Testing Market Efficiency in a Controlled Environment: The Case of Parimutuel Gambling

by

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I. Introduction

The pricing efficiency of agricultural futures markets has long been a question of considerable interest and concern. Numerous authors have recognized that futures markets generate information about future prices which producers and marketing firms use in making production, marketing, and inventory decisions. If these prices do not appropriately reflect expectations of supply and demand conditions, a misallocation of resources may result, bringing about a reduction of economic surplus.

Since publication of Fama's seminal work, numerous empirical studies have attempted to evaluate the efficiency of markets. By Fama's (1970) definition, a market is considered to be efficient if all relevant and ascertainable information that is available to market participants is reflected in prices or in the returns to profit-seeking activities. Most empirical studies of market efficiency have examined commodity or financial asset markets and have concerned themselves with the adjustment of prices to three relevant information subsets, as proposed by Fama. "Weak" form tests evaluate whether past prices alone can be used to predict current prices. "Semi-strong" form tests concern whether prices efficiently adjust to other information that is publicly available. Finally,"strong" form tests are concerned with demonstrating whether any special group is able to achieve a higher than average rate of return.

A limitation of many empirical studies of market efficiency lies in the difficulty associated with defining and measuring the information that is available to the market participants. Most empirical tests of market efficiency carry with them the maintained hypothesis that the researcher can accurately measure all relevant information. In this light, empirical tests which reject or fail to reject market efficiency with respect to subjective information are problematical, since such information is seldom available in an explicit enough form that it can be easily quantified and analyzed statistically. Another limitation of conventional studies of efficiency is that many use aggregate market-level price data that may introduce aggregation biases (Keane and Runkle, 1990).

The ideal situation would be to study a market in which the majority of participants utilize a common primary source of information. Likewise, it is preferable to observe precise forecasts from experts about the outcomes of a set of investment strategies. Ideally, market information and forecasts should be widely disseminated among participants. The market should also generate a set of prices free from aggregation biases which could be analyzed to see if they fully discounted all the relevant information and the experts' opinions. Neither commodity nor financial markets operate in this manner, but this is the exact situation that occurs in a parimutuel gambling market.

A number of studies have investigated speculative efficiency in parimutuel gambling markets.

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While several of these studies have concluded in favor of efficient markets (Dowie 1976; Snyder 1978; Ali 1979; Figlewski 1979), others have found inefficiencies that permit profitable gambling (Hausch, Ziemba, and Runinstein 1981; Tuckwell 1983; Asch, Malkiel, and Quandt 1984; Gabriel and Marsden 1990). In a similar line of research, Vergin and Scriabin (1978) and Zuber, Gandar, and Bowers (1985) have found significant inefficiencies for Las Vegas gambling on National Football League (NFL) games.

The vast majority of participants in parimutuel racetrack gambling markets utilize the daily racing program as their primary source of information. Thus, a wide range of relevant market information, known to be used by investors (bettors), is available to the researcher. Expert opinions of forecasts are available in the form of handicapping services. Probabilistic measurements of market expectations are also available in the form of post-time (final) odds. These characteristics offer a favorable framework for evaluating speculative efficiency where the information and returns to investment for a relatively small pool of participants may be easily measured and used to construct empirical tests of efficiency.

Racetrack betting offers a particularly interesting environment for efficient market analysis because of its many similarities to financial securities and commodity markets. For examples, in both types of markets a large number of investors (bettors) have access to widely available information. In addition, once an investment (bet) is made, the return can not generally be guaranteed; in other words, the return on an investment (bet) is uncertain. Also, the possibility of "insider information" closely parallels that of the stock market. Such similarities make racetrack wagering a logical and natural candidate for testing the efficient markets hypothesis.

This analysis will assess the efficiency of the Woodlands greyhound parimutuel gambling market in Kansas City, Kansas. Parimutuel gambling was introduced into Kansas in 1989. The industry is young and many market participants are still learning the market's fundamentals. Data from over 500 races have been assembled, yielding 4,200 observations.

Market odds, professional handicappers' forecasts, and detailed handicapping data are used to evaluate the profit opportunities offered by alternative gambling strategies. "Weak" tests of efficiency are conducted in the context of multinominal logit regression models by comparing the in-sample explanatory power of final odds, professional handicapper forecasts, and publicly-available handicapping data collected from a primary information source, the daily racing program. "Strong" tests of efficiency that compare the out-of-sample predictive power and profit opportunities offered by alternative gambling strategies are also conducted.

II. The Greyhound Parimutuel Gambling Market

There are currently 60 greyhound racetracks in the United States. In 1990, nearly $3.5 billion was wagered on greyhound racing in the U.S. (American Greyhound Track Operators Association 1991). According to the American Greyhound Track Operators Association (1991), greyhound racing is considered by many to be the most consistent and predictable form of parimutuel wagering.

