierarchical structure with 12 'Full Members' and 92 'Associate Members' recognized by the International Cricket Council, which governs the sport. In this paper, I only consider the results of matches played between 8 of the 12 'Full Member' countries which ensures that the relative skill level is comparable across the entire dataset.

These 8 teams are: Australia, England, India, New Zealand, Pakistan, South Africa, Sri Lanka and the West Indies. Bhaskar (2009) also includes matches played by Zimbabwe, but I haven't included these matches as the performance of Zimbabwe has been particularly poor relative to the other eight, especially since 2003, and might bias the findings. Moreover, the results from 1971-2003 are similar to that from Bhaskar (2009) even after excluding Zimbabwe from the sample.

In total, 2,567 matches played across both Day (1,485 matches) and Day/Night (1,082 matches) formats are studied. Note that matches that yielded no result (if the teams could not play the entire match due to adverse weather conditions or if a match resulted in a tie, i.e. both teams scored the same number of 'runs') have not been included in this analysis.

c. Advantage for winning the toss

The central question from this paper is whether winning the toss improves a team's likelihood for victory. As the identity of the toss winner is random, I can balance out some of the match specific noise to understand the impact of the toss decision specifically by aggregating over a set of matches. In what follows, I utilize two aggregation techniques:

- When looking at all matches, the identity of the toss winner is not taken into consideration. Thus, a team that is 'less advantaged' for a specific match ex ante has as much chance to be a toss winner as a 'more advantaged' team as the allocation of the decision rights was made via the coin toss. Thus, by aggregating over a set of matches, decisions made by both 'more advantaged' and 'less advantaged' toss winners are aggregated together, allowing me to isolate the impact that winning the toss might have on match outcome. This technique has been carried over from Bhaskar (2009)
- When looking at team specific settings, I compare the set of matches where a particular team won the toss with the set of matches where the same team lost the toss. By aggregating in this way, I can average out the importance of relative skill level, match conditions etc. as that team was assigned to the toss winner group or toss loser group at random
    - The main drawback of this approach is that matches where the team was a toss loser are also affected by the decision making of the rival. If the rival is not making optimal decisions, then the rival's bad decisions improve the odds of the team winning even if it loses the toss. But, as the identity of the rival is also random over the set of matches and not all teams are expected to make incorrect decisions all the time, it is assumed that on average the likelihood of rivals making poor decisions would not be much different than the likelihood of poor decisions being made by the team themselves

Firstly, I test if all toss winners have a higher likelihood for victory across the entire dataset. To test this, I ran Pearson's Chi-squared tests under the following null hypothesis:

$$H_0: P\ (\text{Win Match} \mid \text{Win Toss}) = 0.5 \qquad (1)$$

If the toss winner is advantaged by winning the toss, then this conditional probability should actually be greater than 0.5 implying that winning the toss gives them a higher likelihood to win the match than losing the toss. These tests follow directly from Bhaskar (2009).

I ran these tests along several settings and report my findings in table 1. For instance, row 1 shows that conditional on the team winning the toss and batting first in Day matches, their probability to win the match is 0.42. The p values from the null hypothesis seen in (1) are reported in the table as well.

Overall, I can reject that the hypotheses for both Day matches and Day/Night matches being equal to 0.5 (rows 3 and 6) which means that the toss does have an impact on match outcome in both settings. However, the observed biases are in opposite directions, i.e. toss winners perform better in Day/Night matches and worse in Day matches.

Table 1: Likelihood of toss winners winning the match: aggregate setting

Format	Decision	P (Win)	Matches	p value
Day	Win Toss & Bat	0.4195***	565	0.0001
	Win Toss & Field	0.5141	920	0.3913
	Win Toss	0.4781*	1,485	0.0917
Day/Night	Win Toss & Bat	0.5393**	777	0.0286
	Win Toss & Field	0.5148	305	0.6063
	Win Toss	0.5323**	1,082	0.0333

Notes
- Column 3 gives the probability of winning the match under the conditions specified in columns 1 and 2
- Column 4 lists the number of matches under these conditions
- The p values are for Pearson's Chi-squared test for the reported probabilities being equal to 0.5
- *,** and *** represent the 10%, 5% and 1% levels of significance

Next, I checked the respective trends for each team individually. To test this, I compared the conditional probabilities for each team winning a match when it wins the toss as compared to when it loses the toss in both Day and Day/Night settings. I then ran Pearson tests to compare the equality of these two probabilities.

$$H_0: P\,(\text{Win Match} \mid \text{Win Toss}) = P\,(\text{Win Match} \mid \text{Lose Toss}) \quad (2)$$

I report my findings for (2) across Day (table 2) and Day/Night (table 3) matches and find very similar trends to what was seen in table 1. Every team (except Australia and New Zealand) has a higher likelihood to win matches during Day/Night conditions and lower likelihood to win (except England) during Day conditions. Although, most of these results are not statistically significant as the number of matches for these tests is relatively small, the persistence in the trend from before is an additional point that might indicate that toss winners seem to do better during Day/Night matches and worse during Day matches.

Table 2: Likelihood of toss winners winning the match: per team (Day)

Team	P (Win | Win Toss)	P (Win | Lose Toss)	Matches	p value
Australia	0.55	0.60	361	0.32
England	0.49	0.48	364	0.92
India	0.47	0.48	437	0.77
New Zealand	0.43	0.48	356	0.33
*Pakistan***	0.44	0.53	441	0.05
South Africa	0.56	0.62	227	0.34
Sri Lanka	0.36	0.42	337	0.24
West Indies	0.56	0.58	447	0.69

Notes
- Columns 2 and 3 give the probabilities for each team winning a match conditional on winning the toss and losing the toss respectively
- Column 4 refers to all matches played by the team (where it won or lost the toss) in Day conditions
- The reported p values are for Pearson's Chi-squared test for the equality of the two probabilities from Columns 2 and 3
- *,** and *** represent the 10%, 5% and 1% levels of significance

Table 3: Likelihood of toss winners winning the match: per team (Day/Night)

