Serial Correlation in the Wagering Market for Professional Basketball

Dale R. Oorlog
Central Missouri State University

New evidence is presented on pricing efficiency in the market for wagering on sporting events. Data from the National Basketball Association for 1989-1990 and 1990-1991 strongly support the notion of a weak-form efficient point spread market for sports gamblers. Teams' performances against the point spread show no autocorrelation; previous outcomes are shown to bear no relationship to subsequent results. In addition, simple betting strategies based on the identity of the teams, location of the game, and size of the point spread are unlikely to be profitable. The point spread is unbiased with respect to these factors as a predictor of the actual result.

INTRODUCTION

Debate continues over the validity of the efficient market hypothesis (EMH), which holds that security prices fully reflect all available information at any given time. Fama (1970) has categorized market efficiency into three levels in which the definition of information varies:

- The weak form, which deals with the information contained in previous prices or price trends;
- The semi-strong form, which broadens the definition to include all publicly available information; and
- The strong form, which broadens the definition to include even privately held information.

Exhaustive tests have been conducted to determine the level of efficiency of large financial markets. This paper shifts the focus of the debate to a smaller speculative market—sports gambling—where new, more definitive evidence is available that suggests that this more thinly traded market achieves a high degree of weak form efficiency.

If the EMH is true, no systematic trading strategy will result in significantly abnormal returns. At the weak level this refers to strategies based on previous prices or price trends. By analogy to the sports gambling market, the fact that a team is successful in its last game (after adjusting for the handicapping of the point spread) should provide no information on its expected success in the next game.

This paper conducts primarily weak form tests on the National Basketball Association (NBA) for the 1989-1990 and 1990-1991 seasons. Previous research in this field has dealt with semi-strong form tests of contests of the National Football League. The length of the NBA season (82 games versus 16 in the NFL) affords the opportunity to conduct more powerful tests of the market's ability to accurately adjust point spreads for a team from game to game throughout a season. The results indicate that this adjustment is highly accurate, so that betting strategies based on previous performances fail to provide abnormal returns after transaction costs.

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POINT-SPREAD GAMBLING

Professional bookmakers offer the opportunity for speculators to wager on the outcome of games in the NBA.[1] Betting is facilitated by establishing a point spread between the two competing teams: the less favored (underdog) team has a predetermined number of points added to its actual score. For example, if Orlando is a six point underdog against Milwaukee, the Orlando team will have six points added to its final score for the purpose of determining which team covers (wins the bet). In case of a push (a tie after adjusting for the spread), all money is returned to the bettors.

In Nevada winning bettors receive $10 for every $11 wagered, i.e., an $11 winning bet returns $21. Therefore, if $11 are wagered on each team, the bookmaker collects a total of $22 and pays $21 to the winner, leaving an instantaneous risk-free profit of $1 (the vigorish). The purpose of the point spread is to equalize the betting support for the two teams. If the market is imbalanced, the point spread must be adjusted (for example, by giving Orlando another point to induce more speculators to take their side). The point spread, therefore, represents the betting public's opinion on the probable outcome of the game, not the bookmakers'.[2]

Seen in this light, the point spread on a sporting event corresponds to the price of each team in the market. The bookmaker functions as a market maker, matching customer orders and adjusting prices to bring the market into balance (and earning a fee for his or her services). Speculators in this market analyze the participants exhaustively, searching for new information and market-beating systems.[3]

Persons unfamiliar with bookmaking may assume that the market is not as efficient as the stock market, given that markets are driven to efficiency by the depth of trading volume and analysis. For example, common stock trading in the U.S. currently averages between $3 trillion and $4 trillion a year, while sports wagering is estimated to be only about $100 billion a year (Cook 1992). In addition, the underground nature of most sports gambling means that the market is unregulated and not freely accessible, while information on the participants is not as readily disseminated.

PREVIOUS LITERATURE, DATA, AND METHODOLOGY

Previous papers investigating the point-spread gambling market have focused on measuring the ability of simple betting rules to generate returns significantly different from 50 percent and/or whether the point spread is an unbiased predictor of actual results. Dare and MacDonald (1991), Gandar *et al.* (1988), and Zuber *et al.* (1985) support the

[1] In the United States, such gambling is legal only in Nevada and a few other locations, but a thriving illegal gambling industry also exists.

[2] The bookmaker may take a position on the outcome of the game, if desired, by not balancing the action on each team. And if there is an imbalance, it may lie in the direction of either the favored or underdog team. Therefore, a common misstatement among sportscasters following major upsets to the effect of "the bookies really took a bath on that one!" has no basis in fact.

