Introduction to the Efficiency of Racetrack Betting Markets in England

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The parimutuel betting system utilizing electric tote boards is the dominant method of betting at North American racetracks. Under the parimutuel system, the win bet fractions may be interpreted as consensus subjective win probabilities provided by the public. In England, and in other Commonwealth countries, such as Australia and New Zealand and other European countries, such as Italy and France, the dominant system is the fixed-odds system where it is bookies who establish and offer the odds.

The fixed-odds system operates as follows. Bookies set odds that my vary throughout the betting period. Bettors lock in the odds at the level they are offered at the time of purchase, even if the offered odds changed later. Quite differently, locking in odds is not possible in the parimutuel system where odds are established only when the betting period is over. Under the fixed-odds system, changes in the odds are largely due to the bookies' efforts to balance their books to ensure a profit no matter which horse wins. Such price dynamics can allow an opportunity to hedge one's bets. Lane and Ziemba (1992)[2] analyzed how this can be accomplished for a race with two horses. Although far less popular, a parimutuel betting system using the tote board is also available in England for betting both on course and off course.

To test the market efficiency under the fixed-odds system, one can use the starting prices (SP) reported at the track. They are the bookies' final offered odds. Most off-course betting is offered at SP. Table 1 reports the rates of returns in lower odds ranges and lower returns for long odds horse. Thus, the favorite-longshot bias is present, despite the odds being the bookies' offerings.

Dowie (1976)[1] and Crafts (1985)[2] studied the efficiency of British racetrack markets. Dowie (1976)[1] considered two types of prices (odds): (i) Forecast prices (FP) - forecasts odds are estimated long before start of the race in *Sporting Life* which is widely regarded as the most authoritative racing information available in the press. Thus, it is similar to the morning line odds determined by the official handicappers in North America. (ii) Starting prices (SP) - the final odds made by the bookies as mentioned above. Dowie found that the correlation between forecast price and winning frequency is not significantly less than that between starting price and winning frequency. He considered that if insider information does exist, it will not be available to the public and only the final SP can reveal it. Therefore, he concludes that there is no insider information.

Crafts (1985)[2] disagreed with Dowie's point of view. His argument is that a gambler possessing inside information can bet earlier on more attractive odds than the final starting odds. To verify his argument empirically, he classified the win odds data using the ratio FP/SP, and then compared the expected returns in each range of FP/SP. The FP/SP ratio is an indication of the movement of the odds. For high FP/SP ratio ranges (i.e. the favorites are getting more popular), expected returns are positive and are better than the average. For low FP/SP ratios, on the other hand, the average expected returns are negative. This result is clearer for more favorite horses when the data is further classified by the SP odds levels. Hence, a gambler with insider information can bet long before the announcements of SP odds in order to gain much higher returns. According to his analyses, the market is "weakly efficient" since no strategy based on publicly available information would allow a profit at the odds available at the end of trading (SP). However, the market is also not weakly efficient because a bettor placing a bet early enough in a particular odds range can reduce expected losses (or increase expected returns) by betting

Table 1
Rates of returns for different SP odds ranges in British flat racing before taxes

SP odds Ranges	Rate of Return				
	1950	1965	1973	1975[a]	1976[a]
1-100 to 2-5	97.2	108.1	108.5	112.1	107.0
4-9 to 2-5	98.8	89.4	109.7	108.4	107.8
8-11 to 1-1	94.8	88.4	93.6		
21-20 to 3-2	96.5	87.2	88.6		
13-8 to 9-4	90.4	95.9	83.6		
95-40 to 4-1	95.5	95.0	95.5		
9-2 to 9-1	90.1	89.5	89.1		
19-2 to 18-1	64.5	64.9	66.5		
larger than 18-1	23.8	37.3	23.2		

Source: Ziemba and Hausch (1984)[2]. It is assumed that every horse in each odds range was bet to return 100 to break even.
[a] Data not available in some entries.

on those going in markedly in the betting (i.e. high FP/SP ratio). His results suggest that British racing offers considerable potential for profitable insider trading.

