THE JOURNAL OF FINANCE • VOL. XLIII, NO. 4 • SEPTEMBER 1988

Testing Rationality in the Point Spread Betting Market

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ABSTRACT

This paper presents empirical tests of market rationality using data from the point spread betting market on National Football League games. Data from this market avoid many common pitfalls of tests of rationality in conventional financial markets. The authors test for rationality with two types of tests, statistical and economic. Results of the tests reveal that the statistical tests cannot reject market rationality while the economic tests do reject market rationality.

MARKET RATIONALITY CAN BE empirically examined with either pure statistical tests or direct economic tests. Statistical tests look at statistical properties of markets, such as price correlations. Economic tests attempt to detect unexploited profit opportunities. This paper compares the results of these two types of rationality tests with data from the point spread betting market on National Football League (NFL) games. We conclude that the statistical tests are too weak to reject rationality in a market where irrationality appears to exist.

Our results are strikingly consistent with those of Summers [26], who simulated a model of stock prices incorporating nonrational expectations and then showed that standard statistical tests are too weak to detect the absence of rationally formed expectations. Summers employed simulation because market rationality is difficult to test directly in conventional financial markets: the ongoing nature of securities markets means that there exists no point at which an objective fundamental value can be observed and compared with actual prices.[1]

In contrast, the point spread market offers an objective, though uncertain, game outcome to decide the end-of-horizon payoff. Moreover, once a bet is placed in these markets, the impact of subsequent betting does not affect the odds on the placed bet (unlike pari-mutuel betting). Because of this elementary market

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[1] This difficulty is exemplified by the controversy between Shiller [21, 23] and Marsh and Merton [13]. Options and futures markets would also *appear* to have an objective end-of-horizon payoff (Figlewski [7]). However, the commodity underlying options and futures is typically ongoing in nature, and its prices at the option/future horizon could possess some irrationality and thus so would the derivative security.

structure, market rationality issues can be unambiguously addressed by directly comparing observed "prices" (betting spreads) with actual game outcomes.[2]

In the next section, we describe the NFL point spread betting market. In Section II, we review the academic literature on the subject. Empirical analysis and results are presented in Sections III through V, and the paper is summarized in Section VI.

I. The Point Spread Betting Market

Suppose that the current "line" on the upcoming Chicago-MIT game has Chicago favored by six points. A bet on "MIT plus 6" wins if MIT wins the game or loses by five points or less. A bet on "Chicago give 6" wins if Chicago wins the game by more than six points. If Chicago wins by exactly six points, the game is a "push" and all money bet at this line is refunded. Point spread betting is carried out on the "eleven for ten" rule; the bettor must lay out $11 to win $10, $11,000 to win $10,000, and so forth. This asymmetric "eleven for ten" rule provides the bookmaker with a commission, called vigorish, and means that a bettor must pick winners in 52.4 percent of bets to break even.

Opening point spread linemaking begins in Las Vegas with the consensus of a handful of expert linemakers. Using this consensus as a guide, the major licensed sports books establish (virtually) consistent opening betting lines for a week's games. By reports, this opening line is designed with the anticipation that it will bring in equal dollar betting on both sides of the line by the time the book is closed. If this "matched book" actually occurs, books risklessly profit solely from the vigorish.

An opening line need not be an unbiased predictor of the game outcome. If linemakers anticipated some predictable irrationality on the part of the betting public, they would purposely bias an opening line to try to get a matched book. This situation might arise, for example, if linemakers anticipate a tendency for the general public to overreact to a big score run-up by a team in its previous game.[3] To be sure, linemakers would also try to anticipate the countervailing ability of the expert handicappers to detect and exploit line biases. The question of potential biasedness in opening lines thus boils down to the linemakers' belief in the relative "dollar-vote" influence of these two types of bettors. Linemakers report that the betting action of the unsophisticated general public far outweighs that of the informed handicappers in the NFL market and that this situation

[2] Moreover, in order to conduct a valid test in conventional financial markets, risk should be adjusted for in a theoretically correct manner. However, because of measurement problems and a lack of consensus on the proper measure of equilibrium security risk, particularly in the situation of some degree of market irrationality, this adjustment has proved difficult. In contrast, it seems reasonable to assume the absence of systematic risk in spread outcomes and thus to ignore this problem in the point spread market. Our reasoning follows the traditional diversification-equilibrium models with their emphasis on systematic risk. For views of nondiversification equilibria in the betting markets, see Smith [24] and Quandt [19].