[3] If a strategy is *statistically* significant, it should result in a rate of success statistically different from 50 percent. This is distinct from being *economically* significant: because a winning bet results in a $10 profit for every $11 bet while a losing bet results in an $11 loss, the break-even win percentage, p, is found by solving for $10p - 11(1-p) = 0$. A gambler must be successful $p = .524$ of the time to break even after transaction costs.

efficient market hypothesis, while Golec and Tamarkin (1991), Lacy (1990), and Amoako-Adu, Marmer, and Yagil (1985) find mixed evidence of small inefficiencies over limited time periods.[4] All of these papers study the National Football League over one or more years in the 1980s; Dobra *et al.* (1990) find similar results for the basketball wagering market.

The tests used in these papers are performed from the viewpoint of only one team playing in each game of the sample (otherwise, the mispricings would cancel and any evidence of inefficiency would be lost). For the selected teams the tests involve either a regression between the results of a set of games and the corresponding point spreads or a binomial test of whether the teams win their bets at a rate statistically different from 50 percent. This methodology requires a selection rule for which team to study in a given contest. Most previous studies have based their selection rule on the teams' status as a home team versus a visitor or a favorite versus an underdog. Other studies have used more complex selection rules based on offensive and defensive statistics, grass versus artificial turf playing surfaces, and so forth. These papers are in effect studies of investment strategies based on some subset of publicly available information (the information used to select the team). As a result, such tests can reach conclusions only on whether the market is semi-strong form efficient with respect to those particular items of information.

In addition, these papers only test whether the point spread is accurate, on average, by the end of the season; they do not measure whether the point spread is an accurate pricing mechanism from game to game during the season. As a hypothetical example, suppose that Atlanta falls five points short of covering the spread in every game for the first half of the season, but then beats the spread by five points in every game during the second half of the season. The team would have a winning percentage of exactly 50 percent against the spread, and a regression between the point spread and results may show the two types of pricing errors canceling each other, obscuring any evidence of mispricing. The regression errors, however, would display strong serial correlation. Thus, only by testing for serial correlation could it be determined that the team was mispriced systematically. In an efficient market, prices adjust to fair levels at any moment, rather than merely averaging to fair levels by the end of a given time period. To support the hypothesis of an efficient gambling market, it also must be shown that residuals from expectations show no serial correlation.[5]

Camerer (1989) attempts to show that this is the case by testing a limited betting rule based on streaks against the point spread: for each game, identify the team with the larger number of previous consecutive identical outcomes against the spread and bet on their ability to repeat that outcome in the current game. Such a rule is not found to be profitable. Dobra *et al.* (1990) do conduct a single test for serial correlation in the basketball wagering market but make methodological errors. (See footnote 8.)

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[4] The Amoako-Adu (1985) result may be due to their use of the point spread as the dependent rather than independent variable, while they examine the outcome only from the viewpoint of the favored team. The point spread for such teams has a lower bound of zero, violating the OLS assumption of normally distributed dependent variables.

[5] A stronger statement would require that the residuals follow a random walk, in which the residuals are not only independent but identically distributed (constant mean and variance).

Data on the point spread and identity of the home team for each game in this study for the 1989-1990 and 1990-1991 NBA seasons are taken from the Sports Feature Syndicate in the Kansas City *Star*.[6] Tests of market efficiency are grouped into three categories. The first tests are for serial correlation in each team's performance against the point spread. The residual from the point spread is measured from the equation:

(1) $A_{ij} = PS_{ij} + \varepsilon_{ij}$

where:

A_{ij} = The actual result of game i (team j's score minus their opponent's score);
PS_{ij} = The number of points by which team j is predicted to win game i (< 0 if j is an underdog); and
ε_{ij} = The residual (= A_{ij} - PS_{ij}).

The null hypothesis is that for each team, ε displays no autocorrelation; that is, successive results against the spread are independent. This hypothesis is tested in three ways: first, the Durbin-Watson test statistic for autocorrelation is calculated for the above residuals. Second, an autoregressive estimation is performed in which the value of the correlation coefficient among the residuals (ρ) is estimated through the Cochrane-Orcutt iterative procedure. The null hypothesis is that ρ is insignificantly different from zero. Third, a runs test is performed on the signs of the residuals. The null hypothesis is that the number of runs (a sequence of consecutive positive or negative residuals) observed is insignificantly different from the number of runs that would occur if the residuals were sequenced randomly.

The economic interpretation of failing to reject the null hypotheses of these tests is that betting strategies based on previous outcomes would not provide abnormal returns. For example, the number of runs constitutes the number of times a bettor would succeed by betting against a team to repeat its most recent performance against the spread. Of n games, there would have to be significantly more than .524n runs or fewer than .476n runs for any strategy based on previous results to provide a positive return after transaction costs.