Crafts (1994)[1], in support of earlier work by Crafts (1985)[2], utilized the information provided by special decision rules (racing systems) which are sold to the public, with advertising reporting that they are profitable. However, his results indicate that gamblers who buy racing systems in the hope of profits do so in vain. Thus he concluded that all these advertisements of profitable systems are in fact misleading. Instead, following the results obtained in Crafts (1985)[1], he found a 55.8% return by betting on horses with a marked difference between FP and SP (FP/SP $\geq$ 1.5) which had been off the course for a long period. The results suggest that the British market includes insiders with potentially highly profitable information not known to the outsiders who buy racing systems which contain unprofitable methods of betting.

In Britain, the tote system is also being used as well as the fixed-odds system. Gabriel and Marsden (*1990*[1],*1991*[1]) compared the returns to *starting price bets placed with bookies and pari-mutuel* tote bets. They concluded that tote returns are higher than starting price returns, even though both betting forms are of similar risk and the payoffs are widely reported. This appears to reject semi-strong form efficiency. The result continued to hold as the season progressed, in spite of their argument that even if insiders exist, the final starting price and tote payments to winners should converge.

Ziemba and Hausch (1994)[1] propose a capital growth betting strategy for place wagering in Britain. This strategy is a modification of the one proposed by Hausch, Ziemba and Rubinstein (1981)[1] and further developed in Ziemba and Hausch (1984,1987)[2], because the British place bet is different from North American's.

Other articles using the U.K. racing data include Henery (1984)[2] and Henery (1985)[2]. Assuming the running times of horses are extreme-value distributed, Henery (1984)[2] tested predictive ability for the win probabilities. However, based on his U.K. fixed-odds system data, only the tail of the empirical distribution functions is consistent with the proposed extreme-value model. Henery (1985)[1], on the other hand, proposed an empirical linear regression model to explain the favorite-longshot bias in the U.K. racing market.

[1] included in this volume
[2] cited in our Annotated Bibliography

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On the Efficiency and Equity of Betting Markets

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I

Confident in the belief that vital resource allocation decisions depend on well functioning capital markets, economists over the last two decades have spent a good deal of their time, and not a little of the computer's, studying the behaviour of stock market prices. Their main aim has been to discover the extent to which capital markets, and in particular markets in equity shares, are "efficient". Perhaps surprisingly to the layman, their answer has usually been "very efficient", and despite the amount of effort devoted to attempts at refutation, Fama was able to conclude that "the evidence in support of the efficient market's model is extensive and (somewhat uniquely in economics) contradictory evidence is sparse" (Fama, 1970, p. 416).

The definition of "efficiency" being used is not, however, the usual one and reflects the fact that stock markets are being examined as information markets, not as service industries. A stock market is "efficient" if its prices always "fully reflect" "available information". Almost all the empirical work proceeds on the assumption that the conditions of market equilibrium can be stated in terms of expected returns, and it is becoming conventional to talk of three subsets of information in relation to the determination of equilibrium expected returns: historical prices (and returns), other publicly available information (e.g. announcements of earnings, issues, etc.) and "inside" information (i.e. information to which particular groups or individuals have monopolistic access at relevant points of time). Defining "available information" as each of these in turn produces "weak", "semi-strong" and "strong" tests of efficiency.

If prices always fully reflect historical prices in the sense that price changes approximate a random walk, the market is said to be "weakly efficient". The bulk of empirical work has been done in this area. While some drift is usually found and some filters (mechanical trading rules) have been discovered that produce profits in excess of a naive buy-and-hold policy, it is generally agreed that these have little practical significance given the transaction costs (brokerage) needed to implement them.

If prices fully reflect public announcements as soon as they are made, the market is said to be "semi-strongly efficient". Only a small, though rapidly growing, volume of work has been done on this, particularly on dividend announcements and bonus issues.

The third form of test is in many ways the most interesting, because it raises the problematic link between "efficiency" and "equity" in information markets. Do corporate insiders or others in the investment community (e.g. financial journalists) have monopolistic access to information that they can exploit in such a way as to produce above-average returns and contribute to, or even produce, the semi-strong and weak efficiency ordinarily found? (Samuelson has recently shown (1973, p. 373) that "there is no incompatibility in principle between behaviour of stocks' prices that behave like random walk at the same

time that there exist subsets of investors who can do systematically better than the average investors.") To the extent that such subsets exist, the phenomena of semi-strong and weak efficiency are of reduced interest, the implication being that publicly available information plays a less than crucial role in the allocation process. While Fama and others talk of "inside information"—using this as a catchall term—detracting from "strong efficiency" there seems to be a reasonable case for reserving the term "efficiency" for the publicly available information subsets (historical prices, public announcements) and using the term "equity" in place of "strong form efficiency". In other words, we will talk of a market as *efficient* to the extent that it passes the weak and semi-strong tests and *equitable* to the extent that it passes the strong test.