Team	P (Win | Win Toss)	P (Win | Lose Toss)	Matches	p value
Australia	0.65	0.66	416	0.86
England	0.48	0.42	214	0.33
*India***	0.56	0.42	302	0.02
New Zealand	0.37	0.40	235	0.57
*Pakistan***	0.55	0.42	285	0.03
*South Africa**	0.65	0.54	238	0.10
Sri Lanka	0.48	0.46	298	0.68
West Indies	0.34	0.24	176	0.13

Notes

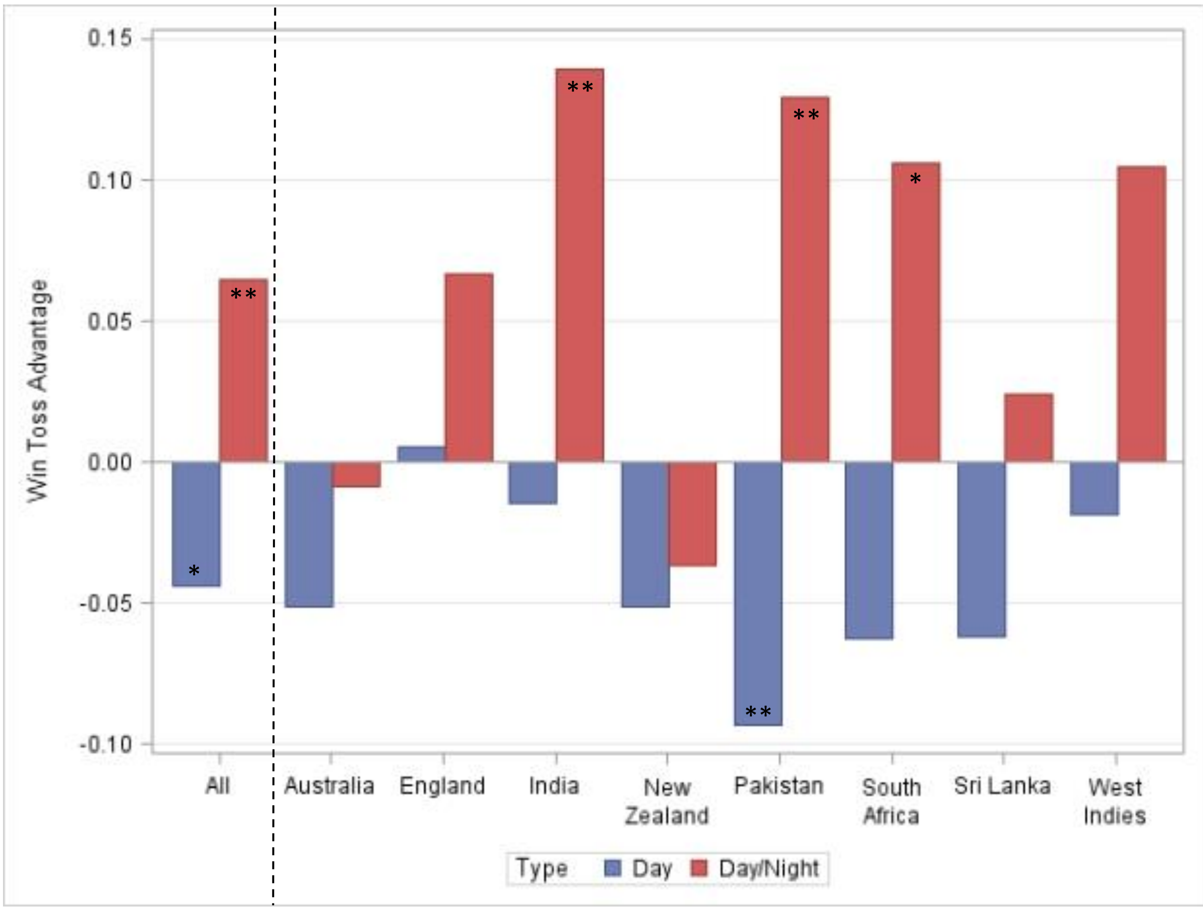
- Columns 2 and 3 give the probabilities for each team winning a match conditional on winning the toss and losing the toss respectively
- Column 4 refers to all matches played by the team (where it won or lost the toss) in Day/Night conditions
- The reported p values are for Pearson's Chi-squared test for the equality of the two probabilities from Columns 2 and 3
- *,** and *** represent the 10%, 5% and 1% levels of significance

To establish the findings more clearly, I show a plot of the following metric in figure 1:

$$\text{Win Toss Advantage} = P\,(\text{Win} \mid \text{Win Toss}) - P\,(\text{Win} \mid \text{Lose Toss}) \tag{3}$$

As stated earlier, toss winners do better in Day/Night matches and worse in Day matches. The difference between these two is especially more pronounced for teams such as Pakistan, South Africa and India. Even though for teams such as Australia, England and New Zealand the bias is in the same direction (negative for Australia and New Zealand, positive for England), the trend is still the same, i.e. they are more likely to win Day/Night matches as compared to Day matches if they win the toss.

Figure 1: The 'advantage' for winning the toss



Notes

- This figure compares the 'Win toss advantage' (equation (3)) for each team over the entire dataset, and the aggregate performance of all teams together (All)
- The values statistically different from zero are: All (Day and Day/Night), Pakistan (Day and Day/Night), India (Day/Night) and South Africa (Day/Night). * or ** next to a bar represents the 10% and 5% levels of significance respectively for the test of the value being different from zero

5. Introducing beliefs and learning

Section 5a aims to build on the findings of section 4 and introduces biased beliefs as an explanation for the observed trends. Biased beliefs may be borne out of incomplete information and/or different expectations about the behaviour of conditions that affect the match. In section 5b, a framework of learning via belief-updating is also presented that is tested in section 6.

a. Team beliefs

In section 4a it was stated that the toss is relevant to the match outcome under the assumption of complete information sharing and the agreement about the true state, ω. However, in practice, teams may not view this true ω, but their *beliefs* over it and the decisions they make might be biased by these beliefs.