[3] For a study of imperfections in subjective assessments of football point spreads, see Winkler [31]. For an overview of the problem and biases in forming subjective probability assessments in general, see Kahneman, Slovic, and Tversky [11].

dictates opening line biases for purposes of trying to create matched books. Of course, this matched book strategy might be a rational one for an optimizing bookmaker, even if it leads to market irrationality in the sense of biasedness when comparing a betting line with an expected outcome.[4]

Following the posting of an opening betting line on a game, legal betting begins in Nevada and illegal betting takes place all over the world. The illegal bookies in non-Nevada locations lay off the exposure created by their bettors via a network that connects back to the casino sports books in Las Vegas. This vast network of betting can cause the betting line to move, as the originating Las Vegas books attempt to maintain a balanced "order flow" on both sides of the line. Books may also adjust the betting line as new information about pertinent variables such as weather and injuries is received. Thus, the roles of the bookmaker are similar to those of a securities market dealer.[5]

In addition to market irrationality that might be anticipated by linemakers in the opening lines, the line movements caused by unanticipated trends in public betting might also be irrational. Irrational betting trends that cannot be anticipated are (a) the direction of gullible group reactions to random "touting" by questionable "experts" and (b) the extent of impulsive public reactions to random line movements as if the movements contained information. The countervailing "dollar-vote" influence of rational and knowledgeable handicappers may not be strong enough to balance the aggregate betting trend of the unsophisticated general public. One could argue that public perception errors would "wash out" in the aggregation process, but our view is that there could be some "shared errors" in the sense of Treynor [28] or Shiller's [22] social fads.[6]

The betting line at the close of the book on a game is called the closing line (or sometimes the public line, reflecting, as it does, the aggregate public betting influences on the betting line). Given the expected outcome at the time the game starts, if aggregate public betting is rational, then the closing line should be at

[4] One could argue that a rational population of bettors need not generate a market-clearing spread that is equal to the expected value of the distribution of score differentials. Rationality requires that the odds of winning the bet be equal for a bet on either team. For that to happen, the market should be clear at the *median*, not the *mean*, of the distribution, which will be different if the distribution outcomes are skewed. However, Stern's [25] analysis indicates that this distribution is symmetric, and indeed normality was not rejected in several types of tests. Thus, we proceed throughout the paper to compare betting spreads with expectations.

[5] The role of the bookmaker has been formally considered by Jaffe and Winkler [10]. In prior times, bookmakers would move the line only if the money being bet was judged to have information, analogous to the marketmaking activity discussed by Treynor [27]. However, bookmakers report that this activity ceased around 1980 because of the difficulties in distinguishing informed betting from noninformed. Reportedly, no more than five percent of all line movements are due to public information about injuries and weather. The rest are in response to order flow.

[6] This behavior could sometimes be regarded as an example of the "risky-shift" phenomenon observed in the organizational behavior theory literature (for example, Sanders [20]), where persons as a group make decisions that individuals of the group would deem irrational if they were to make the decisions on their own. (Sadly, we have had personal experience of this phenomenon in our Las Vegas field trips.) The prevailing view among the Las Vegas establishment of oddsmakers, bookmakers, and professional bettors is that the "aggregate" of the unsophisticated general public somehow manages to take the wrong side of bets more frequently than would be expected by random chance. This lore is reminiscent of the old "odd-lot theory" of the stock market.

least as close as the opening line to that expected outcome. On the other hand, irrational public betting behavior, of a kind that cannot be anticipated in the opening line, could cause a closing line to be farther than the opening line from the expected outcome.

Although betting lines are *designed* to split the expected betting, bookmakers usually realize some degree of betting imbalance on each game. In situations where a line has moved, the imbalance is in the direction of the betting that causes the line to move. Thus, if the public betting causes the line to move toward the eventual game outcome, the public will have won at the expense of the bookmakers, and vice versa.[7]

II. Literature Review

Pankoff [17] was the first author to recognize that the football betting market permits an unusually direct test of market efficiency. Essentially, Pankoff tested the unbiasedness of the betting market's "forecast" of game outcomes by regressing actual game point spread outcomes (defined as the visitor's score minus the home team's score) on betting lines (similarly defined). Using the terminology of Brown and Maital [4], this is a test of "partial" rationality. Using various betting lines published in the media for the 1956 to 1965 NFL seasons, Pankoff reported evidence of market rationality in this weak, aggregate sense. Of course, these results do not imply that the betting lines were unbiased on a line-by-line basis.

