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Comment

Hold Your Bets: Another Look at the Efficiency of the Gambling Market for National Football League Games

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I. Introduction

Many observers of gambling markets are familiar with pamphlets and books—backed by considerable statistical "evidence"—that for a small price provide the reader with one or more "profitable" betting systems. In a recent paper, Zuber, Gandar, and Bowers (1985) presented such a system that they claim represents "true exploitations of inefficiencies in the NFL gambling market" (p. 805). In addition to this "stronger test" of efficiency, Zuber et al. presented a "weak test," in which they were unable to reject the hypothesis that the scores of National Football League games are *unrelated* to the predictions given by the Las Vegas gambling line.

We are grateful to Tom Goodwin, Levis Kochin, Charles Nelson, and Frank Wolak for their comments. We also wish to acknowledge the contribution of Rick Zuber and John Gandar, who checked our data and provided helpful criticism of an earlier draft. Remaining errors are, of course, our own.

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In this comment, we argue that the tests performed by Zuber et al. are misleading, and we present a variety of evidence that contradicts their assertion that the betting market for NFL games is inefficient. Specifically, a more powerful specification of the weak test decisively rejects the hypothesis that scores are unrelated to the Vegas line. In addition, we show that the predictors of net efforts used by Zuber et al. in betting simulations add essentially no information to that already incorporated in the Las Vegas line. This result is substantiated when the betting system proposed by them is extended out of sample in an unsuccessful attempt to produce profits.

II. Weak Tests of Market Efficiency

The initial efficiency test examined by Zuber et al. required estimation of the equation

$$PS_{it} = b_0 + b_1 \times VL_{it} + u_{it}, \tag{1}$$

where PS_{it} denotes the actual point differential between teams playing the ith game in week t, VL_{it} is the Las Vegas gambling line, and u_{it} is the error term. The efficient markets hypothesis (EMH) asserts that VL_{it} is an optimal, unbiased predictor of PS_{it}. A test of the EMH is thus a joint test of the null hypothesis that $b_0 = 0$ and $b_1 = 1$. An "extreme alternative" test proposed by Zuber et al. is the joint test that $b_0 = b_1 = 0$, that is, that the actual point differential is unrelated to the Vegas line. They estimated equation (1) for each of the 16 weeks of the 1983 season and could not reject the null hypotheses for 13 and 15 of the 16 weeks, respectively. They concluded that an alternative testing strategy is required.

We agree. In particular, there is a stronger "weak" test. In the absence of systematic differences in the *PS*-*VL* relationship between different weeks, there is no a priori reason (and no justification offered by the authors) to base efficiency tests on weekly samples of 14 games each, given data for the entire 16-week season. It is well known that the variance of the least-squares estimator is inversely related to sample size (see, e.g., Judge et al. 1982, pp. 263–66). By splitting the season into 16 parts, Zuber et al. effectively increased the sample variance of their estimators, thus making it more likely that they would be unable to reject the hypothesis that the coefficient of the Vegas line is zero.[1] Splitting one large sample into many small samples makes for a less powerful test.

[1] This problem is particularly acute given the unpredictable nature of NFL games. The standard deviation of the difference in scores is 3.5 times that of the Vegas line for 1983. The likely reason for this is that large differences in scores are difficult to predict.

TABLE 1

OLS Regression of Equation (1): 1983 Regular NFL Season
(Dependent Variable: Home-Away Score Differential)

Coefficient	Estimate	t-Statistic
Intercept (b_0)	−.354	−.345
Vegas line (b_1)	.918	4.579
R^2	.086	
Degrees of freedom	222	

Increasing the sample size from 14 to 224 yields a different picture. In table 1 we present ordinary least squares (OLS) estimates of equation (1) using the full sample of data for the 1983 season. One cannot reject the null hypothesis that $b_0 = 0$ and $b_1 = 1$ at the 95 percent level (the calculated F-statistic is 0.25, well below the critical value of 3.0).[2] As did Zuber et al., we are unable to reject the EMH. Contrary to their results, the "extreme alternative" hypothesis that the score differences and the Vegas line are unrelated ($b_0 = b_1 = 0$) is decisively rejected when data for the full season are simultaneously utilized ($F = 12.2$).[3]

