Loss aversion and high stakes[#]

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Abstract

Following Kahneman and Tversky (1979), studies such as those by Haigh and List (2005), Ert and Erev (2013), and Mukherjee et al. (2017), find that loss aversion increases as stake increases. This study extends the work of Berger and Pope (2011) by analysing over 68,000 United States professional basketball games played from the initial NBA season in 1946 / 1947 to the 2018 / 2019 season, and over 69,000 NCAA games played from the 2007 / 2008 season to the 2018 / 2019 season. We posit that, a priori, stakes, and therefore loss aversion, will be greater for NBA teams than for NCAA teams, and higher for home teams than for away teams. Further, loss aversion is expected to be greater for favourites, that is, teams that are expected to win.

We model outcomes using a digital call option. This model allows for necessary non-linearity in the relation between halftime score and winning percentage. It also provides an analysis for which the result for home (favourite) teams is not simply the converse of that for away (underdog) teams.

We find evidence of better-than-expected performance for NBA home teams that are behind by up to four points, and for favourites that are behind by between two and seven points. We find no evidence of this effect with respect to NBA away teams, NBA underdogs, nor for NCAA teams – whether home or away. Our results suggest that loss aversion is apparent when stakes are high.

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1. Introduction

Berger and Pope (2011), using an analysis of more than 18,000 United States professional basketball games played between the 1993 / 1994 season and 2009, show that, for both home and away teams, being behind by one point at halftime leads to a discontinuous increase in winning percentage. Their methodology does not allow for differential effects for home and away teams. They attributed their result to loss aversion and the increased motivation that is manifest when teams are slightly behind. This argument is based on the work of Heath, Larrick and Wu (1999), Kahneman and Tversky (1979), Kivetz, Urminsky and Zheng (2006), and Tversky and Kahneman (1992), amongst others. Heath, Larrick and Wu (1999) argue that goals or targets can act as reference points. Consequently, position relative to a goal can influence motivation in a manner consistent with the three key tenets of prospect theory (Kahneman and Tversky (1979 and Tversky and Kahneman (1992)). These tenets are: that people categorize outcomes as gains (success) or losses (failure) depending on where they fall relative to a particular standard; loss aversion, whereby losses are more painful than gains are pleasurable; and diminishing sensitivity, whereby outcomes have a smaller marginal impact as they move further from the reference point. Loss aversion suggests that compared to people who are above their goal by a similar amount, people who are below or behind their goal will work harder because they see their performance as a loss. Furthermore, because of diminishing sensitivity, people who are slightly below their goals should work harder than those for whom the goal is further away (Heath, Larrick and Wu (1999) and Kivetz, Urminsky and Zheng (2006)).

This paper extends that analysis be examining the importance of what is at stake. There is a considerable literature across a range of domains that loss aversion increases as stake increases. In their seminal work, Kahneman and Tversky (1979, page 279) noted that "the aversiveness of symmetric fair bets generally increases with the size of the stake". Subsequently, a range of studies have supported Kahneman and Tversky.

Harinck et al. (2007) ran a series of trials which documented the reactions of participants subject to experimental losses and gains. While they found evidence strongly supportive of loss aversion when the gains and losses represented significant amounts of money, they reported that this effect reversed when the stakes were low. That is, when dealing with small amounts of money, the happiness derived from a small gain more than offset the unhappiness experienced when incurring a loss of the same magnitude. Ert and Erev (2013) also found in experimental settings that "… absolute loss aversion is observed under high stakes but not under relatively low stakes" (Ert and Erev (2013 p. 221). Further, Mukherjee et al. (2017) found no evidence of loss aversion for low magnitude outcomes. In contrast, for the same participants, loss aversion was evident for higher magnitudes. They concluded that "While prospect theory probably remains one of the hallmark theories in decision making, mounting evidence suggests a modification in its value function to accommodate differences across low and high magnitudes" (at page 87).

Additional evidence of the relation between stakes and loss aversion is provided by Haigh and List (2005), who found that professional traders exhibited greater loss aversion than students in an experimental laboratory setting.

We posit that, a priori, stakes will be higher for NBA teams than for NCAA teams. Only the elite college players are drafted into the NBA, and many college basketball players do not choose professional careers. For example, only 52 out of 4,181 (1.2%) of draft eligible NCAA participants were drafted in the 2018 NBA draft (NCAA 2019). Financial stakes are markedly higher for NBA players. College players are at least nominally amateur, while the average (median) salary for an NBA player in the 2019 / 2020 season was $6,665,745 ($2,625,359) (basketball-reference.com).

We also posit that, a priori, stakes will be higher for home teams than for away teams. Physiological evidence supports this proposition. Explicitly related to our study, Fothergill et al. (2017) test for changes in hormone levels for soccer players playing at home versus away. They find significantly elevated post-game levels of cortisol, a hormone commonly related to the body's management of stress, in home games but not away games and report that this result is independent of the outcome of the game at hand. This result confirms the earlier results of Arruda et al. (2016) which also found elevated levels of cortisol in elite sportspeople in home games but not away games, with the authors concluding "…that the pressure to perform well at home may impose a higher level of stress on the players" (at page 81). Finally, Goldman and Rao (2017) track player effort through the use of optical tracking systems employed by the NBA. These tracking systems provide precise two--dimensional coordinates of each player every 40 milliseconds of the game. Their analysis of the 2014/15 season not only confirms evidence of loss aversion in the actions of individual players, but also provides support that this effect is greater for home-teams[1].