Zuber, Gandar, and Bowers [32], using data from only the 1983 NFL regular season, found that the "partial" test of market rationality (in the form of the test of the null hypothesis that the intercept and slope parameters for the linear regression of game outcomes on betting lines are, jointly, zero and one) could not reject rationality for the season as a whole and for thirteen of the sixteen weeks of the season considered separately. However, they also found that the extreme alternative hypothesis that betting lines are unrelated to actual game outcomes, while rejected for the season as a whole, could not be rejected for fifteen of the sixteen weeks considered separately. Hence, this type of test was regarded as too weak to establish firm conclusions. However, as Brajer and Sauer [3] point out, splitting the season into weekly samples of fourteen games makes for a less powerful test in that it increases the variance of the estimators and makes it more likely that the extreme alternative hypothesis (that the slope and intercept parameters are jointly zero) cannot be rejected.

Amoako-Adu, Marmer, and Yagil [2] attempted to conduct a "partial-rationality" test for the 1979 to 1981 NFL seasons and concluded that, because betting lines appear not to provide good estimates of actual game outcomes, this betting market was not efficient in this sense. However, in their test, the authors

[7] Las Vegas sports books do not, in general, allow lines to vary from the opening to the closing of the book by more than three or four points. Such "limit move" constraints arise from fears of being "middled". A classic example of the problem created for books by large line changes occurred with the 1979 Super Bowl, where Pittsburgh beat Dallas 35 to 31. Pittsburgh was an early 2½-point favorite. So many bettors favored Pittsburgh at this line that the books were forced to move the line to 4½ or 5 to try to even up the money bet on both sides. However, Pittsburgh bettors vanished at this line, and Dallas bettors had been holding back, hoping for more points. The four-point actual game outcome caused the books to lose to both sides.

regressed betting lines on actual game outcomes. This represents a reversal of regressor and regressand from the standard rational-expectations equation (realized values expressed as a linear function of forecasted values). In effect, they conducted a test of Mills' [14] concept of implicit expectations rather than of Muth's [16] concept of rational expectations.[8]

Zuber, Gandar, and Bowers also tested a fundamental-prediction model for the 1983 season. For the last half of the 1983 NFL season, a 58.8 winning percentage was obtained against a late-week betting line reported in the media. This winning percentage was judged sufficiently above the 52.4 percent break-even level to conclude that speculative inefficiencies appear to exist in this market. However, Brajer and Sauer presented evidence that suggested that the model might *not* break even in out-of-sample data.

A number of studies (Canes [5], Peters [18], Vergin and Scriabin [30], and Tryfos et al. [29]) have investigated various technical betting rules on NFL games. Canes found no profitable technical rules that could be applied in the present market structure, while Peters did. Many of the betting rules that Vergin and Scriabin reported to be profitable with one sample were found by Tryfos et al. to be unprofitable in a subsequent sample.

In summary, the existing literature does not permit a firm conclusion on the existence of rationality or irrationality in the NFL betting market. Our empirical analysis below builds on the techniques of this literature.

III. Description of the Point Spread Data

The point spread data used in this paper cover all NFL regular season games for the years 1980 through 1985. These data were collected from a single source, the "College and Pro Football Newsweekly." In these six years of NFL play, 1246 regular season games were played. However, in thirteen instances, no line was posted either at the opening or at the closing of the Las Vegas books. Hence, our usable sample contains 1233 observations. Three variables were collected for each game: the opening betting line at the Las Vegas books (VLO), the closing line (VLC), and the actual game point spread (PS). For consistency, each of these variables is defined from the home team's perspective.[9] Summary statistics are given in Table I.

[8] The different assumptions of these alternative expectations hypotheses are clearly spelled out in Lovell [12]. It will be clear from the results in Section IV that the relative sizes of variances of actual game point spreads and betting lines do not accord with the structure of expectations (implicitly) assumed by Amoako-Adu et al.

[9] Conventionally, betting lines are quoted in terms of the favorite team minus so many points. (For instance, on September 29, 1985, the favored Chicago Bears opened at $-6\frac{1}{2}$ over the underdog Washington Redskins.) Redefining the betting lines from the home team's perspective changes this convention: the home team is a favorite team when $VL > 0$. (Thus, in the above game, we quote the home-team Bears as $+6\frac{1}{2}$.) The importance of this redefinition is that results are highly sensitive to the manner in which the relevant variables are defined. For example, Amoako-Adu et al. define these variables in terms of the betting line favorite. Defining the variables in this fashion constrains the possible range of betting lines to nonpositive values but allows actual game point spreads to take on both positive and negative values. This method of defining the variables produces regression results that are vastly different from those of our more defensible approach.