III. Information Provided by the Zuber et al. Variables

Zuber et al. presented regression results that demonstrate that the actual home-away point differential is highly correlated with the contemporaneous difference in the efforts of the two teams on that day.[4]

Indeed, 34 games in the 1983 season were decided by a three-touchdown margin or more (21 points), but there was no instance in which the Vegas line exceeded 15.5 points. The average difference between the predicted and actual scores for these outliers is 25.7 points. Furthermore, the favorite *lost* in nine of these games. The effect of one or two of these so-called blowouts in a sample size of 14 is likely to be severe.

[2] It is worth noting here that, under the EMH, the 224 observations in the sample are presumed to be independent (otherwise bettors could make use of the dependence to make profits, contradicting the EMH). Without knowing if the EMH is true, one cannot be sure that this is so. For example, it could be that the Vegas line adjusts slowly to superior or inferior performance, in which case this week's *PS*, *VL* pair would be partially dependent on last week's pair. But the effect on eq. (1) would be to bias standard errors downward, making more likely a rejection of the hypothesis that $b_0 = 0$ and $b_1 = 1$. Hence this consideration strengthens the result that we are unable to reject the EMH. We are grateful to Sam Peltzman for bringing this point to our attention.

[3] Zuber et al. were aware of the full-season results but included only the weekly results in the published version of their paper. We conducted tests for 1984 also, with similar results (the F-statistics are 2.46 and 40.82, respectively).

[4] The variables used as proxies for "team efforts" were yards passed, yards rushed, fumbles lost, interceptions, penalties incurred, percentage of passing plays, and two indexes of team strength: number of rookies and number of previous wins.

TABLE 2

CONTEMPORANEOUS MODEL OF ZUBER ET AL.
(Dependent Variable: Home-Away Score Differential)

Explanatory Variables	1983 NFL Season (Zuber et al.) Coefficient Estimate	1983 NFL Season (Zuber et al.) t-Statistic	1984 NFL Season (Sauer et al.) Coefficient Estimate	1984 NFL Season (Sauer et al.) t-Statistic
Intercept	1.547	2.66	1.548	2.40
Rushing yards	.047	4.70	.025	1.99
Passing yards	.044	6.29	.046	6.67
Previous wins	.697	2.32	.539	3.47
Fumbles lost	−2.299	−5.50	−2.671	−5.15
Interceptions	−2.619	−7.61	−2.654	−6.27
Penalties	−.424	−2.48	−.188	−1.07
Percentage passing to total plays	−.217	−4.34	−.262	−4.10
Rookies	−.319	−2.45	−.607	−3.71
R^2	.733		.805	
Degrees of freedom	103		103	

SOURCE.—Data on all variables except rookies were obtained from box score summaries printed in the *Los Angeles Times*. Data for the number of rookies per team were obtained from the office of the National Football League.

Specifically, they estimated the OLS equation

$$PS_{it} = \boldsymbol{\beta} \cdot (\mathbf{X}^h_{it} - \mathbf{X}^v_{it}) + e_{it}, \qquad (2)$$

where $\mathbf{X}^h_{it}$ is the vector of team efforts for the home team during game i in week t, $\mathbf{X}^v_{it}$ is the corresponding vector for the visiting team, h and v are indexes identifying the home and visiting teams, and $\boldsymbol{\beta}$ is the coefficient vector. The summary statistics in table 2 confirm that, for 1984 as well as 1983, equation (2) "explains" a large percentage of the variance of score differentials.