We also test for differences in evidence of loss aversion for favourites as opposed to underdogs, as defined by betting market odds. Extant physiological evidence with respect to the stakes faced by favourites as compared with underdogs, similar to that cited above with respect to home as compared with away teams, is not available. However, favourites are expected to win, and a reasonable expectation is that stakes are higher when teams are expected to win.

The additional contribution of the paper is allowance for non-linearity in the relation between halftime score and winning percentage, non-linearity that is robustly supported by theory and tractable empirically. Importantly, this modelling also provides analysis for which the result for home (favourite) teams is not simply the converse of that for away (underdog) teams.

This superior methodology is applied to an analysis of over 68,000 United States professional basketball games played from the initial NBA season in 1946 / 1947 to the 2018 / 2019 season, and over 69,000 NCAA games played from the 2007 / 2008 season to the 2018 / 2019 season.

We find evidence of better-than-expected performance for NBA home teams that are behind by up to four points, and for favourites that are behind by between two and seven points. We find no evidence of this effect with respect to NBA away teams, NBA underdogs, nor for NCAA teams – whether home or away. Loss aversion as found by Berger and Pope appears to only apply to NBA home teams and favourites. These results suggest that loss aversion is apparent when stakes are high.

This paper proceeds as follows. The expected relation between halftime score and winning percentage is presented in Section 2. The empirical results of examining this relation are presented in Section 3. A summary is provided in Section 4.

[1] Interestingly, Goldman and Rao (2017), also show strong evidence of a positive relationship between individual player age and the incidence of patterns of on-court behaviour consistent with loss aversion. This result offers another explanation, in addition to the financial stakes involved, as to why we might expect evidence of loss aversion to be more prevalent in the NBA than in the NCAA.

2. Expected relation between halftime score and winning percentage

Any test for abnormality in winning percentage conditioned on halftime score difference must necessarily be a joint test of the expected or normal winning percentage. To model expected winning percentage, Berger and Pope use the regression discontinuity design introduced by Thistlethwaite and Campbell (1960) and developed by Imbeds and Lemieux (2008) and Lee and Lemieux (2009). To provide what they argue will be an expected linear relation between halftime score difference and winning percentage (with a discontinuity at a halftime score difference of zero), they restrict their analysis to those games where the halftime score difference was less than or equal to 10 points and exclude any games that were tied at halftime. They also include a cubic function in their analysis – a robustness check that does not substantially alter their findings.

With respect to NBA games, they summarise their results by stating that the "relationship is approximately linear over the range in our data. Every two points better a team is doing relative to its opponent at halftime is associated with a six to eight percentage point increase in the probability of winning" (page 819). However, they also conclude that there is a strong discontinuity around zero. Specifically, they demonstrate that home teams that are behind by one point are actually more likely to win than are home teams that are ahead by one point (triumphing in 58.2% relative to 57.1% of games).

A priori, there is no basis for expecting the relation between halftime score difference and winning percentage to be linear. Indeed, the expected relation must be non-linear. The winning percentage must approach an asymptote of zero for large negative halftime score differentials and an asymptote of one for large positive halftime score differentials. Modelling using digital call options provides for such non-linearity.

In a two-team sporting contest, the probability of a team winning may be modelled as the value of a digital call option C. The terminal pay-off to this digital call option may be expressed as:

$$Payoff_T = \begin{cases} 1 & if\ SD_T > 0 \\ 0 & if\ SD_T < 0 \end{cases} \qquad (1)$$

where SD_T is the score differential, defined as the home team score less the away team score, at the completion of the game at time T. It follows that at any time t prior to the completion of the game, the value of the option may be expressed as a function of four parameters, namely the score differential at time t SD_t; the time remaining in the game $\tau = T - t$; the volatility σ of the underlying diffusion process of the score differential, and the drift in the score differential towards the home team df. It is important to control for this drift in the score differential in order to exclude any findings as simply being a natural consequence of mean reversion in the performance of the home team relative to the away team during the second half. Berger and Pope (2011) make no allowance for mean reversion. Stern (1994) has shown that an arithmetic Brownian process with an expected mean of df and a standard deviation of σ may approximate the diffusion process of the score differential in basketball. Given that diffusion process, and following the work of Stern (1994), the value of the digital call option may be written as:

$$C = N(d) \text{ where } d = \frac{(SD_t + df.\tau)}{\sigma\sqrt{\tau}}, \qquad (2)$$

where N (d) is the cumulative distribution function of the standard normal distribution, and SD_t, df, σ and τ are as previously defined. The value of such a digital call option may be represented as a sigmoidal function as shown in Figure 1.