Table I

Descriptive Statistics

	1980	1981	1982	1983	1984	1985	1980–1985
Number of Games	217	221	125[a]	222	224	224	1233
PS Mean	1.820	2.453	1.328	1.667	2.286	4.513	2.459
(Standard Deviation)	(14.459)	(14.852)	(13.491)	(14.481)	(15.596)	(14.847)	(14.640)
VLO Mean	2.669	2.409	2.240	2.252	2.444	2.353	2.405
(Standard Deviation)	(5.444)	(4.613)	(4.835)	(4.542)	(5.735)	(5.770)	(5.201)
VLC Mean	2.657	2.427	2.200	2.189	2.307	2.438	2.388
(Standard Deviation)	(5.589)	(4.670)	(5.016)	(4.803)	(5.596)	(6.217)	(5.430)
Number of Games Where $(VLC\text{-}VLO) \neq 0$	151	163	80	162	172	160	888
$\|(VLC\text{-}VLO)\|$ Mean	1.070	1.086	0.756	1.019	0.974	1.325	1.063
(Standard Deviation)	(1.681)	(1.699)	(1.135)	(1.677)	(1.633)	(2.041)	(1.699)
Number of Games Where Line Changed toward Game Outcome[b]	72	65[c]	33	76	88[c]	79	413
Number of Games Where Line Changed Away from Game Outcome[d]	79	97[c]	47	86	83[c]	81	473

[a] This season was shortened to nine weeks because of the players' strike.

[b] For $(VLC\text{-}VLO) > 0$ (<0), these are the games for which $PS \geqq VLC$ ($\leqq VLC$). For the nine games where either $VLO < PS < VLC$ or $VLC < PS < VLO$, there are the four games for which, respectively, $(VLO\text{-}PS) > (PS\text{-}VLC)$ and $(VLC\text{-}PS) < (PS\text{-}VLO)$.

[c] For the nine games where either $VLO < PS < VLC$ or $VLC < PS < VLO$, there were two games for which $(VLO\text{-}PS) = (PS\text{-}VLC)$. These games, one in 1981 and the other in 1984, were omitted from these two counts.

[d] For $(VLC\text{-}VLO) > 0$ (<0), these are the games for which $PS \leqq VLO$ ($\geqq VLO$). For the nine games where either $VLO < PS < VLC$ or $VLC < PS < VLO$, there are the three games for which, respectively, $(VLO\text{-}PS) < (PS\text{-}VLC)$ and $(VLC\text{-}PS) > (PS\text{-}VLO)$.

IV. Statistical Rationality Tests

The defining characteristic of rational expectations requires market probability distributions of economic variables, conditional on available information, to be equal to objective probability distributions, conditional upon the same information set. In markets with no systematic risk (such as the point spread betting market), one need only consider first moments of conditional probability distributions. Thus, empirical evidence that conditional market expectations are equal to true conditional expectations is evidence for rational expectations. Hence, a zero expectation of the market's conditional forecast error is a necessary condition of rational expectations. That is, rational expectations implies that

$$E(PS - VL \mid \phi) = 0, \tag{1}$$

where *PS* is the point spread outcome on a game, *VL* is the Las Vegas betting line, and ϕ is the set of information available to the market at the time of the betting line. Therefore, in the linear representation:

$$PS = a + bVL + e, \tag{2}$$

when expectations are rational, $a = 0$, $b = 1$, and $E(e \mid \phi) = 0$.

Before turning to a discussion of the results of estimating equation (2), it is apposite to note that the actual means and variances of *PS*, *VLO*, and *VLC* in our sample of six years of NFL play support the requirements of rationality. As reported in Table I, the means of both *VLO* and *VLC* do not differ significantly from the mean of *PS*, and the variance of *PS* is significantly larger than both the variance of *VLO* and the variance of *VLC*. These results hold for all years combined and for each year considered separately. It is clear that the relative sizes of the variances of actual game point spreads and of betting lines do not accord with the structure of expectations (implicitly) assumed by Amoako-Adu et al.