It is another matter to *predict* the efforts of the teams. In their betting simulation, Zuber et al. used as predictors of future effort per game averages of their effort variables, calculated from previous weeks. But do these predictors add any information to that already provided by the publication of the Vegas line in daily newspapers? The EMH implies that market forecasts such as the Vegas line fully reflect all relevant information. Hence, including the Zuber et al. predictors along with the Vegas line in a regression equation in which the dependent variable is the score differential would not, under the EMH, improve on a forecast based solely on the Vegas line.

We address this question by employing the OLS equation

$$PS_{it} - VL_{it} = \boldsymbol{\beta} \cdot (\hat{\mathbf{X}}^h_{it} - \hat{\mathbf{X}}^v_{it}) + w_{it}, \qquad (3)$$

TABLE 3

INFORMATION ADDED BY THE ZUBER ET AL. VARIABLES: 1983
(Dependent Variable: Score Differential Minus Vegas Line)

Coefficient	Estimate	t-Statistic
Intercept	−.217	−.158
Rushing yards	−.077	−1.192
Passing yards	.027	.772
Wins	.781	1.331
Fumbles	2.544	.571
Interceptions	3.715	1.102
Penalties	.011	.013
Pass percentage	−.224	−.668
Rookies	.282	.714
R^2	.051	
$\bar{R}^2$	−.023	
Sum of squared residuals	21,513	
Total sum of squares	22,674	
Degrees of freedom	101	

NOTE.—These results are for the final 8 weeks of the 1983 season. Similar results for several subsets of the 1983 and 1984 seasons are available from the authors on request.

in which the difference between the home-away point differential and the Vegas line is regressed on the Zuber et al. predictors: $\hat{\mathbf{X}}_{it}^{h} = 1/(t-1) \cdot \Sigma_{s=1}^{t-1} \mathbf{X}_{s}^{h}$, with $\hat{\mathbf{X}}_{it}^{v}$ similarly defined.[5] The equation is estimated for the second half of the 1983 season, the same period during which the authors' system showed a positive profit. Summary statistics are presented in table 3. One cannot reject the null hypothesis (EMH) that the coefficients of their variables are all jointly equal to zero (the F-test statistic for the hypothesis that $\beta_1 = \beta_2 = \ldots = \beta_9 = 0$ is 0.55, well below the critical value of 1.91 at the 95 percent level).[6] Furthermore, the regression "explains" only 34 points of the score differential that are not accounted for by the Vegas line.[7] This amounts to a difference of 0.35 points per game, which seems difficult to exploit. We conclude that the Zuber et al. variables add virtually no information to that already imbedded in the Vegas line.

[5] This procedure is equivalent to regressing the point differential on the Zuber et al. variables and the Vegas line, with the restriction that the coefficient on the Vegas line equal 1.0. See the Appendix for estimation results in which the coefficient of the Vegas line is unrestricted.

[6] Note that this test uses an information set restricted to the authors' variables; hence more powerful tests of the EMH that use additional relevant information could be constructed. The purpose here, however, is to focus on the forecasting power of their variables. Note also that, by the argument in n. 2, the t-statistics for the Zuber et al. variables in table 3 would have an upward bias.

[7] This figure is the square root of (22,675 − 21,514) from table 3. For 1984, the figure is 39 points and the F-statistic for the test of the EMH is 0.94.

IV. Betting Simulations for 1984

The argument of Zuber et al. that the market for NFL betting is inefficient rested on the demonstration that, for 1983, positive profits could have been earned by employing a particular betting strategy. The evidence presented above suggests that their result may be spurious.

The authors' method uses sequential reestimations of the contemporaneous explanatory model over the last half of the season to provide parameter estimates, which are then applied to the predicted net efforts of the two teams. This procedure yields the prediction

$$\widehat{PS}_{it} = \boldsymbol{\beta}_t \cdot (\hat{\mathbf{X}}^h_{it} - \hat{\mathbf{X}}^v_{it}), \quad t = 9, 10, \ldots, 16, \tag{4}$$

where the vector $\boldsymbol{\beta}_t$ is obtained by estimating equation (2) with data through week $t - 1$, and $\hat{\mathbf{X}}^h_{it}$ and $\hat{\mathbf{X}}^v_{it}$ are as previously defined.