The greyhound racing market may offer a simpler informational environment for gamblers

to formulate their expected probabilities than traditional horse racing.[2] This is because performance uncertainty is limited to the animal and environmental conditions whereas bettors at a horse track must also contend with uncertainty regarding the rider's performance. In addition, there are always eight entries in every dog race while the number of entries in horse races may vary between four and twelve entries. In light of these points, handicapping may be more straightforward for greyhound racing than for other forms of parimutuel gambling.

Each greyhound performance involves 13 to 15 races of eight dogs in each race. Betting windows open approximately 20 minutes before each race. Opening odds (i.e., the morning line) are set by the track management and reflect their expectation of post-time odds. The odds are adjusted approximately every 30 seconds throughout the betting period. As bets are posted throughout the wagering period, the odds may shift significantly. The betting window closes immediately before the race and the final odds which determine actual payouts become known approximately 30 seconds later. Although the opening odds may significantly influence the final odds, the two can differ substantially.[3] Thus, bettors have limited information and face uncertainty about final odds while the betting window is open.

The final odds on a given bet reflect the market's estimate of the probability associated with winning that bet. However, the exact market odds will differ slightly from the posted final odds because the latter are adjusted for the commission (take) of the State and track (18 percent of the total pool on win, place, and show bets and 19 or 20 percent of the total pool on exotic bets) and are rounded down to the nearest tenth. This second adjustment is known as "breakage" and is retained for purse winnings. As Asch, Malkiel, and Quandt (1984) note, because of the take, speculative efficiency should ensure that returns to any gambling strategy should be approximately −18 percent on standard bets and −19 or −20 percent on exotic bets. Because the odds for each entry are affected in a homogeneous manner by the take, the final odds provide a suitable metric for measuring the final market odds, subject to the limitations imposed by breakage rounding.[4]

III. Subjective Information, Market Odds, and the Daily Racing Program

Efficiency of a market requires that prices and returns incorporate all publicly-available information. In a parimutuel gambling market such information can be grouped into three categories: publicly-available subjective information such as professional handicappers' forecasts; market odds which summarize the market's best estimate of winning probabilities for each entry; and factual performance and physical characteristics data that are relevant to the formulation of

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[2]In contrast to conventional gambling on games of chance with known probabilities where participants wager against the house, parimutuel gamblers wager against one another and thus face uncertain odds. Thus, bettors with superior forecasting ability will be successful at the expense of less-informed gamblers.

[3]A regression of opening odds on final odds for the sample evaluated below yielded an R^2 of .44, confirming the limited reliability of opening odds as an indicator of final odds.

[4]Over the 1990-91 racing season at the Woodlands, breakage totaled 1.79% of the total commission and .35% of the total pool (Kansas Racing Commission 1991). Thus, on average, the expected rates of return should be reduced by .35% to account for breakage.

bettors' own subjective forecasts of winning probabilities.[5] Handicapping guides emphasize the importance of the factual performance data that are summarized in the daily racing program to successful parimutuel gambling (see, for example, Ainslie 1986; Romanelli 1989; and Illich 1971). Ainslie (1986) states that the daily racing form is "indispensable" and that successful handicapping is "impossible" without it.

The *Official Program of the Woodlands* is the daily racing form available to bettors at the track under study. This program contains a wide range of factual data that are available to bettors for handicapping purposes. In addition, the morning-line odds on each entry and a professional handicapper's predicted finish order are provided in the racing form.

IV. Model Specification

An empirical model for assessing the speculative efficiency of a gambling market will relate *ex-ante* observable information to actual *ex-post* event outcomes. In an informationally efficient market, the final market odds should reflect all available information, including performance data and professional handicappers' forecasts. Thus, a simple test of efficiency can be considered by evaluating the explanatory power of publicly available information in a forecasting model containing the market odds. If the professional handicapper's forecasts or other handicapping data are statistically significant in the presence of final market odds, informational inefficiencies are implied.

Parimutuel gambling typically involves wagers made on discrete events. That is, bettors wager that a certain discrete event will occur (i.e., that the ith dog wins) and payouts are made if the discrete choice is correct. In such an environment, the magnitude of the win (e.g., the distance between the winner and the second place finisher) is irrelevant. In modeling probabilities of discrete events such as finish places in a dog race, models that explicitly recognize the discrete nature of the dependent variable are necessary. In this analysis, ordered multinomial logit regression models are utilized to model finish outcomes of greyhound races. For the ordered multinomial logit model, the probability that entry i will finish at a position greater than or equal to j is given by:

$$(1) \qquad P_i^j = F(\alpha_j + X_i\beta) = \frac{1}{[1 + \exp(-\alpha_j - X_i\beta)]} \, .$$

The logit parameters do not directly correspond to probability changes implied by changing the explanatory variables. However, the signs of the parameters do correspond to predicted finish orders. That is, the predicted finish place (1 through 8) is directly related to the sign of the parameter and thus the probability of winning varies inversely with the parameter estimate.