Table II reports the results of the ordinary least squares (OLS) estimates of equation (2) for the 1980 to 1985 NFL seasons. There appears to be little difference between the estimated regression equations using *VLO* or *VLC* as regressors. For most years considered separately and for all years combined, intercept terms are insignificantly different from zero and slope terms are insignificantly different from one. The exceptions are 1984, where the slope parameter for *VLO* is significantly greater than unity, and 1985, where both intercept terms are significantly different from zero. However, in every case, *F*-tests of the rational-expectations hypothesis are unable to reject the null hypothesis that $[a, b]$ is jointly $[0, 1]$. Overall, the evidence reported in Table II does

Table II

Regression Results for Initial Rationality Tests (Equation (2))[a]

	1980	1981	1982	1983	1984	1985	1980–1985
Opening Lines (*VLO*)							
Intercept	−0.900	−0.079	−0.654	−0.428	−0.967	1.998	−0.165
	(1.015)	(1.068)	(1.267)	(1.039)	(0.988)	(0.977)	(0.427)
Slope	1.017	1.060	0.885	0.930	1.341	1.069	1.081
	(0.168)	(0.206)	(0.239)	(0.206)	(0.159)	(0.157)	(0.075)
R^2	0.146	0.108	0.101	0.085	0.242	0.173	0.146
F^b	0.447	0.044	0.432	0.255	2.304	2.952	0.593
n	217	221	125	222	224	224	1233
Closing Lines (*VLC*)							
Intercept	−0.784	−0.161	−0.494	−0.326	−0.636	2.116	0.007
	(1.009)	(1.073)	(1.267)	(1.019)	(0.978)	(0.973)	(0.438)
Slope	0.978	0.948	0.806	0.910	1.278	0.983	1.017
	(0.164)	(0.205)	(0.231)	(0.194)	(0.154)	(0.146)	(0.092)
R^2	0.142	0.089	0.090	0.091	0.238	0.170	0.140
F^b	0.437	0.032	0.676	0.265	1.639	2.631	0.034
n	217	221	125	222	224	224	1233

[a] Standard errors are in parentheses.

[b] This is the F-statistic for the null hypothesis that the true parameters $[b_0, b_1]$ are jointly $[0, 1]$.

not contradict the hypothesis that both opening and closing lines are rational expectations of actual game outcomes.

As was pointed out in Section II, the tests above are a relatively weak form of statistical tests for rationality, in the sense that only aggregate biases are being considered. One way to strengthen the statistical analysis is to incorporate information that relates to game-specific situations.

Following Abel and Mishkin [1], the following projection equation is estimated:

$$PS - VL = w \times X, \tag{3}$$

where X is a vector of information known at the time of the betting line and w is a vector of estimated coefficients. Rational expectations requires that market "forecast errors" ($PS - VL$) be uncorrelated with any information, or linear combination of information, contained in ϕ. Thus, as Abel and Mishkin point out, the vector w should not differ from zero, except by chance, under the null hypothesis of rationality. This condition, which is necessary but not sufficient for rationality, holds even if the vector X does not contain all of the information that bears on the game outcome.

The X variables for this study are the differences (home team minus visiting team) in the averages of the following values for the season's preceding games: yards rushed, yards passed, number of wins, fumbles, interceptions, number of penalties, proportion of passing plays attempted to total offensive plays, and the number of rookies. These variables are the same as those employed by Zuber, Gandar, and Bowers. We allowed eight weeks of a season for the production of the information to predict the ninth week's games. Thereafter, the information was updated with weekly results for purposes of the following week's predictions. Constructing the X variables in this fashion, equation (3) is estimated with observations for the second half (weeks 9, $\cdots$, 16) of the 1983, 1984, and 1985 seasons. Thus, these were 112 observations, one half of the games, per season.

The F-values computed for equation (3) for the three seasons for the opening lines were 0.193 (1983), 1.039 (1984), and 1.666 (1985); for the closing lines, they were 0.149, 1.063, and 1.615, respectively. None of these F-values allows for rejection of the null hypothesis that the estimated coefficients in w are jointly zero at any conventional levels of significance. Hence, the Abel-Mishkin approach, with our 112 observations per season and eight informational variables, does not permit a rejection of market rationality.