II

This preamble establishes the context for an excursion into another sort of market in information: betting on horse races. Even though it is quite possible that the detrimental effects on social welfare arising from inefficiency and inequity in betting markets are commensurate with those arising in capital markets, the more conventional justification for moving into this area is that

> . . . institutional forms of betting are of scientific interest for two reasons. They yield behavioural implications for individual decision-making under uncertainty. Furthermore, since these betting schemes give rise to wager markets with equilibrating functions similar to ordinary security (or commodity) markets, they afford opportunities for the study of market mechanisms under a widened class of contingency and institutional conditions. (Smith, 1971, p. 242)

A brief guide to betting markets on horse-racing in Britain is required. Conceptually there are two distinct forms of betting: fixed odds betting and pool betting. In the former a bookmaker accepts bets at specific, but changing, odds throughout the betting on an event, and the return to any individual bet is unaffected by bets made subsequently. In the latter a bet is made with less-than-complete certainty as to the return if successful, the odds being determined by the weight of money on each runner at the conclusion of betting. The conceptual difference does not produce practical differences in average returns to all successful bettors to the extent that (a) bookmakers are able to adjust their odds to the weight of money on each runner; and (b) pool (totalizator, pari-mutuel) bettors are kept informed about, and act upon, the number of units invested on each runner (note that these pool bettors may include bookmakers). In any event the conceptual distinction is not preserved institutionally in the United Kingdom because most betting with bookmakers is *not* at fixed and known odds. The bulk of on-course betting certainly is, and so is quite a lot of the betting on the more important races of the year on which ante-post books are opened. But most off-course betting—95 per cent or more according to "Michael Rolfe" of the *Sporting Life* (personal communication)—is at "starting price" (SP, defined as the odds at which a "sizeable" bet could have been made *on the course* just before the " off"). This is in one sense a fixed price, but it is clearly not known with certainty at the time of making the bet. The weight of off-course SP money is reflected in on-course prices as information, and money, is relayed to the course, and the actual SP is thus determined by both off- and on-course activity. Instances of manifestly imperfect equilibration are the focus, at different times, of complaints by both smaller off-course book-

makers and off-course punters, as well as constituting the basis for many "betting coup" attempts. But it is assumed here that these instances are not significant enough to undermine the general validity of the SP as an equilibrium price.

Pool betting has one great advantage from the investigators' point of view, and the limited American analysis in this area has all been done on this basis. Since bookmaking is illegal, except in Nevada, psychologists (Griffiths, 1949; McGlothlin, 1956), economists (Weitzman, 1965; Rosett, 1965) and others (Fabricand, 1965; Harville, 1973; Hoerl and Fallin, 1974) made use of pari-mutuel data. The great advantage is that a constant percentage is taken out of the pool by the operators. As a result the prices for every horse in every race are homogeneous in the sense that each odds always represents precisely the same proportionate weight of money invested. There is, therefore, no question as to *differentially* "unfair" odds being offered against the runners in the race. In contrast, in a bookmaking setup, we *cannot* be certain that all horses starting at any particular price represent equivalent obligations on the bookmakers' part. Despite this advantage, totalizator data in the United Kingdom suffer from three major disadvantages that more than offset this particular advantage.

The first is the low relative turnover. The proportion of total turnover accounted for by totalizator betting is less than five per cent. It would be dangerous to generalize upon this limited basis. The second factor is even more crucial. The Tote is still basically a manual operation in Britain, and consequently only the dividend of the winner is published—indeed, only the dividend of the winner is calculated except when there is a photo finish. As a result we have no comprehensive record concerning the totalizator odds at which every runner started, contrary to the American situation. The third and final advantage of concerning ourselves with bookmakers' starting prices rather than totalizator data is the existence of systematic *forecasts* of the former in the daily press. It is on these forecasts that we hinge much of the argument concerning the *equity* of betting markets.