Three logit models are estimated and used to evaluate a "weak" in-sample form of efficiency. The first contains only the market's final odds. The second contains the subjective forecasts of a professional handicapper. The third contains a wide range of performance and physical characteristics data that are offered in the daily program for handicapping purposes. Nested likelihood ratio tests are used to compare the informational content of the alternative models.

Data related to each entry's past performance, grade, and post patterns for over 500 races

[5]Other intangibles, such as privately held information about the physical condition of an entry, may also be relevant but are impossible to measure.

ran in March and April of 1991 were collected from selected issues of the *Official Program of the Woodlands*. A professional handicapper's predicted finish order was also collected for each race. Final market odds and actual finish orders were collected for each entry from results charts in subsequent issues of the program. "Maiden" grade races were deleted from the empirical analysis because such entries did not have a performance history for use in the models.[6] These data yielded 4,200 entry-level observations. Factual performance and physical characteristics variables are discussed in detail below. Variable names are given in parentheses. Of course, the performance indicators are highly correlated, raising the issue of multicollinearity. However, in light of the forecasting motivation of the logit model, such correlation is of limited concern.

A number of performance characteristics are made available in the daily program for handicapping purposes. Several of these variables were considered as being possible indicators of a given entry's expected performance. The average of the entry's five best running times from its previous ten races (Average Best Time) was used as an explanatory variable. In addition, the entry's fastest time ever (Best Time Ever) and the time of the entry's last race (Last Race Time) were included in the logit model.

In addition to the time performance variables, a number of performance indices were constructed and included in the logit model. An overall performance index for each category was constructed by weighting the proportions of first place finishes by one-half, second place finishes by one-third, and third place finishes by one-sixth.[7] Thus, the empirical model included four variables that indicated past performance at the same grade (Grade Performance Index), distance (Distance Performance Index), post position (Post Performance Index), and track (Track Performance Index).

Grade change patterns in the history of an entry may be an important indicator of expected performance. According to the handicapper's guide in the *Official Program of the Woodlands*, there can be a large difference in the level of competition from one grade to another. Greyhounds that have not been winning at higher grades may improve dramatically when they drop in grade and vice versa. Dummy variables equal to one when an entry has risen from a lower grade (Grade Change Up) or has fallen from a higher grade (Grade Change Down) are included in the model.

The post position refers to the position of the track where the entry begins the race. This may be an important indicator of the probable finish probabilities for two reasons. First, most dogs develop a preference for running in a certain portion of the track (i.e., inside, middle, or outside). These preferences are indicated in the racing program. If a dog is starting in the section of the track where it prefers to run, a dummy variable (Preferred Running Style) is given a value of one. Second, dogs that start in the middle portion of the track are at a significant disadvantage because they are more subject to crowding.[8] A dummy variable (Mid-Track Posting) that is given a value

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[6]Entries are grouped (graded) according to previous performance to ensure competitive racing. Novice entries without a track record are termed "Maidens."

[7]The selection of this particular form of index, while admittedly ad-hoc, was based upon its superior empirical performance relative to other alternatives.

[8]An examination of the average finish positions by post confirms this disadvantage. In particular, dogs starting in post positions 1 (the inside portion of the track) and 8 (the outside portion of the track) had average finish positions of 4.28 and 4.13, respectively. In the absence of

of one for those dogs starting in post positions 3-6 is included in the empirical model to represent post position biases.

There are 18 kennels licensed to enter dogs in races at the Woodlands track. The kennels train and condition dogs for racing. Two variables ranking the success of the individual kennels were included in the model. The first indicates the entry's kennel's rank, based upon total winnings, among the eighteen kennels for the entire season (Season Kennel Rating). The second variable contains an identical evaluation for the ten preceding racing days only (Recent Kennel Rating).

Physical characteristics such as an entry's age, weight, and sex may also be relevant to finish probabilities. The entry's age (Age) and weight (Weight) are included in the model. A dummy variable equal to one if the dog is female (Sex) is also included in the model. Finally, the dog's total career winnings (Career Winnings) were included in the equation. Winnings are another important indicator of past performance.

Comparisons of performance variables must be undertaken in relative rather than absolute terms. In order to undertake such relative comparisons, the mean values of each continuous performance variable for the eight entries in each race were calculated. The continuous performance characteristics for each entry were then subtracted from the mean of all entries in that race in order to permit evaluating each characteristic relative to the mean for all entries in the race. For example, the average best time variable for entry i in race j is entered in the empirical model as the deviation from the mean average best time for all entries in race j.[9] One exception to this adjustment was made for the winnings variable, which performed much better when entered into the empirical model in absolute terms.

V. Empirical Application and Initial Efficiency Tests

Three alternative empirical models were considered for the initial efficiency tests. Model I contained only the final market odds, which summarize the market's forecasts of finish probabilities. Model II contained only two dummy variables representing the professional handicapper's first and second place forecasts. Model III contained the handicapper's forecasts and the performance and physical characteristics data that are hypothesized to be relevant to bettors' subjective handicapping. It is important to note that only Models II and III could be used by bettors to construct *ex-ante* forecasts since the explanatory information contained in Model I is unknown to bettors during the betting period. Weak, in-sample tests of efficiency can be considered by comparing the explanatory power of the performance data and the professional handicapper's subjective forecasts to the market's best estimate of the finish probabilities, as indicated by the final odds. If the performance data and/or the professional handicapper's forecasts are statistically significant in the presence of the final odds, the market is not incorporating all available information into its forecasts. A similar result is also implied if the models containing the handicapping data have more explanatory power than the model containing only the market's final odds.