Finally in this section, we compare statistically the forecasting accuracy of opening lines with that of closing lines. As we pointed out in Section I, closing lines should be at least as good a predictor of game outcomes as opening lines, except in cases where the public betting is dominated by a type of "shared-error" irrationality that cannot be anticipated. In Table III, we report the mean square forecast errors (MSE) of the opening and closing lines for the 888 games where the lines changed. The MSE of the closing lines exceeds that of the opening line for five of six seasons considered separately and for all years combined. That is, in our sample of six NFL seasons, the closing line does not provide a more accurate forecast than does the opening line. However, with the exception of the 1981 season, the differences between MSE for the two lines are generally small

Table III

Forecasting Accuracy of Opening and Closing Lines (Mean Square Forecast Errors)

	1980	1981	1982	1983	1984	1985	1980–1985
VLO	184.60	186.12	143.44	187.22	175.62	168.77	177.058
VLC	185.67	191.95	147.48	185.50	175.70	169.00	178.41
r[a]	−0.03	−0.16*	−0.19	0.05	−0.002	−0.005	−0.04
n	151	163	80	162	172	160	888

[a] This is the correlation coefficient of the two series, $e^o = PS - VLO$ and $e^c = PS - VLC$, for the test of statistical significance of two competing predictions suggested by Granger and Newbold [9]. A finding that r is significantly different from zero (using the standard t-test) implies that a significant difference exists between the mean square errors of the two forecasts (VLO and VLC).

* Significant at the five percent level.

and statistically insignificant. Thus, we cannot statistically reject the hypothesis that the unanticipated public betting adds rationality to the market.

In this section, we have found that standard statistical tests do not reject the hypothesis that the NFL point spread betting market is characterized by rational expectations.

V. Economic Rationality Tests

While the tests described above use statistical criteria to evaluate market rationality, more direct tests of market rationality attempt to detect unexploited profit opportunities. In this section, we perform a variety of these direct tests by examining betting strategies based on simple technical rules. To facilitate this examination we subdivide these rules into two categories: (a) ad hoc, mechanical rules and (b) rules based on some specific idea of irrational public betting behavior in this market.

In terms of our definitions of betting lines and game point spreads, the mechanical rules are as follows:

Rule 1. Bet on the favorite (the team for which $VL > 0$) when $0 < |VL| \leq 5$.

Rule 2. Bet on the underdog (the team for which $VL < 0$) when $|VL| > 5$. This rule is subdivided by specifying ranges for VL: (a) $5 < |VL| \leq 10$, (b) $10 < |VL| \leq 15$, and (c) $|VL| > 15$.

Rule 3. Bet on the team that has the highest average winning margin over the previous n weeks ($n = 1, \cdots, 5$).

Rule 4. Bet on the team that beats the betting line by the highest average margin over the previous n weeks ($n = 1, \cdots, 5$).

Rules 1, 2, 3, and 4 are technical rules developed by Vergin and Scriabin. These authors report each of these rules as profitable both in terms of win-to-bet percentages above the 52.4 percent break-even level and in terms of estimated Z-values for each rule sufficient to reject the null hypothesis of randomness at conventional levels of significance. Tryfos et al. retested these rules and found them generally unprofitable or statistically insignificant in a different sample.

The behavioral rules are as follows:

Rule 5. Bet on the team that becomes less favored (more of an underdog) over the course of the week's betting. In effect, one is generally betting against the direction bet by the majority of the public.

Rule 6. Bet against the public (as in Rule 5) for games in weeks following "winning" weeks for the public. "Winning" weeks were those for which at least fifty percent of line changes from *VLO* to *VLC* moved the betting line closer to the eventual game outcome.

Rule 7. Bet the underdog against a favored team that, as a favorite in the previous week, covered the spread by at least 10 points.

Rule 5 is a direct test of the hypothesis that the aggregate unanticipated betting by the public is more often than not irrational and that profits are possible by betting against the movement in the line produced by public betting activity. Because of the difficulty in collecting information and because "information moves" are reported to account for only about five percent of all line moves (see footnote 6), we do not make any attempt to uncover which line movements might have been due to information, as opposed to public betting behavior.

Rule 6 is a modification of Rule 5. It is suggested by Gilovich's [8] observations of football bettors' behavior. He finds that bettors tend to remember the details of losses for purposes of "explaining them away" and correspondingly not remember the details of wins. Thus, in weeks after losing records, public bettors' information processing is clearer. Hence, losses by the public in one week could mean a better informed (less irrational) betting action for the next week's games, and vice versa.