III

The basic data resource for our investigation of betting markets are sets of starting prices (SP) and forecast prices (FP). A typical example of each, along with the arithmetic of their "standardization" (to be discussed later) appears in Table 1. The examples are typical in the sense that they relate to a ten-runner event in which the SP set is about 20 per cent "over-round" and the FP set about 35 per cent "over-round", these three figures being close to the medians of their respective distributions. The column following the SP and FP in Table 1 gives the unit stakes required to yield a return (stake plus winnings) of 100 at that price. Calculated as $100/(P+1)$, these are known in racing parlance as the "percentages". The sum of these percentages indicates, under the (strong) assumption that stakes were held appropriately, the bookmakers' gross percentage margin over the bettor on the event. Naturally they do not normally add to 100 and, even more obviously, they rarely fall below 100: no instance of a "Dutch" set of SP returns was found in the 1973 flat season in Britain.

The starting prices are returned by the representatives of the two daily racing papers, the *Sporting Life* and *Sporting Chronicle*. They observe the betting

TABLE 1

EXAMPLE OF STARTING PRICES (SP) AND FORECAST PRICES (FP) AND STANDARDIZATION PROCEDURE: CHERRY HINTON STAKES, NEWMARKET, 3 JULY 1973

		SP	Percentages	Probabilities	Standardized SP	FP	Percentages	Probabilities	Standardized FP	"Life" betting report
2nd	Mrs Tiggywinkle	15/8	34·8	29·0	5/2	2	33·3	24·6	3	proved a solid favourite at 7/4, 2/1 and finally 15/8
1st	Celestial Dawn*	4	20·0	16·7	5	12	7·7	5·7	16	good second best, although always returning to 4 from 7/2
	Caught in the Rye	6	14·3	11·9	15/2	9/2	18·2	13·4	13/2	sound business for at 7 and 6 (11/2 at times)
4th	Belle Tigresse	13/2	13·3	11·1	8	7	12·5	9·2	10	sound business for, closed in at 13/2 after touching 9 from 6
	Slipperty	7	12·5	10·4	17/2	3	25·0	18·5	9/2	receded from 5 to 7
	Ribella	12	7·7	6·4	15	14	6·7	4·9	20	receded from 8 to 12
	Wheal Jane	14	6·7	5·6	16	11/2	15·4	11·4	8	receded from 12 to 14
3rd	C'est Vrai	20	4·8	4·0	25	10	9·1	6·7	14	receded from 14 to 20
	Princess Donna	33	2·9	2·4	40	25	3·8	2·8	33	—
	Finishing Touch	33	2·9	2·4	40	25	3·8	2·8	33	—
			119·9	99·9	(99·5)		135·5	100·0	(99·9)	

* Tote 0·60 or approximately 11/2 SP.

in the principal ring (Tattersalls), concentrating on those bookmakers who can be relied upon to lay a substantial bet:

> These [bookmakers] are the men who take any money "unloaded" by bookmakers' offices through the "Blower", which usually arrives in the last few minutes and often causes rapid changes in the odds. These bookmakers co-operate with the newspaper men by allowing them to see the books if necessary, though most of the wagers can be overheard. The two journalists record the fluctuations of the odds from start to finish and immediately the "off" is signalled they meet to compare notes and fix the prices on which millions of starting-price bets will be settled. Just occasionally the market has been so stable that the two men are in perfect agreement, but this is rare and usually adjustments have to be made. One may have the favourite a sound even money chance, whereas the other can obtain 6–5. So that 11–10 is obviously a fair return. Similarly 11–4 is often a compromise between 5–2 and 3–1, while prices such as 13–2, 15–2 and 17–2 usually means that each man has "given" half a point to strike a correct balance. (O'Neill, 1971, pp. 57–58)

It is worth noting in passing that the results reported later suggest that the agreement is sometimes not reached until *after* the outcome of the race is known. Horses at compromise prices or "split odds" often tend to have a higher percentage return than those on either side—there being clearly a greater need to establish maximum agreement in the case of a winner or placed horse than in the case of a loser.