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any such biases, the average finish position should be 4.5 for all posts. In contrast, dogs starting in positions 4 and 5 had average finish positions of 4.57 and 4.59, respectively.

[9]A small number of the entries had never started at the post, grade, or distance of the race being evaluated. In this case, the particular mean-adjusted performance index was given a value of zero, implicitly replacing the missing performance index value with the mean value of the other dogs in the race.

Maximum likelihood parameter estimates and summary statistics for the three logit models are presented in Table 1. Model chi-square tests indicate overall statistical significance of the various factors in explaining finish orders in each model. In spite of the suspected presence of multicollinearity, several of the performance variables are highly significant and are of the expected signs in Model III. In particular, the handicapper's first place pick, opening odds, the recent kennel rating, the average best time variable, the post performance index, the mid-track dummy variable, sex, the grade change up variable, and winnings are all significantly related to finish probabilities.

A comparison of the relative in-sample explanatory power of the three logit models may be drawn from an evaluation of the maximized log-likelihood function values. The largest log-likelihood function value is obtained for Model III, which contains the performance data, physical characteristics information, and the professional handicapper's subjective forecasts. The model containing the final odds had the second largest log-likelihood function value. The model containing only the professional handicapper's forecasts has the lowest degree of in-sample explanatory power. The finding that the bettors' handicapping data has greater explanatory power than the aggregate market's forecast, as indicated by the final odds, has important implications for the speculative efficiency of the market. In particular, it implies that market participants are not using all available information in formulating their forecasts about the outcome of the race. The significance of the differences in explanatory power between the alternative logit models can be evaluated using nested specification tests. A number of nested likelihood ratio tests are presented in Table 1.

Market efficiency suggests two important questions that may be addressed by the nested hypothesis testing. First, are the professional handicapper's subjective forecasts fully discounted by the market? Second, does the market fully discount relevant information about past performances and physical characteristics? The first question may be addressed by considering the significance of the professional handicapper's picks in a model containing final odds. The likelihood ratio test statistic has a value of 21.62 which exceeds the chi-square critical value at the .01 level of significance. Thus, based upon the in-sample performance of the models, weak speculative inefficiency is implied since the market does not appear to fully discount the professional handicapper's subjective forecasts. A likelihood ratio test of the significance of the performance and physical characteristics data in a model also containing the final odds has a value of 216.22 which strongly rejects the null hypothesis that the bettor handicapping data is not statistically significant in the presence of final odds. This result also suggests a weak form of speculative inefficiency because the market is not fully discounting relevant handicapping data. In both cases speculative inefficiencies are implied since relevant information that could be used to form improved finish forecasts appears to be neglected by the aggregate market.

Other nested hypothesis tests are also of interest. One may consider whether the aggregate market utilizes additional information relative to the professional handicapper and whether the handicapper incorporates all relevant performance data in constructing his or her forecasts. A likelihood ratio test of the significance of final odds in the presence of the handicapper's picks has a value of 269.47 and thus suggests that additional information is contained in the final odds. This result is not surprising since the market bettors may utilize information, such as track and weather conditions and the physical appearance of the entries, that is not available to the professional handicapper when he or she makes their forecasts. A test of the significance of the bettor handicapping data in the presence of the professional handicapper's picks has a value of 398.40, strongly suggesting that the handicapper's forecasts do not incorporate all relevant market data.

Finally, one may consider whether the final odds contain information that is not available in the bettor handicapping data and whether the professional handicapper's forecasts contain subjective information in addition to the past performance and physical characteristics data. Likelihood ratio tests suggest that both the final odds and the handicapper's forecasts are statistically significant in the presence of the bettor handicapping data. The first result is not surprising since, as noted above, market bettors may have additional information at the time bets are placed. The second result suggests that the professional handicapper may have knowledge of certain intangibles that are not reflected in the past performance and physical characteristics data.

VI. Out-of-Sample Prediction and Alternative Efficiency Tests

A stronger test of speculative efficiency addresses the issue of whether a rate of return significantly above that required for efficiency can be earned through gambling. If a parimutuel market is fully efficient, the final odds will fully reflect the actual finish probabilities and any gambling strategy will earn the same negative rate of return over the long run. Thus, this stronger form of efficiency requires that returns to any given gambling strategy should not exceed the −18 to −20 percent rate of return that is imposed by the proportion of the total gambling pool that is withheld from gamblers.