The second and third categories of tests repeat the binomial and regression experiments of previous papers, both to provide a more complete assessment of market efficiency and to apply the methodology to a new data set. Use of (the normal approximation to) the binomial distribution permits measurement of the probability of any observed deviation occurring even under the null hypothesis that the true success rate is .500. (An even stronger test would require that the success of any strategy be statistically greater than .524, the success rate needed to cover transaction costs.) The test is performed on each individual team for each season, as well as on subsets of teams as defined by various betting strategies.

[6] Note that the line is published on the morning of the game; it does not reflect any last minute market adjustments before the game begins. Such adjustments are infrequent, however, and rarely amount to more than a point. The wager-winning team is virtually never altered in such a case.

Alternatively, the regression test measures whether the point spread is an unbiased predictor of the actual result. This is estimated by running the simple linear regression:

(2) $A_{ij} = \alpha + \beta(PS_{ij}) + \varepsilon_{ij}$

where:

A_{ij} = The actual result for team j in game i (team j's score minus their opponent's);
α = An intercept (constant);
β = The coefficient on the independent variable;
PS_{ij} = The point spread for team j in game i (< 0 if team j is an underdog); and
ε_{ij} = Error term (residual).

If expectations are unbiased with respect to the information used to select team j, the intercept in (2) should equal zero, and β should equal one, so that on average, the actual result equals the point spread.[7] An intercept passing through the origin implies no overall mispricing, while a slope of one means that the team is priced fairly at all of the various point spreads it faces during the season.[8]

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[7] Note that team j can be identified by any method: home team, favorite, or a team identified by any conceivable betting rule. Dare and MacDonald (1991) and Golec and Tamarkin (1991) argue that using the home team as team j could disguise the bias in their status as favorite or underdog, while using the favorite as team j could disguise the bias in their status as home team or visitor. Therefore, they attempt to respecify equation (2) to account for the home/visitor and favorite/underdog effects simultaneously (through the use of dummy variables). Dare and MacDonald use all favorites as team j in

$A_{ij} - PS_{ij} = \beta_1 D_1 + \beta_2 D_2 + \beta_3(PS_{ij} * D_1) + \beta_4(PS_{ij} * D_2)$,

while Golec and Tamarkin randomly select one team from each game in

$A_{ij} = a + \beta_1 PS_{ij} + \beta_2 D_3 + \beta_3 D_4$,

where:

D_1 = 1 if team j is a home favorite;
D_2 = 1 if team j is a visiting favorite;
D_3 = 1 if team j is a home team; and
D_4 = 1 if team j is a favorite.

The aggregate results in Tables 5 and 6 reflect an alternative approach: simply running separate regressions for home teams, favorites, home favorites, and home underdogs. The Dare and MacDonald and Golec and Tamarkin specifications also are run and are reported in note 11.

[8] The binomial test only measures whether the number of residuals is equal on both sides of the line implied by equation (1). The regression test measures whether the sum of squared residuals is equal on both sides of the line.

Equation (1) is a restricted version of equation (2), in which the intercept is suppressed and beta is constrained to equal unity. Equation (1) is the proper specification in which to search for serial correlation: we are looking for patterns in residuals from the point spread itself, not from the empirical relationship between the point spread and the actual result. Dobra *et al.* (1990), however, use equation (2) to compute the Durbin-Watson statistic. They also divide the samples for each team into home games and away games, so that the residuals tested do not represent a continuous sequence of games over the course of a season.

RESULTS

The Durbin-Watson statistics, measuring the serial correlation of performances against the point spread for each of the 27 NBA teams, are listed in Table 1 for the 1989-1990 season and Table 2 for the 1990-1991 season. The test rejects autocorrelation at the 5 percent significance level for 51 of the 54 team-seasons. The strongest exception is the 1989-1990 Charlotte team, where autocorrelation is significant (and positive) at the 1 percent level. The D-W statistic for Charlotte indicates insignificantly negative autocorrelation in the next season, however. No team evidences significant autocorrelation persisting in both seasons.