Next, a filter test is employed, indicating that bets are to be placed whenever $|\widehat{PS}_{it} - VL_{it}| > \delta$, where δ is an arbitrary filter value. Once it is determined that a bet should be placed, the sign of $(\widehat{PS}_{it} - VL_{it})$ indicates the team to bet. A positive sign implies a bet on the home team; a negative sign indicates a bet on the visitor. Winning bets are those for which $(PS_{it} - VL_{it})$ and $(\widehat{PS}_{it} - VL_{it})$ are of the same sign.

The procedure was undertaken for $\delta = 0.5$, 1, 2, and 3. Table 4 presents the 1984 results along with those for 1983 using $\delta = 0.5$. Only 39 of 101 bets were winners in 1984. The winning percentage of 38.6 percent is far less than the 52.4 percent needed to break even (see Zuber et al. 1985, p. 804), resulting in net losses of \$2,920.[8] This occurs despite the fact that the explanatory power of the contemporaneous Zuber et al. model for 1984 exceeds that for 1983 (R^2 of .805 vs. .733). We conclude that the authors have not constructed a model that can consistently produce profitable gambling opportunities.

V. Conclusion

Zuber et al. qualified their claim of uncovering a speculative inefficiency in the market for football betting. The evidence in this note amplifies their qualification. Hypothesis tests for the 1983 and 1984 seasons are uniformly consistent with the efficient markets hypothesis and reject the extreme alternative hypothesis of Zuber et al. Furthermore, for the purpose of predicting game outcomes, the net effort variables used in their model add no information to that already incorporated in the Las Vegas gambling line. The method for exploit-

[8] Simulations using $\delta = 1.0$, 2.0, and 3.0 yielded returns of $-\$2,510$, $-\$1,600$, and $-\$1,520$, respectively.

TABLE 4

A. Gambling Simulations: Final 8 Weeks of 1984 Season

Week	Number of Bets	Number of Wins	Wins/ Bets (%)	Sum Gambled ($)	Net Return ($)	Rate of Return (%)
9	12	5	41.7	1,320	−270	−20.5
10	14	4	28.6	1,540	−700	−45.5
11	12	6	50.0	1,320	−60	−4.5
12	14	5	35.7	1,540	−490	−31.8
13	11	4	36.4	1,210	−370	−30.6
14	13	4	30.8	1,430	−590	−41.3
15	12	5	41.7	1,320	−270	−20.5
16	13	6	46.2	1,430	−170	−11.9

B. Cumulative Net Dollar Returns

Week	1983 NFL Season (Zuber et al.)	1984 NFL Season (Sauer et al.)
9	140	−270
10	390	−970
11	640	−1,030
12	470	−1,520
13	90	−1,890
15	1,340	−2,750
16	1,380	−2,920

ing the supposed inefficiency claimed by the authors is shown to incur substantial losses when extended out of the sample on which it is based. Their paper thus fails to provide sufficient evidence to support the argument that speculative inefficiencies exist in the betting market for NFL games.

Appendix

TABLE A1

Unconstrained Regressions for Information Added by the Zuber et al. Variables: 1983 (Dependent Variable: Home-Away Score Differential)

Coefficient	Estimate	*t*-Statistic
	First Regression: Zuber et al. Variables Plus Vegas Line	
Intercept	−2.331	−1.165
Rushing yards	−.087	−1.351
Passing yards	.004	.097
Fumbles	1.320	.292
Interceptions	2.904	.854
Penalties	.254	.298
Pass percentage	−.210	−.629
Wins	−.491	−.465
Rookies	.473	1.141
Vegas line	1.865	3.111
R^2	.324	
Sum of squared errors	21,082	
Total sum of squares	31,186	
Degrees of freedom	102	
	Second Regression: Vegas Line Only	
Vegas line	1.290	6.962
R^2	.304	
Sum of squared errors	22,185	
Degrees of freedom	111	

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