Figure 1

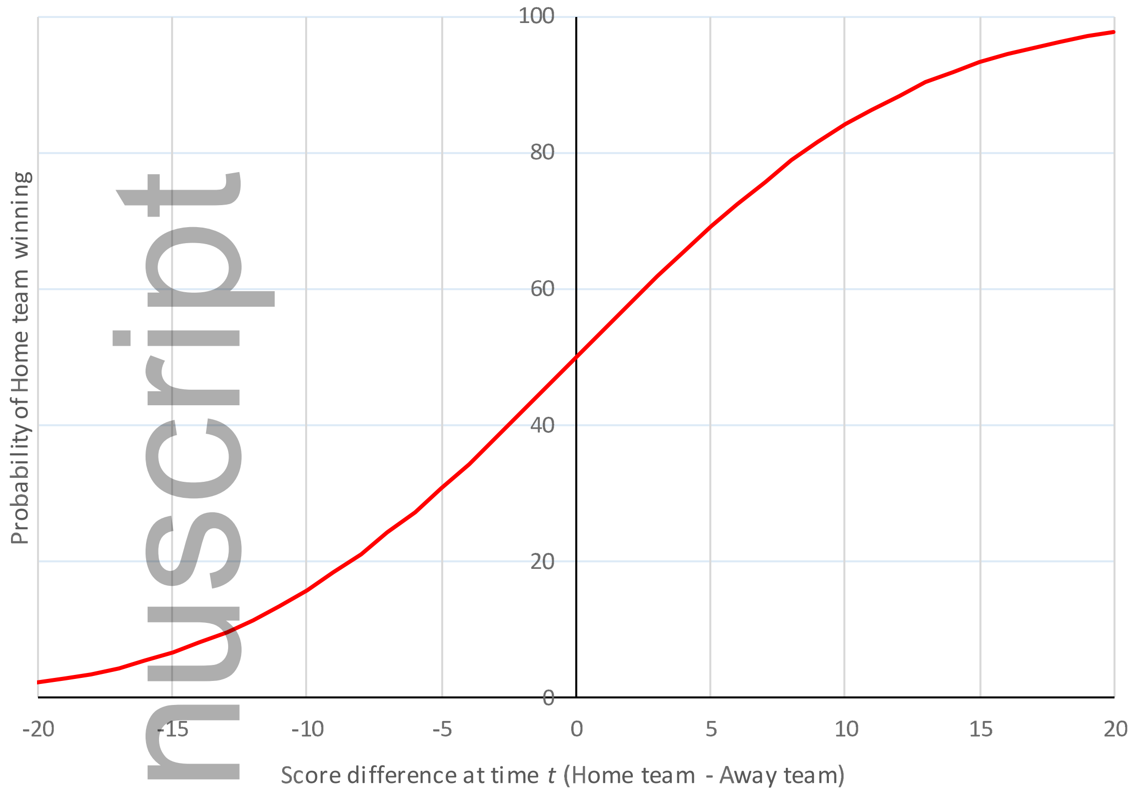

Figure 1: The expected relation between score difference a time t and winning percentage modelled as a digital call option. This figure uses the model provided in Equation 2, with the assumption that there is no drift in the score differential towards the home team.

In the empirical analysis below, we first examine the capacity of the digital call option to model expected winning percentages conditional on halftime score difference. We then compare observed and expected winning percentages across halftime score differences.

3. Empirical examination of the relation between halftime score differential and winning percentage

Data for 68,380 NBA basketball games were obtained from the initial NBA season in 1946 / 1947 to the 2018 / 2019 season inclusive. These data were obtained from www.basketball-reference.com, www.espn.com, and www.nba.com.

These data included the date of each game, team identifiers, and indicator of the home team, and the scores at quarter time, halftime, three quarter time, and the final scores. NBA games are divided into 12-minute quarters, with a 15-minute break at halftime and overtime periods if the game ends in a tie.

Betting market odds for 15,511 NBA games from the 2007 / 2008 season to the 2018 / 2019 season were also obtained from www.sportsbookreviewsonline.com. Data for 69,212 National Collegiate Athletic Association (NCAA) basketball games were also collected. These data were obtained from the 2007 / 2008 season to the 2018 / 2019 season from www.espn.com and www.sportsbookreviewsonline.com. NCAA games are divided into 20-minute halves but like NBA have a 15-minute break at halftime.

Descriptive statistics for NBA games are provided in the first six columns of Table 1.

Table 1: NBA Results

Score difference at halftime (home team less away team)	Number of games	Percentage of games won by home team	Average change in score differential in the second half	Median change in score differential in the second half	Standard deviation of the change in the score differential in the second half	Expected percentage of games won by home team
-20	197	4.57	4.52	5	9.49	5.84
-19	286	8.39	3.50	4	11.20	6.82
-18	345	6.96	3.83	4	9.52	8.18
-17	412	7.52	3.50	3.5	9.41	9.34
-16	466	12.23	3.96	4	10.23	10.76
-15	566	12.90	3.53	4	10.32	12.46
-14	741	14.04	3.33	4	9.99	14.45
-13	802	18.08	3.78	4	10.20	16.39
-12	950	22.32	3.93	4	10.03	18.73**
-11	1130	21.86	3.59	3	9.58	21.61
-10	1257	26.01	3.30	3	10.12	24.48
-9	1360	28.09	3.15	2	9.76	27.32
-8	1589	31.78	3.08	3	9.71	30.27
-7	1769	33.30	2.74	2	9.68	33.53
-6	1980	38.99	2.77	3	9.78	36.83*
-5	2055	40.83	2.49	2	9.64	40.15
-4	2230	46.05	2.75	2	9.81	43.52**