Table 1—Autocorrelation Tests for Individual Teams, 1989-1990

Team	D-W Statistic	ρ	(t-ratio)	Runs	Z-score
Atlanta	1.6677	0.1106	(0.9891)	36	-1.0077
Boston	2.1432	-0.1153	(-1.0509)	49	1.5812
Charlotte	1.3381**	0.3105	(2.8481)**	25	-3.2182**
Chicago	2.2120	-0.1073	(-0.9710)	44	0.5723
Cleveland	1.8737	0.0566	(0.5068)	39	-0.4501
Dallas	2.0808	-0.0411	(-0.3726)	44	0.5889
Denver	2.1636	-0.0827	(-0.7425)	44	0.7729
Detroit	1.9860	0.0050	(0.0453)	39	-0.3345
Golden St.	1.6497	0.1590	(1.4584)	41	0.3403
Houston	2.0657	-0.0533	(-0.4806)	40	-0.3235
Indiana	1.9874	-0.0543	(-0.4896)	37	-1.0051
LA Clippers	2.0272	-0.0301	(-0.2674)	40	-0.1118
LA Lakers	1.8802	-0.0257	(-0.2285)	46	1.2603
Miami	2.1944	-0.1195	(-1.0898)	51	2.1683*
Milwaukee	2.0662	-0.0409	(-0.3662)	43	0.6002
Minnesota	1.7956	0.0975	(0.8764)	39	0.2498
New Jersey	1.8025	0.0622	(0.5606)	44	0.6794
New York	1.7720	0.1058	(0.9578)	42	0.2841
Orlando	2.0642	-0.0414	(-0.3685)	38	-0.3331
Philadelphia	2.0376	-0.0562	(-0.4999)	39	0.3150
Phoenix	1.9961	-0.0259	(-0.2286)	40	0.5004
Portland	1.8187	0.0272	(0.2387)	37	-0.1505
Sacramento	2.2113	-0.1087	(-0.9716)	49	1.9408
San Antonio	1.6419	0.1642	(1.4888)	37	-0.8544
Seattle	2.0549	-0.0300	(-0.2616)	38	-0.2310
Utah	2.0153	-0.0106	(-0.0958)	47	1.1663
Washington	1.7972	0.0772	(0.6970)	42	0.1244

* Significant at the 5 percent level
** Significant at the 1 percent level

The Z-score represents the deviation of observed runs from expected number of runs, in units of standard deviations

The results of the Cochrane-Orcutt iterative estimation of the correlation coefficients (ρ) among the residuals in an autoregressive estimation of equation (1) also are given in Tables 1 and 2 with the asymptotic t-ratios of the estimates. The results are identical to those of the previous test: for all teams except Charlotte in 1989-1990, and Boston and Miami in 1990-1991, ρ is insignificantly different from zero at the 5 percent level, indicating an absence of autocorrelation. For Charlotte 1989-1990, ρ is again significant and positive at the 1 percent level.

Table 2—Autocorrelation Tests for Individual Teams, 1990-1991

Team	D-W Statistic	ρ	(t-ratio)	Runs	Z-score
Atlanta	1.9516	0.0090	(0.0818)	40	-0.1364
Boston	1.4988*	0.2442	(2.2803)*	35	-1.4245
Charlotte	2.2118	-0.1061	(-0.9665)	41	0.1263
Chicago	1.7744	0.1058	(0.9632)	41	0.6288
Cleveland	2.0998	-0.0556	(-0.5043)	49	1.8003
Dallas	1.8911	0.0219	(-0.3345)	39	-0.3345
Denver	1.9054	0.0401	(0.7229)	44	0.7299
Detroit	2.0532	-0.0282	(-0.2553)	46	1.3643
Golden St.	2.1327	-0.0924	(-0.8400)	37	-0.8553
Houston	2.3312	-0.1733	(-1.5933)	52	2.2292*
Indiana	2.1265	-0.1029	(-0.9367)	48	1.3584
LA Clippers	1.8604	0.0690	(0.6261)	38	-0.5648
LA Lakers	1.7011	0.1419	(1.2978)	35	-1.2790
Miami	2.6582*	-0.3600	(-3.4940)**	50	2.0878*
Milwaukee	1.9658	-0.0161	(-0.1461)	37	-0.9953
Minnesota	1.7584	0.1031	(0.9390)	39	-0.4017
New Jersey	1.9101	0.0426	(0.3865)	43	0.4061
New York	2.1986	-0.0995	(-0.9056)	45	1.1284
Orlando	1.9894	0.0042	(0.0380)	43	0.6914
Philadelphia	1.9439	0.0157	(0.1421)	40	-0.3137
Phoenix	1.9875	-0.0204	(-0.1846)	43	0.2445
Portland	1.8799	0.0460	(0.4171)	31	-1.8246
Sacramento	2.0411	-0.0212	(-0.1921)	44	0.6994
San Antonio	1.7901	0.0811	(0.7371)	39	-0.4287
Seattle	1.7934	0.1022	(0.9302)	39	-0.3051
Utah	1.6166	0.1528	(1.4000)	39	-0.5578
Washington	2.1145	-0.0874	(-0.7943)	45	0.7962

* Significant at the 5 percent level
** Significant at the 1 percent level

The Z-score represents the deviation of observed runs from expected number of runs, in units of standard deviations

For the runs test, Tables 1 and 2 report the number of runs (sequences of positive or negative residuals in equation (1)) for each team, with a z-score measuring the deviation from the expected number of runs under the null hypothesis of no autocorrelation, in units of standard deviation. Again, Charlotte's 1989-1990 performance against the spread is highly positively autocorrelated at the 1 percent level: the 76 games in which they either covered or failed to cover resulted in just 25 runs; the odds of such an occurrence by random draw are less than 1 in 800. The Charlotte results indicate how autocorrelation could be used to earn abnormal profits: a gambler who could anticipate such an occurrence and simply bet on Charlotte to repeat its most recent performance against the spread in the next game would have lost the bet in only 25 of 76 games (six other games were pushes), giving a return of 28.1 percent for the season—significantly greater than the -4.5 percent random chance would predict.