To build this more formally, I make use of the same notation introduced in section 4a with the critical difference that teams no longer view the true probability distributions (b (ω) and f(ω)). The new notation introduced is:

$p_i(\omega)$: Probability distribution over Ω representing beliefs of team i (=1,2)

$b_i = E(b(\omega))_i = \sum_{\Omega} p_i(\omega) * b(\omega)$: *Expectations of team i over b (ω)*

$f_i = E(f(\omega))_i = \sum_{\Omega} p_i(\omega) * f(\omega)$: *Expectations of team i over f (ω)*

For the sake of simplicity, b_1 and b_2 represent team 1 and team 2's subjective probabilities about *team 1's* chances of victory on batting first. Similarly, f_1 and f_2 represent their subjective probabilities about *team 1's* chances of victory on fielding first.

Thus, their new decision rules are:

Team 1: If $b_1 > f_1$, pick order B. Else pick order F

Team 2: If $1 - f_2 > 1 - b_2$, pick order F. Else pick order B.

- Note, $1 - f_2 > 1 - b_2 \Rightarrow b_2 > f_2$

Under the assumption of homogeneous beliefs, $b_1 = b_2$ and $f_1 = f_2$. The result would then follow in the same form as that presented in section 4a.[22] Thus, if teams have homogeneous

[22] In fact, the results from section 4a are a special case of homogeneous beliefs where $b_1 = b_2 = b(\omega)$ and $f_1 = f_2 = f(\omega)$

beliefs, then 'disagreement' about the order of play can be established, (this holds even if both teams are *wrong* in their assessments simultaneously).

If teams have heterogeneous beliefs, then $b_1 \neq b_2$ and $f_1 \neq f_2$ and the analysis of decision rules is not as straight-forward. Utilising the notation about the order of play from section 4a (Order B refers to team 1 batting first and Order F refers to team 1 fielding first), table 4 lists the possible scenarios after incorporating team beliefs.

Table 4: Decision rules under heterogeneous beliefs

Case	Actual underlying probabilities	Team 1 beliefs	Team 2 beliefs	Optimal Order of play: Team 1 Actual vs. Beliefs		Optimal Order of play: Team 2 Actual vs. Beliefs	
1	$b(\omega) > f(\omega)$	$b_1 < f_1$	$b_2 < f_2$	Order B	Order F	Order F	Order B
2	$b(\omega) > f(\omega)$	$b_1 < f_1$	$b_2 > f_2$	Order B	Order F	Order F	Order F
3	$b(\omega) > f(\omega)$	$b_1 > f_1$	$b_2 > f_2$	Order B	Order B	Order F	Order F
4	$b(\omega) > f(\omega)$	$b_1 > f_1$	$b_2 < f_2$	Order B	Order B	Order F	Order B
5	$b(\omega) < f(\omega)$	$b_1 < f_1$	$b_2 < f_2$	Order F	Order F	Order B	Order B
6	$b(\omega) < f(\omega)$	$b_1 < f_1$	$b_2 > f_2$	Order F	Order F	Order B	Order F
7	$b(\omega) < f(\omega)$	$b_1 > f_1$	$b_2 > f_2$	Order F	Order B	Order B	Order F
8	$b(\omega) < f(\omega)$	$b_1 > f_1$	$b_2 < f_2$	Order F	Order B	Order B	Order B

Notes

- Rows 1-4 correspond to situations where Order B is actually preferable for team 1 and Order F is actually preferable for team 2 as established from section 4a
- Rows 5-8 are the possible cases for the reverse scenario (Order F is preferable for team 1 and Order B for team 2)
- The column 'Optimal Order of play: Team 1 Actual vs. Beliefs' lists the corresponding order of play preferable for team 1 based on the true underlying beliefs (left side) and those based on what team 1 may believe to be optimal (right side) after factoring in their beliefs. A similar column is also presented for team 2

For cases 1, 3, 5 and 7 both teams agree over the ordinal preferences of their subjective probabilities. For these cases, 'disagreement' over the order of play can be established. Note that even if disagreement is established, teams make decisions that help the opponent in cases 1 and 7. If team beliefs are biased like these cases, then the toss winner's chances of winning the match are reduced if they make the predicted (biased) decision!

For cases 2, 4, 6 and 8 the relevance for the toss cannot be established as the teams agree over their optimal order of play. In these cases, one of the teams has significantly biased beliefs that makes it pick the order that actually helps their rival. The other team in all of these instances makes the expected optimal decision.

Thus, under the hypothesis of heterogonous beliefs, two problems arise:

1. The relevance of the toss for a match may not be established for cases 2, 4, 6 and 8. Moreover, one of the two teams might pick the order that helps their rival due to their biased beliefs
2. Even for cases where the toss might be relevant (1, 3, 5 and 7), teams might still make sub-optimal decisions (1 and 7) that give them a lower likelihood to win the match

Heterogeneous beliefs might explain the observed trends from section 4c, i.e. teams might differ in their beliefs over the optimal decision which might bias their decision-making processes and induce them to make an incorrect choice. This bias might adversely impact their decision making during Day matches. During Day/Night matches, teams might have a lesser bias due to their better knowledge of conditions that might affect these matches.[23]

In practice, differing beliefs might manifest themselves through differing views/incomplete information over relative team skill, attributes of specific players and/or match conditions. In fact, the conclusion from Bhaskar (2009) about teams making biased decisions by ‘overweighting’ their own relative strengths is an example of differing beliefs. Another example can be seen in a 1998 article from the Independent about a match between England and West Indies: ‘What perhaps is curious, is that Atherton (England captain) won the toss and batted. According to local consensus, Lara (West Indies captain) would have done the opposite and put England in (to bat), which makes the notion behind Atherton's

[23] See footnote 3 in Section 1

decision… a dubious one'.[24] For this match, differing beliefs about the behaviour of the match conditions meant that 'disagreement' about the order of play could not be established. This meant that the toss was not relevant for that match, corresponding to a situation like case 8 from above (with England as team 1 and West Indies as team 2). As such information is not available for all matches in the dataset, this claim is empirically untestable.

b. Belief-updating and learning

Building on the premise of differing beliefs over the true state of the world, is it possible that teams may recognise the biases (if any) in their respective belief mechanisms and correct them over time? As teams play more matches, they are expected to constantly update their belief mechanisms, $p_i(\omega)$, to reflect not only their pre-existing beliefs but also some potential factor of learning which might include the actual performance of the team till date, performance during training sessions etc. that either confirms their biases or corrects it. By updating their belief mechanisms, teams might improve their knowledge of the true underlying probabilities or make their assessments worse. Specifically, beliefs might be updated in three possible ways:

1. <u>Positive learning</u>- Over time, teams improve their calibrations of the state of the world to evolve them towards the situation under no uncertainty. If this is the case then a reduction in the biases in the decision-making model for teams is expected over time:

$$b_i \rightarrow b(\omega);\ f_i \rightarrow f(\omega)$$

2. <u>No learning</u>- Teams do not update their calibrations of the state of the world at all over time. This means that there is no change to their belief mechanisms and if they are biased to start with, they may remain biased subsequently

[24] Pringle (1998), article from the Independent

3. Negative learning- Under this framework, beliefs get more biased over time. They show a similar trend to section 4a with the critical difference that the likelihood of making incorrect decisions might increase,

$$b_i \nrightarrow b\ (\omega);\ f_i \nrightarrow f\ (\omega)$$

Under the assumption of rationality, the 'positive learning' process is expected to occur more often than the other cases. Teams want to maximise their chances of victory and giving them more information is expected to help remove some of the existing biases in their belief mechanisms. 'Positive learning' might allow teams to improve their decision-making over time, making it closer to the case with no uncertainty as explored in section 4a.

As the belief updating framework can be seen along many dimensions (such as training sessions, watching teams play outside the set of matches considered here, etc.), with these potential factors not captured adequately within the data (these might even be different across teams and over time), testing an explicit learning model empirically might suffer from omitted variable bias. However, I can gauge the impact of learning implicitly by testing if the toss winner has a greater likelihood of winning the match in settings where learning is expected to occur. If such a hypothesis is confirmed, it can be concluded that 'Positive learning' from before has in fact been observed. A failure to observe these trends, might indicate a persistence in the heterogeneity of beliefs. The next section seeks to test whether such an improvement is observed or not.

6. Decisions over time

a. Within a 'series'

As stated in section 2, all matches are played as part of a series, and the ultimate aim of the team is to win as many matches that helps it win the series. The interesting aspect about evaluating a series is that these are played over a brief period (usually less than a month).

These are typically played in the same country, or a group of countries with similar conditions.[25] Most venues in the same country typically have *similar* playing conditions as well (venues in Australia have higher bounce, venues in India assist spinners, etc.) and weather conditions of different matches in a series aren't very different either as these are played over such a brief period. All teams select a specific cohort of players that play during the entire series, with minimal changes to this cohort during the course of the series, if at all. Although the match conditions do change from one match to the other within a series, the variance is not as significant over the course of a series as compared to another series in a different country in a different time. In fact, teams are known to arrive early and play 'warm-up' matches so that they get 'used' to the conditions prior to playing matches.

In any series, at least one of the participating teams is not a 'home team' (the country where all the matches are played). It might take these non-home teams some time to understand the match conditions better as generally they have not played in these venues much before.[26] For all participating teams (including the home team), playing more matches within the series might help them better gauge the relative team skills and performance of players better as they see them actually play. Typically players tend to perform similarly over a short time period (for eg. if a player is playing well in one match it is more likely for him to continue to play well in the other matches). Essentially, watching players play (both own team and those of the rivals) in the early part of the series might help teams to improve their expectations and beliefs about future performance of these players within the series. These are just some of the reasons as to why improvement in decision making might occur over the course of a series as teams update their beliefs.

If learning is to be seen within the context of a series, matches at the latter end of the series are expected to have a higher likelihood of the toss winners winning the match as they have

[25] For instance, the recent 2015 World Cup was played in Australia and New Zealand which have similar match conditions. Mostly, series are played in one country only

[26] Cricketing wisdom suggests that it takes some time for players to play optimally in different conditions than what they are used to in their home conditions

had opportunities to update their beliefs during the series. To test for this, I segregated matches played into two series-types, viz. bilateral series (two teams) and multi-team series (three or more). The reason for this segregation was due to the slightly differing objectives in both series types. In bilateral series, teams purely try to win as many matches that can help them win that series. However, in the multi-team setting there is usually a preliminary round-robin format where teams are grouped together and they attempt to win as many matches that guarantees progress to the next phase (like the bilateral series case). Once teams progress to the next phase (called 'Knockouts' in this paper), winning every match becomes critical as defeat leads to immediate elimination.

Bilateral series typically last for 3-7 matches in total with matches played between two teams (usually one of these teams is a 'home team'). Note that there is no defined point in a bilateral series where learning is expected to occur, so I had to use a few specifications as to what 'early' or 'latter' parts of a series might be. Some of these specifications include learning to have occurred after 50% of the matches played in the series, after the 3rd match in the series and so on. In what follows, I have considered learning to have occurred after 2/3rds of the bilateral series is finished, but my findings are quite similar across the different specifications considered which are presented in the appendix (A.II).

The a priori expectation is to see a positive relationship between playing more matches in the series and the toss winner winning the match. Specifically, it can be expected that:

$$\text{Play More} \propto \text{Win Toss \& Match} \tag{4}$$

To evaluate these coefficients, I ran logistic regressions and present my findings in table 5. The variable of interest, 'Play more' takes a value of 1 in the latter 1/3rds of a bilateral series and 0 otherwise. The dependent variable, 'Win Toss & Match' is 1 if the toss winner wins the match and 0 otherwise. Regression (1) shows the coefficient on 'Play more' with it being the only independent variable in the model. The coefficient is positive, as per expectations, but statistically insignificant which points towards limited improvement in decision-making over a series, if at all. I progressively added other variables of interest in regressions (2), (3) and (4) to control for other factors that might influence the likelihood of winning the match. Adding these variables significantly improved the power of the test, but did not change the inference about the variable of interest, 'Play more'.