The forecast prices are produced by employees of various newspapers in the afternoon of the day preceding the race, and it must be emphasized that the forecast used in this particular analysis is simply one of several. They all differ to a greater or less extent and there is no such thing as "the" forecast. The ones we have chosen to use are those put out daily by the *Sporting Life*. These are produced by a number of individuals (about eight in all during 1973), though the forecast on any one race is produced by a single person. Two basic strategies are available and each is employed by some members of the group. The strategies differ in respect of the use made of the Press Association (PA) forecast that is sent to all subscribers soon after final declaration of runners at 11 am on the day before the race. Some papers' forecasters use this without significant change or modify it as they think fit while retaining the overall shape. Others largely

TABLE 2

	Times; Sun	Mirror	Guardian	Life	SP
2nd Prominent	9–2 Fav.		5	8	15/2
Red Power	5		4 Fav.	5 Fav.	6
1st Spring Stone	13–2		6	7	7
Ballyhot	8	7	6	6	6
3rd Malleny	8			12	14
Negus	10		8	9	13/2
Vedvyas	10				12
Offenbach	12	8	10	10	11/2 Fav.
Buss	12				14
Hardy Scot	14		10		14
Bright Fire	16			16	14
Tack On	20			14	20

ignore the PA forecast, compile a forecast of their own and, if they feel inclined, check the result against the PA. The differing practices are illustrated in Table 2 in relation to the P.T.S. Laurels Stakes run at Goodwood on 4 August (blanks indicate same odds as column (1)). *The Times* and *Sun* used the PA forecast, the *Mirror* brought a couple of middle-order horses in a bit, the *Guardian* made a lot of small changes and the *Life* (in the case of this race) clearly compiled its own forecast.

The only manipulation of the published data necessary was in the case of withdrawals. Where these occurred before the runners came under starter's orders the SP odds on all runners were adjusted in accordance with the official Tattersalls deductions, and this procedure was also followed—much more often, naturally—in the case of the forecast prices. The Tattersalls deductions are based on the odds of the withdrawn horse only, irrespective of the over-roundness of the market, but more precise adjustment was neither practicable nor unambiguously desirable.

IV

It is of course not possible to learn much from the SP return for a single race or small number of races. A number of questions can however be posed if we aggregate the returns for a large number of races. The first question, which has direct relevance to a weak efficiency test of horse race betting markets, is "What is the expected return at each odds (and group of odds)?" Obviously the number of horses that start at each odds varies considerably—from single figures at long odds-on to thousands of runners at 20–1 and 33–1 during a season—but wherever the number is regarded as large enough the expected return calculation can be made (or rather used, given that it can always be made). Table 3 presents the results of such an analysis for the 1973 flat season, column (5) containing the percentage return at each starting price and column (6) giving the cumulative return up to that particular price (e.g. the cumulative return at 10–1 is the result

TABLE 3

1973 FLAT SEASON: RETURN AT EACH STARTING PRICE

Odds	Unit stakes required to return 100	Runners	Winning percentage	Percentage return	Cumulative return	
					Level staking	Staking to return 100
(1)	(2)	(3)	(4)	(5)	(6)	(7)
1–11	91·7	1	100·0	109·0	109·0	109·0
2–13	86·7	1	0·0	0·0	54·5	56·1
1–6	85·7	2	100·0	117·0	85·8	85·8
1–5	83·3	2	100·0	120·0	97·2	96·8
2–9	81·8	4	100·0	122·0	107·1	106·7
1–4	80·0	7	85·7	107·1	107·1	106·9
2–7	77·8	2	50·0	64·5	102·6	102·6
30–100	76·9	1	100·0	130·0	104·0	103·9
1–3	75·0	8	75·0	99·8	102·8	102·9
4–11	73·3	15	66·7	90·7	98·6	98·9
2–5	71·4	18	88·9	124·4	106·2	106·0