In addition, the runs test supports autocorrelation for 1989-1990 Miami at the 5 percent level, although in this case the autocorrelation is negative—games in which Miami covered tended to be followed by games in which they did not, and vice versa. Betting against Miami to repeat its performance against the spread would have succeeded in 51 of

Table 3—Won-Lost Records Against the Spread (individual teams ranked by percentage), 1989-1990

Team	Cover	Push	Fail	Pct.	P-value
Minnesota	51	2	29	0.638	0.0183*
Philadelphia	50	3	29	0.633	0.0239*
Phoenix	48	4	30	0.615	0.0536
Portland	47	5	30	0.610	0.0676
Dallas	46	0	36	0.561	0.3202
Utah	44	0	38	0.537	0.5810
Charlotte	40	6	36	0.526	0.7309
Boston	43	0	39	0.524	0.7406
Chicago	42	1	39	0.519	0.8243
Houston	42	1	39	0.519	0.8243
Washington	42	1	39	0.519	0.8243
Cleveland	40	2	40	0.500	1.0000
Seattle	38	6	38	0.500	1.0000
Indiana	40	1	41	0.494	1.0000
LA Clippers	39	3	40	0.494	1.0000
Atlanta	38	3	41	0.481	0.8221
LA Lakers	38	3	41	0.481	0.8221
Sacramento	38	3	41	0.481	0.8221
San Antonio	37	2	43	0.463	0.5763
Denver	36	2	44	0.450	0.4339
New Jersey	36	1	45	0.444	0.3741
Miami	36	0	46	0.439	0.3202
Milwaukee	35	2	45	0.438	0.3142
New York	35	1	46	0.432	0.2663
Detroit	34	1	47	0.420	0.1820
Orlando	33	3	46	0.418	0.1766
Golden St.	31	0	51	0.378	0.0353*
Home Teams	518	28	561	0.480	0.2010
Favorites	528	28	527	0.500	1.0000
Home Favorites	394	21	426	0.480	0.2790
Home Underdogs	110	7	125	0.455	0.3611
Rule 1	275	15	264	0.510	0.6667
Rule 2	523	26	502	0.510	0.5322
Rule 3	281	14	252	0.527	0.2252
Rule 4	141	6	101	0.560	0.0675

* Significant at the 5 percent level

The P-value represents the random probability of the cover percentage having a deviation that large or larger from the hypothesized value of .500

Rule 1: Bet on teams that covered in their previous games, when playing teams that did not cover

Rule 2: Bet on teams with the better cover percentage for the season to date

Rule 3: In the second half of the season, bet on the team with the better cover percentage in the first half of the season

Rule 4: Bet on teams on the last game of a road trip

82 games, for a profit of 18.7 percent. Similarly, negative autocorrelation is found in the 1990-1991 season for Miami and Houston.

Overall, of 162 separate tests for serial correlation in teams' performances against the spread, the null hypothesis of no autocorrelation is supported 152 times. In only one case (the runs test for Miami) did evidence of autocorrelation persist for a team over both sea-

Table 4—Won-Lost Records Against the Spread (individual teams ranked by percentage), 1990-1991

Team	Cover	Push	Fail	Pct.	P-value
Chicago	47	4	31	0.603	0.0888
Portland	46	4	32	0.590	0.1405
Golden St.	46	1	35	0.568	0.2663
LA Lakers	45	2	35	0.563	0.3142
Orlando	44	3	35	0.557	0.3681
Seattle	42	3	37	0.532	0.6529
Boston	43	1	38	0.531	0.6569
Sacramento	42	2	38	0.525	0.7375
San Antonio	42	2	38	0.525	0.7375
Indiana	43	0	39	0.524	0.7406
Phoenix	43	0	39	0.524	0.7406
Milwaukee	42	1	39	0.519	0.8243
Houston	42	0	40	0.512	0.9121
Cleveland	40	2	40	0.500	1.0000
Utah	40	1	41	0.494	1.0000
LA Clippers	39	3	40	0.494	1.0000
Washington	39	1	42	0.481	0.8243
Charlotte	38	3	41	0.481	0.8221
Denver	37	2	43	0.463	0.5763
Miami	37	2	43	0.463	0.5763
Minnesota	37	2	43	0.463	0.5763
New Jersey	37	1	44	0.457	0.5051
Atlanta	36	2	44	0.450	0.4339
Philadelphia	36	0	46	0.439	0.3202
New York	34	2	46	0.425	0.2184
Dallas	34	1	47	0.420	0.1820
Detroit	33	1	48	0.407	0.1192
Home Teams	532	23	550	0.492	0.6053
Favorites	523	23	528	0.498	0.9018
Home Favorites	388	19	400	0.492	0.6952
Home Underdogs	127	4	134	0.487	0.7104
Rule 1	259	9	271	0.489	0.6328
Rule 2	557	23	527	0.514	0.3788
Rule 3	262	15	270	0.492	0.7615
Rule 4	135	5	131	0.508	0.9012