Rule 7 is a rule suggested by Peters. When applied to the opening line, this rule is based on the idea that linemakers anticipate public overreaction to a team that, as a favorite, beat the spread by a wide margin in its previous game. When applied to the closing line, this rule is based upon both the anticipated overreaction and any additional overreaction after the opening line. The source of this overreaction is presumably the same type of behavioral tendency theorized in De Bondt and Thaler [6] and is based on the representativeness heuristic bias theorized in Kahneman, Slovic, and Tversky [11]. Peters tested and found this rule to be profitable over the 1972 to 1975 NFL seasons.

Summary results of betting simulations using both mechanical rules and behavioral rules for the 1980 to 1985 NFL seasons are presented in Table IV. The profitability of each rule is evaluated based on three criteria: the ability of the rule to achieve a win-to-bet proportion higher than 52.4 percent, the finding of a Z-value for the rule sufficient to enable rejection of the null hypothesis of randomness, and, finally, the finding of a Z-value sufficient to enable rejection of the null hypothesis of unprofitability (the Tryfos et al. test).[10]

None of the mechanical rules can be considered profitable based on these criteria. For example, while several achieve higher winning-bet percentages than needed to break even, none of these have Z-values sufficiently large to reject the null hypotheses of randomness and unprofitability at conventional levels of significance. Moreover, some of these mechanical rules are so unprofitable (Rule

[10] For a description of these tests, see the footnotes to Table IV.

Table IV

The Profitability of Certain Technical Rules: Summary Results for the 1980 to 1985 NFL Seasons

	Opening Betting Lines (VLO)							Closing Betting Lines (VLC)						
	Wins (W)	Bets (B)	W/B (%)	Z_1[a]	s_1[a]	Z_2[b]	s_2[b]	Wins (W)	Bets (B)	W/B (%)	Z_1[a]	s_1[a]	Z_2[b]	s_2[b]
Mechanical Rules[c]														
Rule 1	317	694	45.68	−2.28	0.989	−3.55	0.999	315	689	45.72	−2.25	0.988	−3.51	0.999
Rule 2	218	445	48.99	−0.43	0.666	−1.43	0.924	243	484	50.21	0.09	0.464	−0.96	0.832
2(a)	186	376	49.47	−0.21	0.583	−1.13	0.871	214	419	51.07	0.44	0.330	−0.54	0.705
2(b)	31	64	48.44	−0.25	0.599	−0.63	0.736	36	67	53.73	0.61	0.271	0.22	0.413
2(c)	1	5	20.00	—	—	—	—	3	8	37.50	—	—	—	—
Rule 3 ($n = 1$)	40	87	45.98	−0.75	0.773	−1.20	0.885	39	90	43.33	−1.26	0.896	−1.73	0.958
($n = 2$)	31	73	42.47	−1.29	0.902	−1.71	0.956	31	79	39.24	−1.91	0.972	−2.39	0.992
($n = 3$)	34	69	49.28	−0.12	0.548	−0.52	0.699	32	70	45.71	−0.72	0.764	−1.12	0.869
($n = 4$)	34	63	53.97	0.63	0.264	0.25	0.401	33	66	50.00	0.00	0.500	−0.39	0.652
($n = 5$)	31	55	56.36	0.94	0.174	0.60	0.274	28	58	48.28	−0.26	0.603	−0.63	0.736
Rule 4 ($n = 1$)	41	83	49.40	−0.11	0.504	−0.54	0.705	40	82	48.78	−0.22	0.587	−0.65	0.742
($n = 2$)	30	70	42.86	−1.20	0.885	−1.61	0.946	32	77	41.56	−1.48	0.931	−1.93	0.973
($n = 3$)	26	69	37.68	−2.05	0.980	−2.52	0.994	27	71	38.03	−2.02	0.978	−2.49	0.994
($n = 4$)	24	60	40.00	−1.55	0.939	−1.96	0.975	27	66	40.91	−1.48	0.931	−1.90	0.971
($n = 5$)	32	55	58.18	1.21	0.113	0.87	0.192	30	59	50.85	0.13	0.448	−0.24	0.595
Behavioral Rules[c]														
Rule 5	—	—	—	—	—	—	—	480	874	54.92	2.91	0.002***	1.51	0.065*
Rule 6	—	—	—	—	—	—	—	208	365	56.99	2.67	0.004***	1.78	0.037**
Rule 7	80	143	55.94	1.42	0.078*	0.86	0.195	97	167	58.08	2.09	0.018**	1.49	0.068*

[a] These are the Z-values (Z_1) and significance levels (s_1) for the null hypothesis that the win-to-bet record is random (the long-run win-to-bet proportion is fifty percent) against the alternative hypothesis that it is not random. Using the normal approximation to the binomial distribution, this Z-value is calculated as $Z_1 = [W - 0.5(B)] \times [B(p)(1-p)]^{-1/2}$, where W and B are, respectively, the number of wins and total bets, and $p = 0.5$.