-3	2404	49.17	2.44	2	9.94	47.06*
-2	2619	53.42	2.52	4	9.65	50.34**
-1	2674	56.47	2.58	3	9.41	53.66**
0	2872	55.92	1.75	2	9.80	57.20
1	2746	60.56	1.40	2	9.66	60.63
2	2858	64.21	1.40	2	9.42	63.91
3	2775	68.25	1.27	2	9.80	67.10
4	2777	69.93	0.95	2	9.75	70.16
5	2636	72.95	0.80	1	9.74	73.02
6	2659	77.02	0.88	1	9.69	75.68
7	2430	78.89	0.54	1	9.56	78.24
8	2236	81.22	-0.11	0	9.65	80.75
9	2207	83.60	0.17	0	9.66	82.88
10	2056	85.31	0.14	0	9.79	84.75
11	1913	87.98	0.02	0	9.80	86.81
12	1587	88.91	0.04	0	9.77	88.49
13	1542	90.60	-0.42	-1	9.72	90.09
14	1287	90.91	-0.66	-1	9.95	91.47
15	1217	93.10	-0.79	-1	10.07	92.63
16	954	92.98	-0.81	-1	10.38	93.80
17	887	95.72	-1.05	-1	9.78	94.75
18	772	95.47	-0.95	-1	10.04	95.56
19	621	96.30	-0.76	-1	10.30	96.31
20	517	96.52	-1.94	-2	10.14	96.90

Table 1: Table 1 provides the observed percentage of games won by the home team and the expected percentage of games won estimated using the digital option pricing model described in Equation 2. ** (*) denotes that the observed percentage of games won by the home team was significantly greater than expected at the 0.01 (0.05) level using the two-tailed binomial test.

Of the 68,380 games, 2,999 were excluded from those reported in Table 1 because the absolute score difference at halftime was greater than 20 points. These observations were excluded due to small sample sizes for individual halftime score differences in those ranges. For halftime score differences from -11 to +15 points, the percentage of games won by the home team increases monotonically, with the exception of the score difference changing from

-1 to scores tied at halftime. Here the percentage of games won falls from 56.47% to 55.92%, a result that is consistent with the finding of Berger and Pope.

The range of the standard deviations of the second half score differential conditional on the halftime score difference is only from 9.41 to 10.38 points for halftime score differences from -18 to +20, and there is no obvious relation between score differences and these standard deviations. As documented by Goldman and Rao (2013) and others, teams have an incentive to increase (decrease) the riskiness or range of outcomes when they are behind (ahead). However, there is no evidence of risk-shifting with respect to teams' position at halftime.

There is a marked drift in the second half score differential towards the home team. This is evidenced by a mean (median) drift towards the home team of 1.75 (2) points where the scores are tied at halftime, with the home team winning 55.92% of these matches. The drift also varies across score differences at halftime, with a drift of the order of 3 to 4 points where the score difference is greater than -10 points at halftime, to between 2 and 3 points where the home team is trailing by less than 10 points at halftime. There is a drift away from the home team when the home team is leading by more than of the order of 13 points at halftime.

To estimate the value of the digital call option and therefore the expected winning percentage for each halftime score difference across the range from the home team being 20 points behind to 20 points ahead, it is necessary to estimate the expected standard deviation of the second half score differential ($\sigma . \sqrt{\tau}$ where $\tau = 0.5$), and the expected drift in the second half score differential towards the home team for each of those score differences ($df.\tau$, where $\tau = 0.5$).

The expected standard deviation of the second half score differential, for each halftime score, was calculated as the average of the observed standard deviations of the second half score differentials for those games where the halftime score was between plus or minus 10 points of the halftime score of those games for which the estimate was being obtained. The games for which the expected standard deviation of the second half time score were being calculated were omitted. For example, the expected standard deviation of the second half score differential for games tied at halftime was calculated as the average of the standard deviations of those games where the halftime score differential was between minus 10 and plus 10 points, with the standard deviation of the second half score differential for games tied at halftime omitted.

The expected drift in the second half score differential towards the home team for each score difference was calculated using the same approach.

The results are provided in the final column of Table 1 and in Figure 2.