* Significant at the 5 percent level

The P-value represents the random probability of the cover percentage having a deviation that large or larger from the hypothesized value of .500

Rule 1: Bet on teams that covered in their previous games, when playing teams that did not cover

Rule 2: Bet on teams with the better cover percentage for the season to date

Rule 3: In the second half of the season, bet on the team with the better cover percentage in the first half of the season

Rule 4: Bet on teams on the last game of a road trip

sons tested. The evidence strongly supports the notion that there is no such thing as momentum against the spread; the wagering public accurately digests the information contained in previous outcomes in setting the new point spread. The pattern of previous outcomes does not allow the formation of profitable betting strategies. Attempting to form such a strategy is the gambling market's equivalent of technical analysis.

Each team's performance against the point spread is reported in Tables 3 and 4, along with the probability (as measured by the binomial distribution) that the observed deviation from .500 is due to chance. Only two of the teams in 1989-1990 had a record against the spread that was significantly (at 5 percent) better than .500: Minnesota (51-29) and Philadelphia (50-29); one team was significantly below .500: Golden State (31-51). Further investigation shows that Golden State's significance can be attributed to just a few points over the season: the team was 4-12 in close games (decided by three points or fewer against the spread).[9] In 1990-1991 no team deviated from .500 at a 5 percent significance level.

Tables 3 and 4 also report the aggregate results of a number of other simple betting strategies. A strategy of betting either for or against the home team fails to exceed a winning percentage of .500, either statistically or economically, in either season. On average, the market seems to assess the home court advantage accurately. Betting for or against the favored team also fails to generate profits. Further, betting for or against favorites playing at home and betting for or against underdogs playing at home result in winning percentages insignificantly different from .500 in either season.

Tests of three other betting rules provide further evidence on the issue of momentum against the spread. The most direct test is a rule of betting on teams that covered in their last game, when playing teams that did not cover (Rule 1). If the market fails to take the previous outcome into account (underpricing the momentum factor), the hot team should win the bet significantly more often than the cold team. Alternatively, if momentum is overpriced by the market, the hot team should lose a disproportionate number of times. This rule, however, is successful .510 and .489 of the time for the 1989-1990 and 1990-1991 seasons, respectively. Similarly, a rule of betting on the team that has the better record against the spread on the season to date (Rule 2) is successful only .510 and .514 of the time. Another interesting question is whether abnormal performance against the spread carries over from the first half of the season to the second half or whether the market wises up by midseason and realizes that it has been mispricing certain teams. A rule of betting in the second half of the season on teams with the better record against the spread in the first half of the season (Rule 3) is successful .527 and .514 of the time.[10] For all three of these betting rules, none of the winning percentages are statistically different from .500 or economically profitable.

Another rule tested is to bet for the team playing on the last game of a road trip (Rule 4), since (sic) anecdotal evidence suggests that such road-weary teams rarely give a top-notch effort. But this rule succeeded .560 of the time in 1989-1990, not quite significantly different from .500 at the 5 percent level, and .508 of the time in 1990-1991. If anything, the betting public overreacts to this fatigue factor.

The results of the regression in equation (2) are reported in Tables 5 and 6, first for all individual teams, then for the separate betting strategies. For individual teams the

[9] Other teams also are examined for the same factor. Only in one marginal case (Portland 1989-1990) does exclusion of close games change the significance of the results at the 5 percent level: eliminating the Blazers' 10-9 record in close games reduces the p-value of their remaining results from .0676 to .0480.

[10] In addition, ranking the teams by cover percentage for both halves of the 1989-1990 season and conducting the Spearman rank coefficient test shows that the two rankings are not correlated.