The preceding analysis suggests two possible approaches to constructing *ex-ante* out-of-sample forecasts for use in gambling. The simplest approach would be to adopt the professional handicapper's forecasts for use in gambling. The professional handicapper forecasts the order of the top four finishing entries in each race. A gambler could utilize this forecasted finish order to construct a number of different wagers. If, as suggested by the weak-form in-sample tests, the handicapper's forecasts are not fully discounted by the market, the potential for above-normal profits may exist.

A second gambling strategy making use of information available prior to a race involves the construction of *ex-ante* finish forecasts from the logit model using available handicapping data. Predicted values from the logit model represent finish probabilities which can be evaluated among entries in a race to formulate a wager. The in-sample tests of efficiency suggested that the market odds do not fully incorporate potentially relevant handicapping data and thus suggest the potential for above-normal rates of return to gambling.

Past tests of speculative efficiency in gambling markets have typically limited considerations to simple win, place, and show wagers. Win wagers pay the bettor if the entry finishes first. Place and show wagers pay for first and second or first, second, and third place finishes, respectively. Over the 1990-91 gambling season at the Woodlands track, 17.1 percent of all funds wagered were for win, place, and show bets (Kansas Racing Commission 1991). A number of alternative wagers are also available to bettors, some of which are considerably more popular at the Woodlands than the win, place, and show wagers. A quinella wager requires that the bettor correctly choose the first and second place finishers, without regard to the finish order. In a race with eight entries, there are 28 possible quinella wagers. Over the 1990-91 season at the Woodlands, 20.6 percent of all wagered funds were bet in quinellas (Kansas Racing Commission 1991). An exacta wager requires that the bettor correctly choose the first and second place finishers in order. In a race with eight entries, there are 56 possible exacta wagers. Exacta wagers accounted for less than 2 percent of the total 1990-91 handle at the Woodlands (Kansas Racing Commission 1991). The most popular wager at the Woodlands is the trifecta, which accounted for 41.6 percent of the 1990-91 handle (Kansas Racing Commission 1991). With the trifecta, the bettor must select the first, second, and third place finishers in order. In a race with eight entries, there are 336 possible trifecta wagers. The exotic wagers are not available in every race. Each wager costs the bettor $2.00 and payouts usually reflect the number of possible wagers, with the trifecta typically paying the highest return.

Two out-of-sample gambling simulations were performed to conduct alternative stronger-form tests of speculative efficiency in the parimutuel market. The last 32 performances of the sample were isolated and used to conduct the simulation. Each performance consisted of 13 to 15 races, yielding a total of 402 races for the evaluation. A rate of return to each gambling strategy was calculated for each performance. The averages and standard deviations for the rate of returns are used to conduct efficiency tests. If the average rates of return are statistically greater than the rates suggested by an efficient market, speculative efficiency is rejected.[10]

The first simulation utilized the professional handicapper's forecasts to construct simulated win, place, show, quinella, exacta, and trifecta wagers. Table 2 contains rates of return for the simulated wagers constructed from the professional handicapper's predictions. Average rates of return are all negative and appear to be consistent with strong-form efficiency. One-tailed t-tests of the equivalence of the simulated rates of return with efficient rates (−18 percent for the win, place, and show bets, −19 percent for the quinella and exacta wagers, and −20 percent for the trifecta) are evaluated against the alternative hypothesis that the simulated rates of return are above efficient rates.[11] The t-tests support efficiency in every case. In this light, implications of speculative inefficiency from the preceding in-sample weak-form tests are not supported in the stronger out-of-sample evaluations.

The second out-of-sample evaluation of efficiency utilizes forecasts constructed from the logit model of bettor handicapping data. An initial sample of 146 races from 12 performances yielded 1,137 observations that were used to provide initial estimates of the logit model of handicapping data. First-place finish probabilities for each entry in each race were forecast from the logit model, which was then updated after each performance as the new handicapping data became available. This approach yielded out-of-sample forecasts of each entry's winning probability, conditional upon the available handicapping data. Simulated wagers were formulated from the probability forecasts for each entry in a race.

Rates of return to each gambling strategy are presented for the 32 performances of the simulations in Table 3. In general, the model of bettor handicapping appears to offer average rates of return that are above those required for efficiency. Average rates of return for win wagers, the quinella, and the exacta are all positive. Average rates of return for the other wagers are negative but are considerably above the −18, −19, or −20 percent required for strong efficiency. Statistical tests of efficiency, represented by one-tailed t-tests of the equivalence of the average rate of return to efficient values, show significant evidence of strong-form speculative inefficiencies. In particular, the results indicate that statistically significant above-normal rates of return could be earned through win, place, and show wagering as well as through quinella betting. The highest significant rate of return occurs for quinella wagers, which averages nearly 20 percent. A strategy of placing $2.00

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[10]In reality, the simulated bets would have a very small effect on the odds and payouts were such bets actually placed. However, for $2.00 wagers this effect is negligible since the average pool per race at the Woodlands in 1990-91 was over $30,000 (Kansas Racing Commission 1991). In fact, the large size of the average parimutuel pool suggests that much larger wagers would not be likely to significantly lower the simulated rates of returns.