Figure 2

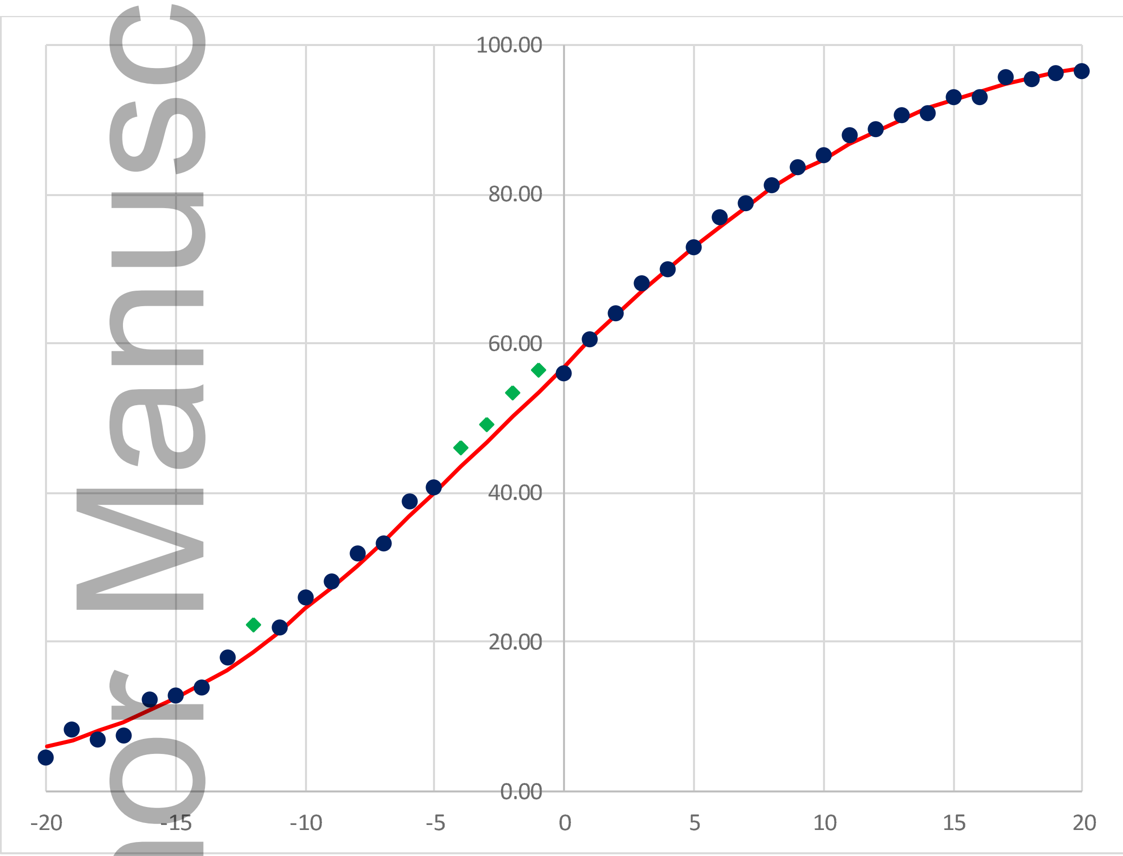

Figure 2: The observed and expected relation between halftime score difference and percentage of games won by the home team. The raw observed data are presented with dots and diamonds. For those observed data presented as diamonds, the observed percentage of games won by the home team was significantly greater than expected at the 0.05 level under the two-tailed binomial test. The line represents the expected percentages of games won as estimated using the digital option pricing model described in Equation 2.

The apparent similarity of the line in Figure 2 with that in Figure 1 suggests that at a descriptive level a sigmoidal function as represented by a digital call option may usefully represent the expected relation. Table 2 and Figure 2 also show that, in contrast to Berger and Pope who find that home teams win significantly more games than expected when behind by 1 point at halftime, these teams win significantly more games than expected when behind by between 4 points and 1 point.

A starker difference in our results to those of Berger and Pope is that their results pertain equally to home and away teams. Given the implementation of the regression discontinuity design, had they chosen to analyse away teams, they would have found simply a mirror image of the results they presented. For example, they found that away teams behind by a point were more likely to win than their opponents (42.9% versus 41.8%), (see page 820). While our results are also presented in terms of the home teams, we measure the expected likelihood of winning in a call-option setting that allows for a drift in scores and show that as home teams do not lose more games than expected when ahead at halftime, necessarily away teams do not win more games than expected when behind at halftime. This finding suggests that loss aversion is apparent when teams are playing in front of a home crowd.

Sensitivity analysis was performed by estimating the expected winning percentage using the option pricing model described in Equation 2 using games where the halftime score was between plus or minus, from 3 to 10 points, of the halftime score of those games for which the estimate was being obtained. Further, sensitivity analysis was performed where those games with score differentials closest to the halftime score of those games for which the estimate was being obtained were also omitted. These sensitivity analyses had virtually no impact on the results.[2]

Table 2 presents an analysis of those games played for the period examined by Berger and Pope, namely from the 1993 / 1994 season to March 1, 2009.

Table 2: 1993 / 1994 Season to March 1, 2009

[2] As noted, we also collected quarter time and three quarter time scores for all NBA games. We repeated the analysis using quarter time and three quarter time score. The winning percentages again appeared to follow those predicted using a digital call option framework, but no abnormalities in terms of observed and expected winning percentages conditional on quarter or three quarter time scores were found.