Table 5—Regression of Point Spread on Actual Results; Individual Teams and Betting Rules, 1989-1990

Team	Constant	(t-ratio)	Slope	(t-ratio)	R^2
Atlanta	0.0658	(0.0524)	0.7124	(-1.6714)	0.1764
Boston	0.4413	(0.3166)	0.9170	(-0.4729)	0.2544
Charlotte	0.0408	(0.0233)	0.9505	(-0.2863)	0.2745
Chicago	0.4113	(0.2841)	0.9506	(-0.2597)	0.2378
Cleveland	-0.5136	(-0.3768)	1.0087	(0.0433)	0.2379
Dallas	-0.3960	(-0.3138)	1.1587	(0.8611)	0.3306
Denver	-0.2142	(-0.1604)	1.1459	(0.8898)	0.3789
Detroit	2.3994	(1.3601)	0.6167	(-1.8911)	0.1037
Golden St.	-2.1817	(-1.5628)	1.1458	(0.8288)	0.3465
Houston	0.3782	(0.2901)	0.9722	(-0.1622)	0.2872
Indiana	0.3933	(0.3017)	0.8488	(-0.8121)	0.2062
LA Clippers	-1.0241	(-0.6851)	0.7317	(-1.4148)	0.1569
LA Lakers	-0.0224	(-0.0122)	0.9710	(-0.1488)	0.2368
Miami	-0.6304	(-0.2736)	1.0880	(0.3894)	0.2246
Milwaukee	-1.6981	(-1.3586)	0.9407	(-0.3352)	0.2610
Minnesota	2.5605	(1.5569)	0.9974	(-0.0151)	0.2898
New Jersey	-2.1849	(-1.3306)	0.8708	(-0.7111)	0.2231
New York	-1.1090	(-0.8289)	0.7374	(-1.4911)	0.1797
Orlando	-3.7139	(-1.7647)	0.6638	(-1.5794)	0.1083
Philadelphia	2.2756	(1.6953)	0.9468	(-0.3093)	0.2750
Phoenix	0.4510	(0.2893)	1.2710	(1.5158)	0.3872
Portland	2.6680	(1.8193)	0.9238	(-0.4261)	0.2502
Sacramento	-1.5212	(-1.0119)	0.7713	(-1.2873)	0.1907
San Antonio	1.8145	(1.7088)	0.7491	(-1.8227)	0.2701
Seattle	0.1332	(0.1017)	1.2208	(1.2955)	0.3907
Utah	0.2716	(0.1774)	1.0717	(0.4165)	0.3265
Washington	-0.7213	(-0.5605)	1.1605	(0.8583)	0.3250
Home Teams	-0.0381	(-0.0872)	0.9834	(-0.3122)	0.2373
Favorites	0.1231	(0.1794)	0.9689	(-0.3780)	0.1161
Home Favorites	0.3019	(0.3529)	0.9590	(-0.4350)	0.1122
Home Underdogs	-0.2145	(-0.1568)	0.9060	(-0.3414)	0.0431
Rule 1	-0.2610	(-0.5497)	0.9689	(-0.5221)	0.3242
Rule 2	0.3425	(1.0031)	0.9874	(-0.3052)	0.3393
Rule 3	-0.5087	(-1.0764)	1.0044	(0.0746)	0.3494
Rule 4	1.1837	(1.2991)	1.0578	(0.5272)	0.2667

t-ratios above are for tests of $\alpha = 0$ and $\beta = 1$, respectively

Rule 1: Bet on teams that covered in their previous games, when playing teams that did not cover

Rule 2: Bet on teams with the better cover percentage for the season to date

Rule 3: In the second half of the season, bet on the team with the better cover percentage in the first half of the season

Rule 4: Bet on teams on the last game of a road trip

intercept of the regression is insignificantly different from zero (except for Dallas and Denver in 1990-1991), and the slope of the coefficient on the point spread is insignificantly different from one (except for New York, Philadelphia, and San Antonio in the 1990-1991 season). Similarly, there is no bias in the point spread when applied to the home team, the favored team, home favorites, home underdogs, or teams selected by any

Table 6—Regression of Point Spread on Actual Results; Individual Teams and Betting Rules, 1990-1991