Table 5: Decision-making in a bilateral series

	Dependent Variable = 'Win Toss & Match'			
	(1)	**(2)**	**(3)**	**(4)**
Play more	0.0741 (0.1157)	0.0729 (0.1157)	0.0922 (0.1165)	0.0569 (0.1197)
Day/Night		0.1322 (0.1129)	0.2891** (0.1202)	0.2737** (0.1233)
Bat First			-0.4792*** (.1171)	-0.4565*** (.1201)
Toss Winner: Home Team				.0480 (.3204)
Toss Loser: Home Team				-0.6491** (.3201)
Toss Winner: Better Win/Loss Ratio				0.3572* (.1820)
Toss Loser: Better Win/Loss Ratio				-0.3189* (.1826)
Observations	1,331	1,331	1,331	1,331
Likelihood Ratio (χ^2)	.4107	1.7864	18.7179	85.4553
Probability > χ^2	.5216	0.4093	0.003	<0.001

Notes
- The dependent variable, 'Win Toss & Match' takes the value of 1 if the toss winner wins the match and 0 otherwise
- The variable of interest, 'Play more' takes a value of 1 if the match is played in the final 1/3rds of a series and 0 otherwise
- Other controls include:
  a. Day/Night: 1 for Day/Night match, 0 for Day match
  b. Bat First: 1 if Toss winner opted to Bat first, 0 for Field first
  c. Home team: If the team is the same as the country where the match is played. For eg. Australia is the home team for matches played in the Melbourne Cricket Ground, Sydney Cricket Ground, etc. 'Toss Winner: Home Team' takes the value of 1 if the toss winner is the home team and 0 otherwise. 'Toss Loser: Home Team' takes the value of 1 if the toss loser is the home team and 0 otherwise. 0 for both represents matches where neither team was at home
  d. Win/Loss Ratio: Probability of winning for each team in the 10 matches prior to the match observed (a higher win/loss ratio would represent a more skilled team). 'Toss Winner: Better Win/Loss Ratio' takes the value of 1 if the toss winner had a better win/loss ratio and 0 otherwise. 'Toss Loser: Better Win/Loss Ratio' takes the value of 1 if the toss loser had a better win/loss ratio and 0 otherwise. 0 in both means that both teams had the same win/loss ratio
- The H_0 of the reported Likelihood Ratio test is for the joint significance of the coefficients on all variables
- *,** and *** represent the 10%, 5% and 1% levels of significance
- Standard errors are reported in parentheses

It must be noted that some of the matches in the latter end of a bilateral series may become inconsequential to the outcome of the series if one of the teams has won enough matches (for instance in a 5-match series, if the one of the teams wins 3 matches it is deemed to have won the series. Thus, if one teams wins the first three matches, then the last two become ‘inconsequential’). Even after removing these matches (about 15.6% of the total sample), the findings from above do not change much (these results can be seen in the appendix A.II.3).

Turning to multi-team matches, the variable for interest considered are matches played in the second (knockout) phase compared to those played in the first (round-robin) phase. Teams are expected to acquire more information by playing through the round robin stage against other teams and by watching their rivals play against each other in matches that they were not a part of themselves. The knockout matches have one more feature which might induce strategic decision making to improve as well. These matches lead to immediate elimination for the defeated team, making it more critical for teams to make the correct decisions here, as sub-optimal decisions could prove more costly than before.

Thus, in the empirical specification, a positive relationship between matches played in the knockouts with teams winning the toss and the match might be expected. More formally, this can be represented as:

$$\text{Knockouts} \propto \text{Win Toss \& Match} \qquad (5)$$

Using a dummy for knockout matches and the same framework as before, my findings are shown in table 6.

The results are similar to that presented above for bilateral series, showing that even though the coefficient on ‘Knockouts’ is positive in all the regressions, it is not statistically significant and decreases in value after I added more controls (regressions (2), (3) and (4)).

Table 6: Decision-making in a multi-team series

	Dependent Variable = 'Win Toss & Match'			
	(1)	**(2)**	**(3)**	**(4)**
Knockouts	0.1264 (0.1409)	0.0926 (0.1157)	0.0911 (0.1419)	0.0381 (0.1467)
Day/Night		0.3181*** (0.1151)	0.2793** (0.1225)	0.2515* (0.1289)
Bat First			0.1134 (.1232)	0.1710 (.1273)
Toss Winner: Home Team				0.5610*** (.1472)
Toss Loser: Home Team				-0.3323** (.1485)
Toss Winner: Better Win/Loss Ratio				0.4001** (.1961)
Toss Loser: Better Win/Loss Ratio				-0.3930** (.1945)
Observations	1,233	1,233	1,233	1,233
Likelihood Ratio (χ^2)	.8047	8.4704	9.3179	84.7857
Probability > χ^2	.5216	0.0145	0.0254	<0.001

Notes
- The dependent variable, 'Win Toss & Match' takes the value of 1 if the toss winner wins the match and 0 otherwise
- The variable of interest, 'Knockouts' takes a value of 1 if the match is played in the knockouts stage and 0 otherwise
- See table 5 notes for other controls used
- The H_0 of the reported Likelihood Ratio test is for the joint significance of the coefficients on all variables
- *,** and *** represent the 10%, 5% and 1% levels of significance
- Standard errors are reported in parentheses

b. Longer term trends

Using the match level data presented thus far, I constructed a panel dataset to look at the relative team performance for each team where it won the toss compared to when it lost the toss for each year that the data is available for. As teams play matches in a series and the selection of the toss winner is random, the matches where a team won the toss and where it lost the toss should be against similar teams with matches played under similar conditions in both groups. Over any given year, the relative team skill is not expected to be very different either which allows me to group all matches in a year together.

Over time, teams might accumulate knowledge from matches played and decisions made in past years. Inexperienced players may also gain more experience by playing more matches which might help them perform more suitably to different conditions over time. They might also watch matches played by rivals, giving them more knowledge about their opponents as they play more matches over time. These are some of the mechanisms by which decision-making might be expected to improve with time.

Using the same methodology from equation (3) in section 4c, I can isolate the impact that the toss decision has on winning the match by comparing the two conditional probabilities defined below but evaluated for each team '*t'* over each year '*y'*. Specifically, this takes the following form:

$$\text{Win Toss Advantage}_{ty} = P\,(\text{Win} \mid \text{Win Toss})_{ty} - P\,(\text{Win} \mid \text{Lose Toss})_{ty} \qquad (6)$$

I restricted my sample to years where a team played at least 3 matches where it won the toss *and* 3 matches where it lost the toss in the same year. This allows me to remove the noisy observations where teams played lesser matches (for eg. if a team played only 1 match during a year then it will have a 0/100% outcome which might give spurious results). Ideally, I would have liked to use more matches than 3, but the number of observations falls dramatically with lesser number of matches and the overall trend is similar to the one shown below. These other findings are shown in the appendix (A.III).