TABLE 3—*contd.*

4–9	69·2	21	81·0	116·6	108·9	108·7
40–85	68·0	1	100·0	147·0	109·3	109·1
1–2	66·7	24	70·8	106·3	108·6	108·5
8–15	65·2	14	64·3	98·4	107·4	107·4
4–7	63·6	23	60·9	95·6	105·5	105·8
8–13	61·9	24	75·0	121·5	107·8	107·7
4–6	60·0	52	67·3	112·4	108·9	108·7
8–11	57·9	58	37·9	65·6	99·9	100·7
4–5	55·6	76	59·2	106·6	101·3	101·8
5–6	54·5	35	65·7	120·3	103·0	103·2
10–11	52·4	79	46·8	89·5	100·7	101·2
Evens	50·0	116	46·6	93·1	99·2	99·8
11–10	47·6	112	41·1	86·3	97·1	98·0
6–5	45·5	32	25·0	55·0	95·3	96·5
5–4	44·4	134	42·5	95·7	95·3	96·4
11–8	42·1	113	35·4	84·2	94·1	95·3
6–4	40·0	186	37·6	94·1	94·1	95·1
13–8	38·1	123	36·6	96·2	94·3	95·2
7–4	36·4	221	30·8	84·6	92·9	94·0
15–8	34·8	101	32·7	94·1	92·9	94·0
2	33·3	305	24·6	73·8	89·9	91·6
85–40	32·0	43	23·3	72·8	89·5	91·3
9–4	30·8	312	27·2	88·5	89·4	91·0
5–2	28·6	363	26·5	92·6	89·8	91·2
11–4	26·7	342	24·9	93·2	90·2	91·3
3	25·0	538	23·6	94·4	90·8	91·6
100–30	23·1	279	22·9	99·3	91·5	92·0
7–2	22·2	590	18·8	84·7	90·6	91·4
4	20·0	734	21·1	105·6	92·7	92·6
9–2	18·2	656	13·9	76·3	90·8	91·5
5	16·7	855	15·1	90·5	90·8	91·4
11–2	15·4	635	15·6	101·3	91·7	91·9
6	14·3	944	13·5	94·2	92·0	92·0
13–2	13·3	450	17·3	130·0	94·0	93·1
7	12·5	983	9·9	78·9	92·4	92·3
15–2	11·8	288	12·9	109·2	92·9	92·6
8	11·1	1290	8·8	78·8	91·3	91·8
17–2	10·5	36	2·8	26·4	91·1	90·5
9	10·0	621	7·6	75·7	90·3	90·1
10	9·1	1564	7·5	83·0	89·4	89·7
11	8·3	513	4·9	58·5	88·3	89·3
12	7·7	1798	4·8	62·2	85·3	88·0
13	7·1	109	5·5	77·1	85·3	85·9
14	6·7	1700	4·7	69·7	83·8	85·3
15	6·3	56	1·8	28·6	83·6	84·4
16	5·9	1501	2·5	41·9	80·3	83·2
18	5·3	124	0·8	15·3	79·9	83·1
20	4·8	3739	1·1	22·5	70·5	79·9
22	4·4	141	0·0	0·0	70·1	79·7
25	3·8	1913	1·3	34·0	67·4	78·8
28	3·4	70	1·4	41·4	67·3	78·8
30	3·2	115	0·0	0·0	67·0	78·7
33	2·9	3314	0·5	18·5	61·3	77·1
40	2·4	152	0·0	0·0	61·0	77·0
50	2·0	506	1·0	50·4	60·8	77·1
66	1·5	59	0·0	0·0	60·7	77·1
100	1·0	57	0·0	0·0	60·5	77·1
'150'	0·7	6	0·0	0·0	60·6	77·1
		29307				

of having level stake bets on all runners at 10–1 and less). From the final figure in column (6) we can see that a unit bet on every one of the 29,307 horses that ran in the 2,777 races included in the analysis would have led to a pre-tax 39·4 per cent loss. In fact, given betting turnover duty—introduced on 24 October 1966 at 2½ per cent, raised on 25 March 1968 to 5 per cent and again—as far as off-course betting was concerned—to 6 per cent on 27 April 1970—the loss would have been 43 per cent. An alternative interpretation of column (6) is that it gives the average return to "pin-pricking" selection among horses up to any particular price. This suggests a small profit even after tax for random selection up to 6–4 *on*, but since the 1974 budget raised the duty to 7½ per cent off-course, with bookmakers normally deducting an extra half per cent "to cover Levy Board commitments", most of this will now have been eradicated.

Given that starting prices are defined as those at which a sizeable bet could be laid, the calculations referred to above have definite policy significance, in contrast to the results of equivalent calculations made—if this were possible—on the basis of totalizator prices.