Score difference at halftime (home team less away team)	Number of games	Percentage of games won by home team	Average change in score differential in the second half	Standard deviation of the change in the score differential in the second half	Expected percentage of games won by the home team
-20	65	6.15	4.49	9.67	5.27
-19	93	7.53	3.04	11.09	6.31
-18	111	9.01	3.77	9.80	7.67
-17	107	8.41	4.43	8.40	8.80
-16	125	7.20	2.56	8.39	10.72
-15	172	12.79	3.45	10.19	12.05
-14	218	16.06	3.27	10.41	13.32
-13	230	17.39	3.67	10.57	15.68
-12	262	28.24	4.85	10.74	17.51**
-11	347	20.17	3.21	9.74	20.92
-10	391	26.85	3.39	10.06	23.78
-9	402	23.63	2.47	9.47	26.68
-8	471	32.27	3.22	9.54	29.57
-7	556	32.01	2.50	9.57	32.80
-6	557	35.91	2.33	9.42	35.90
-5	610	39.02	2.08	9.27	39.60
-4	636	43.87	2.31	9.79	43.01
-3	660	48.48	2.21	9.97	46.48
-2	720	53.61	2.71	9.64	49.61*
-1	757	57.73	2.46	9.41	52.72**
0	767	56.06	1.90	9.83	56.36
1	796	56.41	0.99	9.57	59.76
2	780	61.92	1.47	9.41	63.22
3	769	65.67	0.78	9.81	66.49
4	820	65.61	-0.01	9.89	69.79##
5	719	71.35	0.91	9.85	72.63
6	743	77.79	1.08	9.65	75.25
7	680	77.65	0.47	9.42	78.02
8	584	77.57	-0.50	9.92	80.59
9	585	82.39	-0.35	9.55	82.89
10	581	85.03	0.41	9.87	84.71
11	518	85.14	-0.72	9.94	87.05
12	432	90.97	0.53	9.47	88.68

13	422	91.00	-0.66	9.48	90.38
14	362	92.82	-0.73	9.05	91.52
15	338	93.79	-0.23	10.18	92.89
16	261	90.80	-1.25	10.40	94.02
17	264	95.83	-0.66	9.63	94.96
18	231	93.94	-1.16	10.60	95.93
19	183	98.36	0.75	10.29	96.80
20	149	97.32	-2.05	9.88	97.01

Table 2: Table 2 provides the observed and expected percentage of games won by the home team for the period from the 1993 / 1994 season to March 1, 2009. ** (*) denotes that the observed percentage of games won by the home team was significantly greater than expected at the 0.01 (0.05) level using the two-tailed binomial test. ## denotes that the observed percentage of games won by the home team was significantly less than expected at the 0.01 level using the two-tailed binomial test.

Over this period, our sample comprised 19,281 games while the Berger and Pope sample comprised 18,060 games. Of the 19,281 games, 807 were excluded because the absolute score difference at halftime was greater than 20 points. The percentage of games won by the home team reported in the second column are virtually identical to those reported by Berger and Pope. Like Berger and Pope, we find that home teams win more games than expected when one point behind, but we also find that this result pertains to situations where the home team is two points behind. Further, while the observed percentage of away (home) teams winning when they are one point behind (ahead) appears to be similar to that reported by Berger and Pope, this percentage is not abnormal when assessed using the digital call option framework. Again, in our analysis it is only home teams that appear to display superior performance when behind at halftime.

Table 3 presents an analysis for those NBA games played for which we have betting market odds, namely those games from the 2007 / 2008 season to the 2018 / 2019. The pre-game money line odds provided by sportsbookreviewsonline.com were used to categorize teams as favourites or underdogs.

Table 3: 2007/2008 to 2018/2019 season

Score difference at halftime	Number of games (using home team score less away team score to compute score difference at halftime)	% of games won by home team	Average change in score difference in the second half	Standard deviation of the change in the score differential in the second half	Expected % of games won by the home team	Number of games (using favourite team score less underdog team score to compute score difference at halftime)	% of games won by favourite	Average change in score difference in the second half	Standard deviation of the change in the score differential in the second half	Expected % of games won by favourite
-20	50	8.00	4.34	9.81	5.80	32	18.75	8.50	13.21	10.27
-19	100	8.00	3.28	12.01	7.06	47	19.15	5.95	13.49	11.91
-18	103	5.83	3.16	9.91	8.54	75	12.00	5.21	11.04	14.09
-17	115	10.43	4.95	9.20	9.99	74	20.27	8.16	9.64	15.64
-16	117	15.38	3.27	10.91	11.52	82	28.05	7.65	10.67	18.4 *
-15	145	18.62	3.95	11.58	12.98	104	19.23	6.19	10.88	21.12
-14	204	15.20	3.05	10.68	15.53 *	146	27.40	6.96	9.92	23.32
-13	227	17.18	3.69	10.01	17.27	180	22.78	5.49	9.73	25.30
-12	261	19.54	3.40	10.11	19.71	195	26.67	5.79	10.51	27.97
-11	269	24.54	3.45	9.96	22.20	239	33.47	5.38	10.31	30.76
-10	297	23.57	2.55	10.33	24.89	222	29.28	4.21	10.72	33.37
-9	340	28.82	2.98	10.42	27.49	280	36.79	5.47	9.90	35.41
-8	396	28.28	2.41	10.05	30.41	342	39.47	5.51	9.81	38.24
-7	391	37.85	3.34	9.79	33.39	326	48.47	5.64	9.47	41.37 **
-6	470	37.23	2.82	10.17	36.39	423	47.04	5.29	9.99	44.11
-5	461	41.65	2.51	10.19	39.60	415	51.81	4.65	9.95	47.03 *
-4	475	46.95	2.79	10.18	42.66	475	53.68	4.10	10.19	50.33
-3	558	50.00	2.64	9.61	46.06	534	58.05	4.20	9.89	53.22 *
-2	589	53.82	2.59	9.72	49.34 *	561	61.85	4.34	9.23	56.50 **
-1	578	55.02	1.70	9.48	52.88	564	60.99	3.25	9.57	59.87
0	626	55.27	1.32	10.32	56.26	626	62.46	3.17	9.91	62.94
1	594	59.60	0.97	10.06	59.60	598	64.88	2.37	9.40	66.22
2	601	61.73	1.02	9.93	62.73	620	68.87	2.51	9.51	68.97
3	588	63.78	0.67	10.49	66.06	601	69.88	1.84	9.61	71.76
4	588	67.69	0.74	10.00	68.81	576	73.44	1.85	9.51	74.25