In the regressions, the variable of interest is 'Year' (which ranges from 1971-2016) as I seek to see how decision making changes over time. For both Day and Day/Night matches, I ran two regressions with and without team-specific dummies and the findings of the coefficient on the Year variable is presented in table 7.

Table 7: Decision-making over time

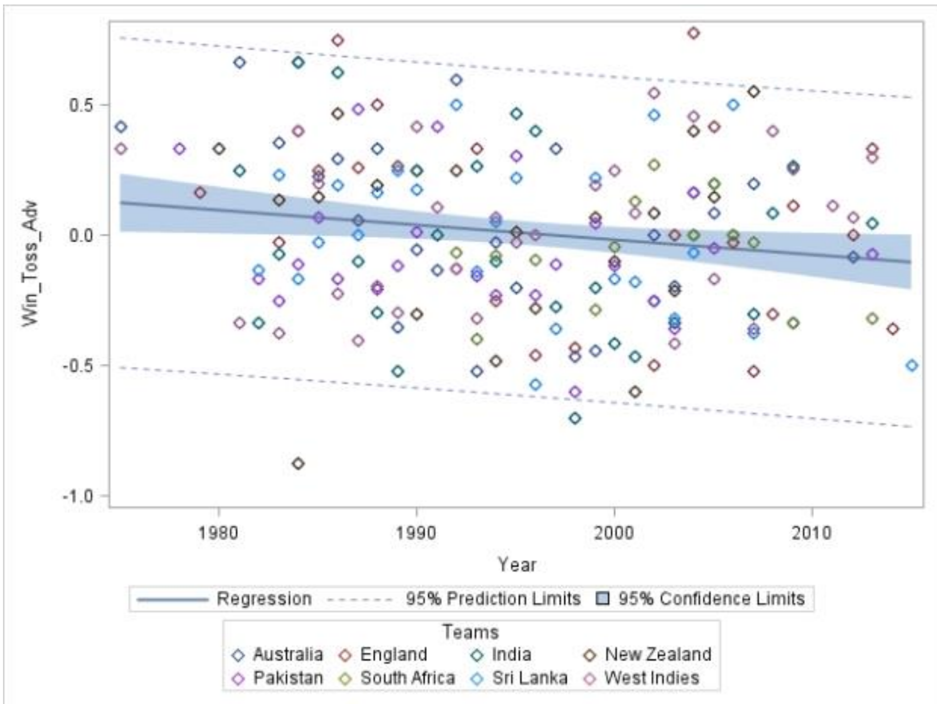
	Dependent Variable = Win Toss Advantage$_{ty}$			
	(1)	**(2)**	**(3)**	**(4)**
Year- Day	-0.0057** (0.0025)	-0.0059** (0.0026)		
Year- Day/Night			-0.0052 (0.0033)	-0.0064** (0.0036)
Team dummies		X		X
Observations	188	188	134	134
R^2	.0273	.0521	.0188	.0834

<u>Notes</u>

- The dependent variable is 'Win Toss Advantage$_{ty}$' as defined in equation (6). This was calculated for each team 't' and each year 'y' that the data is available for
- The variable of interest is 'Year' that ranges from 1971-2016
- Only those observations were considered where a team played at least 3 matches where it won the toss and 3 matches where it lost the toss in the same year
- Regressions (2) and (4) include team dummies in the regressions for each of the 8 teams in the dataset
- *,** and *** represent the 10%, 5% and 1% levels of significance
- Standard errors are reported in parentheses

The negative sign on the 'Year' variable (with and without team dummies) suggests that for both Day matches and Day/Night matches (only statistically significant for the specification with team dummies) toss winners have a lower likelihood of winning the match over time. The findings from this table run counter to the expectations of seeing an improvement in decision-making. As before, although there is a possibility of these findings being biased by the behaviour of the opponent, as the identity of the rival is random, it is expected that the likelihood of one team making poor decisions is similar to that of its rivals over such a long timeframe considered. Thus, this trend (over a 45 year timeframe) across both formats may indicate a diminishing advantage gained from winning the toss. The below graphs illustrate the observed trends more clearly.

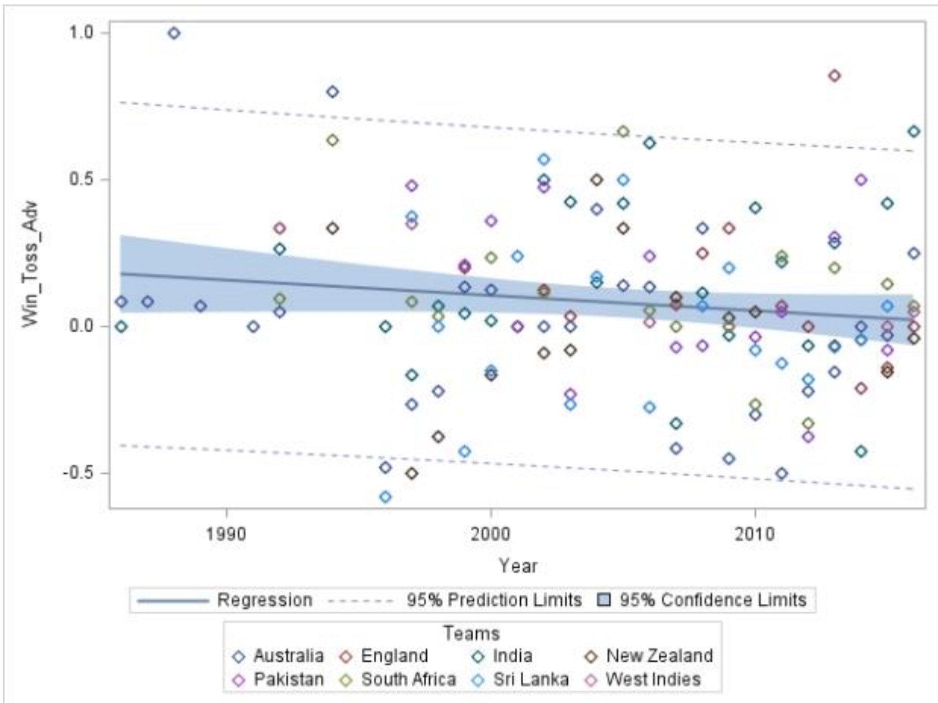
Figure 2: The 'advantage' for winning the toss by team over time (Day)