[11]The t-tests provide a conservative assessment of efficiency since breakage likely reduces efficient rates by about .35%. Thus, efficient rates of return should average −18.35% to −20.35%.

quinella wagers would have yielded a gambler a net return of $147.60 over the 32 performances.[12]

In all, the simulation results using forecasts generated by the logit model of bettor handicapping provides significant evidence against full speculative efficiency in the parimutuel market. A caveat regarding the tests of efficiency should be acknowledged at this point. As is the case with any test of efficiency, the gathering of information is not costless. Handicapping bettors typically must purchase the racing program ($1.00 for each performance). Thus, total net returns should perhaps be reduced by the $32.00 required for an individual bettor to collect the relevant information. Such a correction was applied to the results presented in Tables 2 and 3 and did not alter the conclusions of the efficiency tests.

VII. Summary and Concluding Remarks

The objective of this paper was to evaluate the speculative efficiency of the parimutuel gambling market for greyhound racing. The considerable attention that is focused on bettor handicapping activities in most parimutuel markets suggested an evaluation of efficiency that compared subjective forecasts obtained from bettor handicapping data with those of professional handicappers and with the aggregate market's forecasts.

Speculative efficiency was tested in two ways. First, a weak form of efficiency was considered by comparing the in-sample explanatory power of the final market odds, a professional handicapper's forecasts, and the performance data typically used by bettors for handicapping. A logit regression containing both the final odds and the handicapper's forecasts indicated that the handicapper's forecasts were not entirely discounted by the market. A similar test indicated that relevant bettor handicapping data is not fully discounted by the market. Both results suggest violations of weak-form speculative efficiency. A logit model containing handicapping information available prior to each racing performance was found to have greater power in explaining race finishes than models containing the final market odds.

A stronger test of speculative efficiency evaluated rates of return generated from simulated gambling using out-of-sample forecasts of finish orders. This strong form of speculative efficiency requires that returns to any gambling strategy not exceed the normal rate of returns dictated by the proportion of the gambling pool that is withheld by the track. Two alternative out-of-sample forecasts were evaluated. First, simulated wagers were placed using the forecasts of a professional handicapper. Second, *ex-ante* finish forecasts were generated from a logit model using the bettor handicapping data. Statistically significant above-normal rates of return were revealed for wagers made using the forecasts generated from bettor handicapping data, but not for the professional handicapper's forecasts alone. This result violated strong-form speculative efficiency and suggested that above-normal profits could have been generated using *ex-ante* forecasts generated from the bettor handicapping data. These results are consistent with those obtained by Zuber, Gandar, and Bowers (1985) who rejected strong-from efficiency in an analysis using performance data to generate *ex-ante* forecasts of NFL game point spreads.

Several caveats apply to these results. First, we have largely ignored the potentially significant costs associated with collecting and processing the handicapping data. Recognition of

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[12]A stronger question of efficiency might ask whether the positive rates of return are significantly greater than zero. The average rate of return for the quinella is significantly greater than zero at the .11 level of significance.

such costs would certainly lower expected rates of return to gambling and thus could alter conclusions regarding efficiency. Second, the gambling simulations considered the operation of the parimutuel market only over a two month period. Strong verification of the potential for above-normal rates of return to gambling would require a much longer period of simulation. Finally, the parimutuel market in question is relatively young, having been established in 1989. Because the industry is young, the market's fundamentals may be unknown to many participants, thus offering well-informed bettors profit-seeking advantages. Bettor learning over time may alter the structural relationships between handicapping data, market odds, and the outcome of races revealed in this analysis and thus may improve the market's speculative efficiency.

References

Ainslie, Tom. *Ainslie's Complete Guide to Thoroughbred Racing.* New York: Simon and Schuster Inc., 1989.

Ali, Mukhtar M. "Some Evidence of the Efficiency of a Speculative Market." *Econometrica* 47 (March 1979): 387-92.

American Greyhound Track Operator's Association. *Greyhound Racing in America, 1991-92.* Miami, FL: American Greyhound Track Operator's Association, 1991.

Asch, Peter; Malkiel, Burton G.; and Quandt, Richard E. "Market Efficiency in Racetrack Betting." *J. Bus.* 57 (April 1984): 165-75.

Dowie, Jack A. "On the Efficiency and Equity of Betting Markets." *Economica* 43 (May 1976): 139-50.

Fama, Eugene F. "Efficient Capital Markets: A Review of Theory and Empirical Work." *J. Finance* 25 (May 1970): 383-417.

Figlewski, Stephen. "Subjective Information and Market Efficiency in a Betting Market." *J. P. E.* 87 (February 1979): 75-88.

Gabriel, Paul E.; and Marsden, James R.; "An Examination of Market Efficiency in British Racetrack Betting." *J. P. E.* (August 1990): 874-85.