There is however another set of calculations that can be made on the basis of the SP returns. This set, which can be put to either non-controversial or controversial use, is to be found in column (7). The findings in this column are generated by assuming not that stakes wagered were identical at all odds, but that they were always such as to generate a return of 100. At any particular odds the percentage return is naturally unchanged, but in aggregating we now weight not only by number of runners but also by relative stakes. It is now assumed, for instance, that twice as great an amount of stakes is placed on each horse at even money as on each horse at 3–1. To the extent that the realized percentage returns approach 100 this different weighting system makes no difference to the cumulative return picture, but as the returns depart from 100 a discrepancy arises. In Table 3 it can be seen that the two calculations stay fairly close together below 20–1, but that from this point on a substantial gap opens up. It is a gap in favour of the bettor and the non-controversial conclusion that can be drawn from this calculation is that if every horse (or random selection) had been backed so as to return 100 the pre-tax loss would have been 23 per cent rather than 40 per cent.

The controversial, but more common, use to which this calculation can be put is to estimate the bookmakers' gross margin. For this purpose it has to be assumed that the share of season total stakes placed on horses which started at x to 1 was *actually* $100/(x+1)$. This does not, of course, necessitate that in any particular race the stakes were appropriately distributed, but merely that in the long run the average amount staked at each price is in the appropriate relation, so that the cumulative return over all odds gives a reasonably accurate indication of the gross margin. The standard defence of the assumption lies in the theory of ideal bookmaking together with the empirical assertion that sufficient competition is observable to warrant our believing that *long run* practical outcomes approximate the theoretical prediction: supply and demand do determine price and hence SP returns over a reasonably long period processed in the above way will yield a fairly good indication of the gross margin. Understandably, bookmakers are always keen to deny that a reasonably accurate picture is given by this calculation—naturally they argue that it is too high rather than too low—while vigorously maintaining that bookmaking is highly com-

petitive. We are not in a position to determine this issue, but it can be noted that the invariable reaction to an SP analysis of the present sort fails to address the central, long-run, issue.

> . . . the public are not machines who bet proportionately to the estimated chance of a particular horse. . . . Only on a rare and lucky occasion can any S.P. layer make a perfect book. . . . Any data used without such information [on the volume of turnover at each SP] will produce results which at best can only express an opinion of likely profitability should the betting public follow an imaginary pattern. (letter by John Waugh, *Sporting Life*, 14 March 1974, in reaction to Figgis, 1974, pp. 128–133)

V

Our interest, however, is not in how "fair" a bet is with a bookmaker (its "expected value") but how "efficient" the betting market is: is "available information" "fully reflected" in price? The criterion used is the *pattern* of expected values throughout the odds range: weak efficiency is complete if the expected values are equal throughout the range and decreases to the extent that expected values diverge from equality.

Immediately, however, it will be obvious that the fact that the over-roundness of the SP and FP differ in any one race and that each varies over a series of races makes calculation of genuinely comparable expected values difficult. In Table 3 for instance runners at any SP are grouped irrespective of the sum of the percentages in their race: a horse at evens is a horse at evens whether there were three other horses at 3–1 (market 25 per cent over-round) or four other horses at 3–1 (market 50 per cent over-round). Our solution to this problem is to standardize the SP and FP sets for every race, turning them into hypothetical, perfectly round books, thereby producing a situation where the prices/odds are effectively probabilities. The procedure has already been illustrated in Table 1. Having found the sum of the percentages for each race, each individual percentage is divided by the sum and then allocated to the nearest available SP or FP. This procedure has the effect of producing slight deviations from perfect roundness in any set, but practical reasons favoured the preservation of this discrete basis rather than one in which the standardized SP and FP would have been allowed to take continuous values and subsequently been grouped. As a result of standardization, horses that had different SP (or FP) are grouped together and ones with the same SP (or FP) are separated, but we can now be sure of one thing—that the "probabilities" of the runners in any one race add up to 1.00.

Having generated Table 4, we are now in a position to ask the same questions of the standardized SP and FP data as we did previously about the raw data. And, more important, we are in a position to ask the crucial question in relation to the equity issue: is there any significant difference between the degree to which the SP pattern on the one hand and FP pattern on the other diverge from a strict expectation model (i.e. expected return equal at all odds and, in the case of the standardized prices, equal and zero). Why is this the crucial question?