Notes

- This figure shows how the 'Win Toss Advantage' (as defined in equation (6)) evolves over time for each team in Day matches only
- The trend line corresponds to regression (1) from table 7

Figure 3: The 'advantage' for winning the toss by team over time (Day/Night)



Notes

- This figure shows how the 'Win Toss Advantage' (as defined in equation (6)) evolves over time for each team in Day/Night matches only
- The trend line corresponds to regression (3) from table

c. Discussion

In summary, section 6 shows that there seems to be some improvement in decision-making within a series but these findings are not statistically significant. In fact, the relative team performance points towards a declining advantage for winning the toss from 1971-2016.

The hypothesis from section 5 was that teams might have heterogeneous beliefs but 'positive learning' might lead to an improvement in decision-making over time. These findings suggest that decision making is not improving over time (and may even be getting worse!). This might indicate that there is a persistence in biased beliefs which might lead to a continuing trend of poor decision-making. Teams might respond to incorrect decisions made at the toss differently and might pass off poor decisions to 'bad luck' or an unexpected performance (good or bad) by a certain player.[27] They might expect their 'luck' to improve (gambler's fallacy?) the next time they make the decision which might lead to the case for 'no learning' or even 'negative learning' next time.

In section 3, it was stated that teams might look to maximize their match-specific utility along a few factors. As the matches considered in this paper are from the most competitive form of the sport, winning is critical for each team. As players usually play a significant number of matches domestically prior to playing the matches considered here, it is unlikely that gaining experience for a specific order of play is very important for International Cricket teams. Relative risk preference might indicate that teams view one decision as 'safe' and the other as 'risky' and may choose the 'risky' decision for a match given the context. Especially in the context of a series, if matches are not 'inconsequential' in the 'latter' part, the outcome of the whole series may depend on those matches. For these, teams may choose a sub-optimal 'risky' option if they are highly risk-loving. Although this hypothesis is beyond the scope of

[27] These can be inferred from post-match discussions with players. See footnotes 16 and 17 for two such examples

this study, it might explain why there is a failure to see an improvement in decision making specifically within a series.

7. Conclusion

The main goal of the paper was to understand how decision making evolves over time in an empirical setting. Using the sport of Cricket, I evaluated if winning the coin toss at the start of every match confers the toss winner with any advantage in terms of winning the match. I find that in the Day format of the Men's One-Day International form of the sport, toss winners are less likely to win the match, with a worsening of decision-making over time.

This may point towards significantly, and persistently, biased beliefs which might induce teams to make sub-optimal choices. Teams may not be updating their belief mechanisms either which might explain why decision-making is not seen to improve with time. Other factors to consider might be the relative risk-preferences for the toss winner, which might induce them to make a riskier choice ex-ante if they are risk-loving.

As seen earlier, several studies on learning (Thaler et al (1997), Roth and Erev (1993), Barron and Erev (2003) to name a few) don't find much empirical support for learning. Even within the domain of Sport Economics, studies have shown that teams might consistently make poor decisions despite high monetary stakes and opportunities to learn such as Massey and Thaler (2005) which shows how teams from the National Football League in the USA persistently overvalue players in their annual draft of young players.

The main drawback of this study is that considering a different set of matches (such as other form of Men's International Cricket, domestic leagues, Women's Cricket, etc.) might yield different outcomes. Thus, these findings are limited to the dataset considered for the Men's One-Day International set of matches played from 1971-2016.

Secondly, the findings about improvement in decision making are restricted by the specifications considered. It would be very interesting to see if such an improvement might be seen in a different test, or in another form of the sport other than that considered here. The tests used here were limited with what was available in the data and a richer dataset that might be able to model learning more explicitly might be able to generate different results. It might also be interesting to model using a behavioural approach to the decision-making process to understand the observed trends better. Until then, we might have to contend with the fact that Men's International Cricketers, like the rest of us, are prone to errors in judgement.

References

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Appendix I- Photographs of Cricket

Cricket Stadium- Melbourne Cricket Ground; Source: Website of Cricket Australia

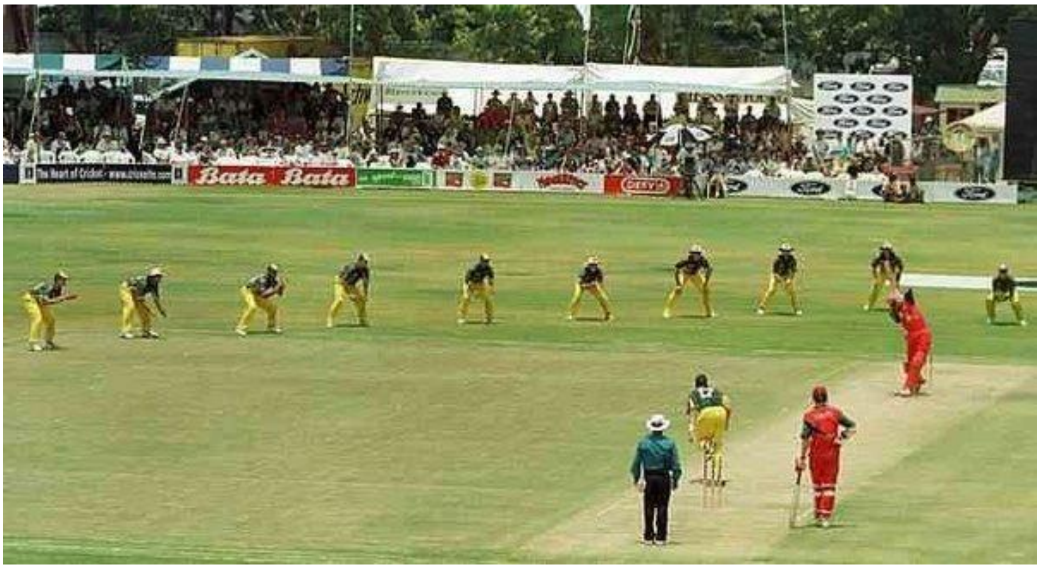
Cricket Pitch; Source : Website of Quora.com