5	545	71.38	0.40	10.08	71.62	586	77.82	1.70	9.60	76.56
6	547	72.58	0.40	10.51	74.46	584	79.45	2.03	9.68	79.04
7	513	78.75	0.35	9.30	76.75	567	82.72	1.19	8.86	81.27
8	516	81.01	0.20	10.07	79.17	562	87.01	1.90	9.31	83.30 *
9	464	83.62	0.40	9.91	81.06	516	86.24	1.32	9.70	85.05
10	458	85.59	0.07	9.99	82.99	527	87.10	0.52	9.56	86.90
11	437	85.35	-0.71	9.89	85.02	462	89.61	0.12	9.30	88.52
12	331	87.31	-0.49	10.65	86.92	393	89.82	0.27	9.95	90.07
13	343	90.96	-0.71	9.05	88.47	384	92.97	-0.15	8.97	91.31
14	275	88.73	-0.88	10.35	90.37	327	93.58	0.50	9.95	92.62
15	239	92.05	-1.48	9.90	91.67	275	91.27	-0.79	10.12	93.86
16	206	93.20	-0.29	10.64	92.95	237	96.62	0.96	9.94	94.65
17	186	94.09	-1.87	10.13	94.15	224	96.43	-1.31	9.43	95.44
18	181	94.48	-1.35	10.10	94.96	207	96.62	-0.92	9.44	96.11
19	160	91.88	-2.13	11.25	95.81 #	211	94.79	-1.31	10.69	96.62
20	107	95.33	-2.39	11.01	96.52	124	97.58	-1.52	9.43	97.15

Table 3: Table 3 provides the observed and expected percentage of games won using two different classifications of teams for the period from the 2007 / 2008 season to the 2018 / 2019 season. The first method of classification is captured in columns two to five and reflects the home and away team identification utilised earlier in the paper. The second classification scheme employs betting odds to classify teams as "favourite" or "underdog" and is employed in columns six to eleven. ** (*) denotes that the observed percentage of games won by the home (favourite) team was significantly greater than expected at the 0.01 (0.05) level using the two-tailed binomial test. # denotes that the observed percentage of games won by the home (favourite) team was significantly less than expected at the 0.05 level using the two-tailed binomial test.

Columns two to five present the results where teams are categorized as home or way teams. Of the 15,511 games, 860 were excluded because the absolute score difference at halftime was greater than 20 points. While the result in these columns are broadly similar to those is Tables 1 and 2, for those games that are close as halftime it is only for those situations where the home team is two points behind that they win significantly more games than expected. This result may be due to the reduced sample size.

However, columns six to ten present the result on this same sub-sample of games where teams are categorized as favourite or underdog. In this case, of the 15,511 games, 130 were excluded because the money line odds for the teams were equal, and 858 were excluded because the absolute score difference at halftime was greater than 20 points. Despite the smaller sample size using only the period 2007 / 2008 to 2018 / 2019, favourite teams win significantly more games than expected when behind by 7, 5, 3 and 2 points. The evidence consistent with loss aversion would appear to be stronger when teams are categorized based on favourite / underdog status rather than based on being the home or away team[3].[4]

In order to examine whether any abnormalities in performance related only to NBA games or whether they also pertained to NCAA games, we repeated the analysis using the 69,212 NCAA games played from the 2007 / 2008 season to the 2018 / 2019 season. The results are reported in Table 4.

Table 4: NCAA Results

Score difference at halftime (home team less away team)	Number of games	Percentage of games won by home team	Average change in score differential in the second half	Standard deviation of the change in the score differential in the second half	Expected percentage of games won by the home team
-20	184	4.89	1.60	11.54	3.06
-19	226	5.75	1.14	9.99	3.87
-18	276	3.62	1.31	9.88	4.50
-17	325	5.85	1.34	10.30	5.55
-16	420	6.67	1.16	9.39	7.04
-15	455	10.33	2.74	9.34	8.78

[3] There is a strong positive correlation between home teams and favouritism, with home teams being the favourite in 10,472, or over 67 per cent, of the 15,511 games. We also undertook the analysis reported in Table 3 using the reduced sample of these 10472 games. The results were broadly consistent with those reported in Table 3, although, as expected given the reduced sample size, the significance of the results was reduced.