Hausch, Donald B.; Ziemba, William T.; and Rubinstein, Mark. "Efficiency of the Market for Racetrack Betting." *Management Sci.* 27 (December 1981): 1435-52.

Illich, Albert G. *How to Pick Winners.* New York: Prentice Hall Press, 1971.

Kansas Racing Commission. "Cumulative Performance Report for Woodlands Kennel Club: September 6, 1990 through May 20, 1991." Topeka, Kansas. May 29, 1991.

Keane, M. P. and D. E. Runkle. "Testing the Rationality of Price Forecasts: New Evidence from Panel Data." *American Economic Review*, 80(1990):714-35.

Romanelli, Charles S. *How to Make Money in One Day at the Track.* New York: Simon and Schuster Inc., 1989.

Snyder, Wayne W. "Horse Racing: Testing the Efficient Markets Model." *J. Finance* 33 (September 1978): 1109-18.

Tuckwell, R. H. "The Thoroughbred Gambling Market: Efficiency, Equity, and Related Issues." *Australian Econ. Papers* 22 (June 1983): 106-18.

Vergin, Roger C., and Scriabin, Michael. "Winning Strategies for Wagering on National Football League Games." *Management Sci.* 24 (April 1978): 809-18.

Zuber, Richard A.; Gandar, John M.; and Bowers, Benny D. "Beating the Spread: Testing the Efficiency of the Gambling Market for National Football League Games." *J. P. E.* 93 (August 1985): 800-806.

Table 1. Parameter Estimates and Relevant Statistics for Multinomial Logit Models of the Parimutuel Greyhound Market

Variable	Model I	Model II	Model III
α_1	1.2482 (.0577)** [a]	2.1713 (.0511)**	1.7986 (.1234)**
α_2	.3605 (.0510)**	1.2982 (.0402)**	.8794 (.1192)**
α_3	-.2629 (.0502)**	.6930 (.0361)**	.2368 (.1183)*
α_4	-.8147 (.0502)**	.1618 (.0346)**	-.3296 (.1184)**
α_5	-1.3655 (.0537)**	-.3670 (.0351)**	-.8935 (.1192)**
α_6	-1.9964 (.0582)**	-.9716 (.0384)**	-1.5345 (.1210)**
α_7	-2.9211 (.0689)**	-1.8587 (.0494)**	-2.4624 (.1259)**
Post-Time Odds	.0930 (.0048)**		
Handicapper First		-.9582 (.0858)**	-.2896 (.0973)**
Handicapper Second		-.6153 (.0826)**	-.1476 (.0905)
Opening Odds			.0450 (.0105)**
Average Best Time			2.0047 (.1809)**
Recent Kennel Rating			.0131 (.0061)*
Season Kennel Rating			-.0060 (.0060)
Post Performance Index			-.5351 (.2674)*
Grade Performance Index			-.6113 (.4208)

[a]Numbers in parentheses are asymptotic standard errors. Single and double asterisks indicate statistical significance at the .05 and .01 levels, respectively.

Table 1. (continued)

Variable	Model I	Model II	Model III
Distance Performance Index			.6390 (1.0854)
Track Performance Index			-1.3623 (1.2089)
Mid-Track Posting			.2146 (.0577)**
Age			.0384 (.0329)
Weight			-.0025 (.0055)
Sex			-.1685 (.0792)*
Best Time Ever			-.1832 (.1027)
Last Race Time			.0004 (.0004)
Grade Change Up			.1911 (.0891)*
Grade Change Down			.1279 (.0864)
Preferred Running Style			-.0314 (.0639)
Career Winnings			-.0148 (.0043)**
Log of Likelihood Function	-8528.10	-8652.03	-8452.83
Model Chi-Square Test [b]	408.98**	161.13**	559.53**
Test of Final Odds		269.47**	65.67**
Test of Handicapper's Forecasts	21.62**		60.17**
Test of Bettor Handicapping Data	216.22**	398.40**	

[b]Test that all β_is are zero.

Table 2. Out-of-Sample Gambling Simulation Results Using Professional Handicapper's Forecasts.