Coin Toss. Players- Rick Ponting (Australia) and Andrew Strauss (England);

Source: Website of Fox Sports

Batting. Player- Brian Lara from West Indies;

[Source](#): Website of Lord’s Cricket Stadium



Fielding team is Australia (yellow). Batting team is Zimbabwe (red);

[Source](#): Website of Quora.com

Appendix II- Different specifications for table 5

A.II.1- ‘Play more’ after ½ of the series

	Dependent Variable = ‘Win Toss & Match’			
	(1)	**(2)**	**(3)**	**(4)**
Play more	0.0537 (0.1104)	0.0520 (0.1105)	0.0624 (0.1112)	-0.0032 (0.1144)
Day/Night		X	X	X
Bat First			X	X
Toss Winner: Home Team				X
Toss Loser: Home Team				X
Toss Winner: Better Win/Loss Ratio				X
Toss Loser: Better Win/Loss Ratio				X
Observations	1,331	1,331	1,331	1,331
Likelihood Ratio (χ^2) H_0: Coeff=0	.4107	1.7864	18.7179	85.4553
Probability> χ^2	.5216	0.4093	0.003	<0.001

Notes
- The dependent variable, ‘Win Toss & Match’ takes the value of 1 if the toss winner wins the match and 0 otherwise
- The variable of interest, ‘Play more’ takes a value of 1 if the match is played in the final 1/2 of a series and 0 otherwise
- See table 6 from above for the definitions of the different control variables used
- The H_0 of the reported Likelihood Ratio test is for the joint significance of the coefficients on all variables
- *,** and *** represent the 10%, 5% and 1% levels of significance
- Standard errors are reported in parentheses

A.II.2- 'Play more' after match 3 of the series

	Dependent Variable = 'Win Toss & Match'			
	(1)	**(2)**	**(3)**	**(4)**
Play more	0.0065 (0.1098)	-0.0028 (0.1101)	0.0235 (0.1110)	-0.0186 (0.1141)
Day/Night		X	X	X
Bat First			X	X
Toss Winner: Home Team				X
Toss Loser: Home Team				X
Toss Winner: Better Win/Loss Ratio				X
Toss Loser: Better Win/Loss Ratio				X
Observations	1,331	1,331	1,331	1,331
Likelihood Ratio (χ^2) H_0: Coeff=0	.4107	1.7864	18.7179	85.4553
Probability> χ^2	.5216	0.4093	0.003	<0.001

Notes

- The dependent variable, 'Win Toss & Match' takes the value of 1 if the toss winner wins the match and 0 otherwise
- The variable of interest, 'Play more' takes a value of 1 if the match is after match 3 of the series is played and 0 for the first 2
- See table 6 from above for the definitions of the different control variables used
- The H_0 of the reported Likelihood Ratio test is for the joint significance of the coefficients on all variables
- *,** and *** represent the 10%, 5% and 1% levels of significance
- Standard errors are reported in parentheses

A.II.3- Removing inconsequential matches. 'Play more' after 2/3rd of the series

	Dependent Variable = 'Win Toss & Match'			
	(1)	**(2)**	**(3)**	**(4)**
Play more	0.0870 (0.1442)	0.0870 (0.1442)	0.1033 (0.1453)	0.0580 (0.1487)
Day/Night		X	X	X
Bat First			X	X
Toss Winner: Home Team				X
Toss Loser: Home Team				X
Toss Winner: Better Win/Loss Ratio				X
Toss Loser: Better Win/Loss Ratio				X
Observations	1,123	1,123	1,123	1,123
Likelihood Ratio (χ^2) H_0: Coeff=0	.4107	1.7864	18.7179	85.4553
Probability> χ^2	.5216	0.4093	0.003	<0.001

Notes
- The dependent variable, 'Win Toss & Match' takes the value of 1 if the toss winner wins the match and 0 otherwise
- The variable of interest, 'Play more' takes a value of 1 if the match is played in the final 1/3rds of a series and 0 otherwise
- See table 6 from above for the definitions of the different control variables used
- The H_0 of the reported Likelihood Ratio test is for the joint significance of the coefficients on all variables
- *,** and *** represent the 10%, 5% and 1% levels of significance
- Standard errors are reported in parentheses

Appendix III- Different specifications for table 7

A.III.1- Minimum 5 matches per team per year

	Dependent Variable = 'Win Toss Advantage'			
	(1)	**(2)**	**(3)**	**(4)**
Year- Day	-0.0038 (0.0034)	-0.0035 (0.0036)		
Year- Day/Night			-0.0089** (0.0033)	-0.0077 (0.0047)
Team dummies		X		X
Observations	94	94	71	71
R^2	0.0138	0.0453	.0535	0.1348

Notes
- The dependent variable is 'Win Toss Advantage$_{ty}$' as defined in equation (6)
- The variable of interest is 'Year' that ranges from 1971-2016
- Regressions (2) and (4) include team dummies in the regressions for each of the 8 countries (7 dummy variables, 0 in all for West Indies)
- *,** and *** represent the 10%, 5% and 1% levels of significance
- Standard errors are reported in parentheses

A.III.2- Minimum 7 matches per team per year

	Dependent Variable = 'Win Toss Advantage'			
	(1)	**(2)**	**(3)**	**(4)**
Year- Day	-0.0097 (0.0062)	-0.0103 (0.0072)		
Year- Day/Night			-0.0050 (0.0082)	-0.0017 (0.0087)
Team dummies		X		X
Observations	42	42	31	31
R^2	0.0577	0.2044	.0126	0.1348

Notes
- The dependent variable is 'Win Toss Advantage$_{ty}$' as defined in equation (6)
- The variable of interest is 'Year' that ranges from 1971-2016
- Regressions (2) and (4) include team dummies in the regressions for each of the 8 countries (7 dummy variables, 0 in all for West Indies)
- *,** and *** represent the 10%, 5% and 1% levels of significance
- Standard errors are reported in parentheses