[4] While the categorisation of home and away teams is dichotomous, it is possible to categorise teams by their degree of favouritism. We undertook sensitivity analysis by excluding games where there were no strong favourite. This analysis reduced the sample size but resulted in similar results to those reported in the table.

-14	588	11.39	2.06	9.93	10.57
-13	664	15.36	3.28	9.35	12.84
-12	781	18.95	2.99	9.94	15.34**
-11	955	16.02	2.00	9.36	18.29
-10	1086	21.64	2.50	9.63	21.02
-9	1258	25.83	2.72	9.66	23.99
-8	1476	29.47	2.78	9.31	27.51
-7	1606	33.06	2.70	9.48	31.34
-6	1736	37.44	2.78	9.29	35.26
-5	1875	38.56	2.37	9.18	39.54
-4	2160	44.54	2.44	9.17	43.57
-3	2118	49.06	2.38	9.46	47.86
-2	2371	52.00	2.45	9.44	51.97
-1	2528	55.85	2.21	9.18	56.20
0	2636	61.46	2.42	9.31	60.51
1	2715	64.90	2.42	9.41	64.59
2	2618	65.66	2.12	9.42	68.56$^{\#\#}$
3	2679	73.76	2.70	9.36	72.10
4	2697	74.05	2.15	9.40	75.68
5	2628	77.28	2.00	9.60	78.91$^{\#}$
6	2563	81.27	2.35	9.55	81.77
7	2530	84.86	2.50	9.46	84.41
8	2309	87.74	2.80	9.60	86.80
9	2302	89.75	2.91	9.83	88.99
10	2130	91.46	3.18	9.81	90.76
11	1920	93.13	2.88	9.73	92.35
12	1756	93.85	3.29	10.08	93.73
13	1634	94.92	3.20	10.00	94.83
14	1565	96.29	3.78	10.49	95.89
15	1423	97.96	3.69	10.13	96.71**
16	1296	97.76	3.77	10.49	97.48
17	1150	99.05	4.41	10.60	98.05**
18	929	98.71	4.81	10.95	98.52

19	876	99.54	5.51	10.94	98.85**
20	748	99.47	5.33	11.50	99.11

Table 4: Table 4 provides the observed and expected percentage of games won by the home team for NCAA games. ** denotes that the observed percentage of games won by the home team was significantly greater than expected at the 0.01 level using the two-tailed binomial test. ## (#) denotes that the observed percentage of games won by the home team was significantly less than expected at the 0.01 (0.05) level using the two-tailed binomial test.

Of the 69,212 games, 5,005 were excluded from those reported in Table 4 because the absolute score difference at halftime was greater than 20 points. For halftime score differences from -11 to +15 points, the percentage of games won by the home team increases monotonically.

The range of the standard deviations of the second half score differential conditional on the halftime score difference is only from 9.17 to 10.08 points for halftime score differences from -16 to +13, and there is no obvious relation between score differences and these standard deviations. There is again no evidence of risk shifting.

As for the NBA games, there is a marked drift in NCAA games in the second half score differential towards the home team. There is a mean drift towards the home team of 2.42 points where the scores are tied at halftime, with the home team winning 61.46% of these matches. The drift also varies across score differences at halftime, although unlike for NBA games the drift appears to increase as the relative position of the home team as halftime improves. The drift is less than 2 points where the score difference is greater than -15 points at halftime, between 2 and 3 points where the halftime score difference is between -15 and 9 points, and more than 3 points where the home team is leading by more than 12 points at halftime.

As to the key finding from Table 4, while for some halftime score differentials the observed percentage of games won by the home team was significantly greater than expected, for other halftime score differentials the observed percentage of games won by the home team was less than expected. There is no apparent underlying relation suggested by these results.

Taken in aggregate, our result suggests that professional basketball teams, namely those in the NBA rather than the NCAA, may win more games than expected when they are behind at halftime by of the order of 1 to 4 points. The argument of Berger and Pope may be used to suggest that, consistent with the work of Heath, Larrick and Wu (1999), Kahneman and Tversky (1979), Kivetz, Urminsky and Zheng (2006), and Tversky and Kahneman (1992), teams in this position may try harder and that their efforts are rewarded. However, our result suggests that it is only for home (favourite) teams that this effort is rewarded; the result does not pertain to away (underdog) teams.

4. Summary

Studies across a range of domains have found that loss aversion increases as stake increases. Berger and Pope (2011) show that for both home and away US professional basketball teams, being behind by one point at halftime leads to a discontinuous increase in winning percentage. Using a sample that is more than three times the size of that used by Berger and Pope, and employing an option-pricing approach that allows for a differential drift in outcomes for teams we find evidence of better than expected performance for NBA home teams that are behind by up to four points, but not for away teams. Evidence consistent with loss aversion is also found for NBA teams that are classified by betting markets as favourites but not for those teams that are underdogs. We find no evidence of this effect with respect to NCAA – whether home or away. Our results suggest that loss aversion is apparent when stakes are high.

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