[b] These are the Z-values (Z_2) and significance levels (s_2) for the Tryfos et al. test for evaluating the profitability of betting strategies. The null hypothesis for this test is that a given rule is unprofitable against the alternative that it is profitable. The Z-value is calculated as $Z_2 = \dfrac{1/B\,[(W/B) - 1.1(L/B)]}{[1/B\{((W/B) + 1.21\,(L/B)) - (W/B - 1.1(L/B))^2\}]^{1/2}}$, where W, L, and B are, respectively, the number of wins, losses, and total bets for a given strategy. To reduce the risk of a type-I error—the probability of erroneously concluding that the strategy is profitable—Tryfos et al. advocated the use of a "low" α level. For further details, see Tryfos et al. [29].

[c] See text for a detailed description of each rule.

* Significant at the ten percent level.

** Significant at the five percent level.

*** Significant at the one percent level.

1 for example) that adoption of the exact opposite strategy would be decidedly profitable in our sample. In that the prior report of profitability of these mechanical rules appears to be sample specific, they cannot be regarded as consistently profitable.

The contrast between the simulations based on mechanical rules and those based on behavioral ideas is marked. All three of the latter rules appear to be profitable for closing line bets. For example, the simple rule of betting against market trends (Rule 5) produces a win-to-bet proportion of nearly fifty-five percent. The reported Z-values indicate both that this proportion is decidedly nonrandom and that the probability of obtaining it by chance when the rule is actually unprofitable is less than seven percent. The fact that the "betting-against-the-public" rule was a profitable strategy indicates that some market irrationality existed that was not anticipated in the opening lines. These results are particularly strong since "information moves" (believed to be about five percent of the sample) could not be separated.

The other two behavioral rules were also profitable. Public betting appears to be more incorrect in weeks following ones in which the public's betting did well. The asymmetry of this reaction by the betting public to winning and losing situations gives rise to a technical rule (Rule 6) that gives a fifty-seven percent win-to-bet ratio. The Peters' rule (Rule 7), while profitable against both opening and closing lines, is even more profitable at closing lines than at opening lines. Thus, there appears to exist some overreaction effect anticipated by linemakers in the opening lines, and there is some additional overreaction by the public beyond that anticipated by opening linemakers.

In summary, we contend that, while the mechanical technical rules examined were not profitable during our sample period, the results of the behavioral technical rules strongly indicate that irrationality characterizes the NFL betting market.

VI. Conclusions

In this paper, we present the results of empirical tests of the rational expectations hypothesis in the professional football betting market. Several different tests were discussed. The first tests were standard statistical ones. Our results did not permit the rejection of the hypothesis that market forecasts in the form of betting lines are unbiased predictors of actual game outcomes. No significant bias is detected in either opening or closing lines, even when adjusting for game-specific information in the manner of Abel and Mishkin. Our findings also indicated that the mean square forecast error of the opening lines is not statistically different from the mean square forecast error of the closing lines.

The economic tests were based on the idea that, if betting lines are rational expectations of game outcomes, it should not be possible to form technical betting strategies that consistently allow one to beat the spread. While certain mechanical technical rules were unprofitable, rules based on specific hypotheses of bettor behavior patterns, some already in the finance literature, were found to be decidedly profitable. Such profit opportunities appear to be evidence against the hypothesis that this market is totally rational. We believe that these results indicate that the pool of money bet by the unsophisticated public dominates the pool of money bet by knowledgeable handicappers. Our findings suggest that the point spread betting market may be a fruitful place to conduct research about behavioral theories that could apply in conventional market settings.

In an interesting recent article, Summers described statistical simulations similar to the tests we have performed. Summers was unable to detect irrationality in simulated stock market prices constructed to diverge from rational valuations. He concluded that standard statistical tests have low power. Our paper can be viewed as an extension, in a real market situation, of his critical examination. The point spread betting market has many similarities with conventional financial markets, and the structure of the betting market permits quite unambiguous conclusions. We appear to have detected irrationality with our economic tests; yet the statistical tests fail to detect it. We are left with the uncomfortable presumption that similar statistical tests will fail to reject the hypothesis of rationality in other markets where irrationality may exist.

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