Team	Constant	(t-ratio)	Slope	(t-ratio)	R^2
Atlanta	-0.4648	(-0.3476)	0.8835	(-0.6318)	0.2229
Boston	-1.8287	(-0.9443)	1.2132	(0.9570)	0.2704
Charlotte	-0.1323	(-0.0809)	0.9219	(-0.3840)	0.2042
Chicago	2.7968	(1.4590)	1.0103	(0.0478)	0.2148
Cleveland	-1.0121	(-0.8716)	0.7366	(-1.6936)	0.2189
Dallas	-2.5309	(-1.9721)*	0.7083	(-1.8502)	0.2014
Denver	-4.1674	(-2.1599)*	0.8766	(-0.6951)	0.2337
Detroit	-1.2356	(-0.8010)	0.9853	(-0.0725)	0.2283
Golden St.	0.6296	(0.4924)	0.9272	(-0.4303)	0.2727
Houston	1.9115	(1.4438)	0.7571	(-1.3447)	0.1800
Indiana	-0.1434	(-0.1092)	1.0092	(0.0518)	0.2875
LA Clippers	-0.2092	(-0.1487)	0.9030	(-0.5507)	0.2474
LA Lakers	0.7138	(0.4300)	0.9120	(-0.4803)	0.2365
Miami	1.1413	(0.6024)	1.1377	(0.6475)	0.2634
Milwaukee	1.0920	(0.8195)	0.7423	(-1.3827)	0.1655
Minnesota	1.7356	(1.2296)	1.2604	(1.4617)	0.3849
New Jersey	-0.2074	(-0.1277)	0.9641	(-0.1796)	0.2250
New York	0.1528	(0.1198)	0.6102	(-1.9624)*	0.1055
Orlando	2.4747	(1.3503)	1.1160	(0.5541)	0.2620
Philadelphia	-1.0064	(-0.8461)	0.4773	(-2.9848)**	0.0850
Phoenix	-0.0066	(-0.0036)	1.0669	(0.3393)	0.2677
Portland	2.0775	(1.2655)	0.9440	(-0.3261)	0.2738
Sacramento	-0.4441	(-0.2301)	0.9767	(-0.1131)	0.2188
San Antonio	1.7562	(1.2930)	0.6736	(-1.9863)*	0.1735
Seattle	0.5666	(0.4071)	1.1531	(0.8635)	0.3458
Utah	-1.1569	(-0.8753)	1.1079	(0.6669)	0.3693
Washington	-1.4719	(-1.0577)	0.8477	(-0.8404)	0.2147
Home Teams	0.0719	(0.1675)	0.9609	(-0.7492)	0.2352
Favorites	-1.0052	(-1.4458)	1.0709	(0.8509)	0.1335
Home Favorites	-0.6360	(-0.7519)	1.0303	(0.3278)	0.1340
Home Underdogs	2.7630	(1.7387)	1.4140	(1.3412)	0.0739
Rule 1	-0.6174	(-1.2683)	0.9927	(-0.1266)	0.3464
Rule 2	0.3680	(1.0611)	0.9659	(-0.0341)	0.3216
Rule 3	-0.0189	(-0.0384)	0.9239	(-1.2219)	0.2877
Rule 4	-0.7064	(-0.7945)	0.7953	(-1.8753)	0.1655

T-ratios above are for tests of $\alpha = 0$ and $\beta = 1$, respectively

* Significant at the 5 percent level
** Significant at the 1 percent level

Rule 1: Bet on teams that covered in their previous games, when playing teams that did not cover

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Rule 3: In the second half of the season, bet on the team with the better cover percentage in the first half of the season

Rule 4: Bet on teams on the last game of a road trip

of the four rules described above.[11] On average, the result of a game is equal to the point spread; in other words, the point spread is an unbiased predictor of the result with respect to the information used in this study to select the team on which to wager.[12]

[11] The Dare and MacDonald model and the Golec and Tamarkin model (described in note 7) were estimated for the 1989-1990 and 1990-1991 seasons. The conclusions are identical to the aggregate regression

There is no consistency in the evidence for inefficiency among the various tests. For example, Charlotte 1989-1990 had strongly positive autocorrelation, yet broke even by year's end according to the binomial and regression tests. Conversely, Minnesota 1989-1990 beat the spread in the binomial test, yet their success was not serially dependent and, according to the regression, their point spreads were unbiased. And Philadelphia 1990-1991 had a regression line with a significantly flatter than expected slope, yet the autocorrelation and binomial tests both conclude that the team was fairly priced. These results indicate that conclusions on inefficiency depend on the specific tests used.

CONCLUSIONS

The results demonstrated in this paper indicate that

- The performances of individual NBA teams against the point spread exhibit no significant serial correlation;
- Virtually no simple betting strategies based on the identity of the team, location of the game, or identity of the favorite are significantly profitable; and
- The point spread is an unbiased predictor of the actual results of NBA games with respect to the factors cited above.

The first result supports the hypothesis of weak form informational efficiency in the basketball wagering market. No relationship is found between a team's deviation from the point spread in one game and its deviation from the point spread in the next. The market is shown to adjust the point spread based on previous outcomes—no simple betting strategies based on previous failure or success against the spread generate abnormal returns. This is analogous to weak form stock market efficiency, which holds that previous increases or decreases in security prices cannot be used to predict subsequent price changes. It is interesting to find such a result in a market as shallow as the NBA wagering book. In addition, the second and third results confirm previous research that indicates that the market is not biased with respect to the home/visitor or favorite/underdog factor, providing limited evidence of semi-strong form efficiency.

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results shown in Tables 5 and 6: in all cases, none of the coefficients are significantly different from their hypothesized values at the 5 percent level. The F-tests and all partial F-tests unanimously reject the hypothesis that the point spread is biased with respect to the identity of the home team or the favorite. Detailed results are available to interested scholars.

[12] In addition, binomial and regression tests were performed for both seasons on games identified by the day of the week or the month of the year in which the game was played. The tests were performed both on home teams and favorites. The results (not shown here) provide little evidence of seasonality in performance against the point spread.

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