Performance	Rate of Return to Gambling (%)					
	Win	Place	Show	Quinella	Exacta	Trifecta
1	33.33	-16.67	-7.08	157.27	-100.00	-100.00
2	-25.00	-0.83	-27.50	-18.18	-100.00	-100.00
3	-22.50	-25.00	-19.17	43.64	66.67	-100.00
4	8.33	-30.83	-20.00	-100.00	-100.00	-100.00
5	12.14	-3.57	-2.86	67.69	-100.00	440.00
6	-50.77	5.38	13.85	44.55	-100.00	-100.00
7	-100.00	-85.00	-64.17	-100.00	-100.00	-100.00
8	-30.83	-54.17	-36.67	-45.45	356.67	-100.00
9	-74.62	-32.31	-33.08	-50.00	-100.00	-100.00
10	83.57	4.29	-20.00	-76.92	-100.00	-100.00
11	76.15	56.92	20.77	45.00	750.00	-100.00
12	-24.17	-33.33	-26.67	-14.55	163.33	-100.00
13	-55.00	-32.92	-17.92	-75.45	-100.00	-100.00
14	-5.00	-0.83	0.83	14.55	-100.00	472.00
15	-9.17	-35.00	-5.00	122.73	-100.00	-100.00
16	-2.50	-23.33	-22.50	-28.18	-100.00	-100.00
17	-15.83	-26.67	-24.17	-11.82	-75.00	-100.00
18	-9.29	-26.43	-29.29	-30.77	47.50	-100.00
19	-65.33	-39.33	-46.00	-100.00	-100.00	-100.00
20	46.67	20.00	-1.67	-100.00	-100.00	-100.00
21	-20.00	-26.67	-30.83	-100.00	-100.00	-100.00
22	-60.00	-39.17	-50.83	71.82	-100.00	-100.00
23	-18.33	-12.50	-18.75	-40.00	90.00	465.56
24	-0.77	-13.08	-28.46	195.83	-100.00	-100.00
25	74.17	5.83	-10.83	-100.00	-100.00	-100.00
26	-44.17	13.33	-23.33	-12.73	-100.00	-100.00
27	-26.43	-22.86	-42.86	36.92	-100.00	-100.00
28	0.71	-9.29	11.07	-14.62	-100.00	-100.00
29	-50.83	-30.83	-35.83	-68.18	-100.00	-100.00
30	-14.62	-20.00	-12.31	-100.00	-100.00	-100.00
31	11.67	-16.67	-20.00	-47.27	-100.00	-100.00
32	-15.83	2.50	2.08	9.09	176.67	-100.00
Total Net Returns	-97.40	-136.50	-157.90	-98.40	-61.20	-301.00
Average Rate of Return	-12.32	-17.16	-19.66	-13.28	-25.76	-47.58
t-test of efficiency[a]	.77	.19	-.51	.57	-.15	-.92

[a]Test of equality of mean rates of return to efficient values. Critical value at $\alpha = .05$ is 1.65.

Table 3. Out-of-Sample Gambling Simulation Results Using Forecasts from Logit Model of Handicapping Data.

Performance	Rate of Return to Gambling (%)					
	Win	Place	Show	Quinella	Exacta	Trifecta
1	100.00	30.00	-5.41	-25.40	-100.00	292.20
2	-1.67	15.83	7.50	23.64	517.50	-100.00
3	8.33	-4.17	19.17	108.18	66.67	564.00
4	8.33	-5.00	-16.60	167.27	200.00	322.00
5	47.14	10.00	12.14	-100.00	-100.00	-100.00
6	-44.62	-5.38	11.53	159.09	410.00	-100.00
7	25.83	17.50	14.17	-12.73	-100.00	-100.00
8	-30.83	-54.10	-36.60	-60.00	60.00	146.00
9	-76.15	-33.00	-36.10	-100.00	-100.00	-100.00
10	81.43	7.86	-22.14	116.92	-100.00	-100.00
11	4.62	0.00	-13.08	-25.83	-100.00	-100.00
12	17.50	16.67	23.33	22.73	-100.00	-100.00
13	45.00	27.92	13.75	174.55	557.50	10.00
14	-25.00	25.00	32.50	71.82	-100.00	-100.00
15	-35.00	13.33	5.83	90.00	-100.00	-100.00
16	22.50	-3.33	-1.67	12.73	-100.00	-100.00
17	-45.00	-15.00	-32.50	-11.82	-75.00	-100.00
18	-9.29	-15.71	-8.57	68.46	47.50	-100.00
19	-38.67	-12.60	-32.60	-57.14	-100.00	-100.00
20	46.67	-14.10	20.00	-33.64	-100.00	367.00
21	-43.33	-44.10	-34.10	-100.00	-100.00	-100.00
22	-77.50	-52.50	-50.83	-77.27	-100.00	-100.00
23	31.67	0.00	14.58	-100.00	-100.00	-100.00
24	36.15	16.92	-8.46	13.33	-100.00	88.00
25	-6.67	0.00	0.00	-100.00	-100.00	-100.00
26	-3.33	24.17	30.00	-12.73	440.00	-100.00
27	22.86	-21.43	-5.00	173.08	-100.00	-100.00
28	-0.71	-20.71	-12.50	133.08	216.67	-30.83
29	-0.83	-13.33	20.83	121.82	-15.00	67.78
30	-63.85	-12.31	13.08	-50.00	-100.00	-100.00
31	4.17	0.00	-0.83	-47.27	105.00	-100.00
32	30.83	13.33	12.91	87.27	176.67	187.78
Total Net Returns	7.80	-29.10	-19.90	147.60	57.40	-51.80
Average Rate of Return	.96	-3.39	-2.06	19.68	25.23	-5.81
t-test of efficiency[a]	2.59*	3.81*	4.21*	2.44*	1.26	.47

[a]Test of equality of mean returns to efficient values. Critical value at $\alpha = .05$ is 1.65. A "*" indicates rejection.