Anyone possessing inside information will presumably exploit it continuously up to the "off", always acting so as to bring the odds on offer back into line with those suggested by the superior information they possess. Given that SP is defined as the odds at which a sizeable bet could have been placed at the "off",

TABLE 4

1973 FLAT SEASON: WINNING PERCENTAGES AT STANDARDIZED STARTING AND FORECAST PRICES

Probability	Standardized forecast prices		Standardized starting prices	
	Runners	Winning percentage	Runners	Winning percentage
(1)	(2)	(3)	(4)	(*v*)
87·5	1	100·0		
85·7			1	0·0
84·6			1	100·0
81·8	1	0·0	2	100·0
80·0			2	100·0
77·8	1	100·0	2	100·0
75·0	1	100·0	6	83·3
73·3			2	100·0
71·4	1	100·0	4	75·0
69·2	5	80·0	9	66·7
68·0	3	100·0	7	71·4
66·7	4	50·0	6	66·7
65·2	5	100·0	12	83·3
63·6	5	40·0	11	81·8
61·9	9	77·8	14	71·4
60·0	8	75·0	17	70·6
57·9	11	81·8	25	68·0
55·6	13	46·2	21	76·2
54·5	17	35·3	23	47·8
52·4	23	56·5	34	70·6
50·0	26	65·4	64	45·3
47·6	38	68·4	73	61·6
45·5	38	44·7	57	57·9
44·4	44	45·5	67	47·8
42·1	49	44·9	111	45·1
40·0	58	50·0	107	43·0
38·1	84	50·0	95	43·2
36·4	87	41·4	113	36·3
34·8	102	45·1	114	48·3
33·3	91	41·8	112	34·8
32·0	114	42·1	122	32·8
30·8	215	34·9	200	30·5
28·6	237	34·6	297	29·6
26·7	307	28·0	277	24·9
25·0	344	26·2	292	25·0
23·5	204	26·5	194	27·8
23·1	162	21·0	166	32·5
22·2	414	19·6	384	20·3
20·0	723	23·5	611	21·0
18·2	757	16·5	578	23·2
16·7	766	17·2	602	20·9
15·4	719	17·1	550	16·4
14·3	675	16·2	570	15·1
13·3	635	16·4	609	17·6
12·5	562	14·8	532	10·9
11·8	611	12·1	542	16·1
11·1	595	12·4	600	11·3
10·5	506	9·7	471	13·8
10·0	695	9·8	720	11·1
9·1	985	8·5	911	12·2
8·3	866	10·9	869	8·5

TABLE 4—*contd.*

7·7	837	7·8	838	7·4
7·1	744	6·6	752	7·3
6·7	714	7·3	713	5·6
6·3	725	6·5	805	6·0
5·9	1116	4·5	1025	5·7
5·3	1266	4·7	1323	4·4
4·8	1182	4·7	1124	4·3
4·4	1360	3·5	1242	2·6
3·8	2065	2·4	1682	1·6
3·4	1858	1·4	1185	0·9
3·2	1767	1·6	1074	1·1
2·9	2465	1·5	1352	1·1
2·4	944	1·1	2403	0·8
2·0	261	1·2	1810	0·3
1·5	143	0·0	675	0·6
1·0	29	3·5	70	0·0
0·7	14	0·0	25	0·0
	29307		29307	

SP can be taken to incorporate any superior or inside information that exists in relation to the event. If inside information plays a significant role in horse race betting markets, then the correlation between the probabilities embodied in the SP returns and the realized probabilities should be significantly higher than the correlation between the latter and any other set of probabilities assigned prior to the "off" (and certainly any set assigned prior to betting on the event). If, then, the correlation between the probabilities embodied in the betting forecasts in a morning newspaper and the realized probabilities is as high as the SP correlation, we can conclude that the existence of superior "inside" information is in doubt.

The exercises reported in Table 5, and particularly the more reliable results

TABLE 5

REGRESSION OF SP AND FP PROBABILITIES ON REALIZED PROBABILITIES

	Starting prices	Forecast prices
All probabilities (no minimum number of observations at any probability)		
N	67	64
R	0·91	0·88
R^2	0·83	0·77
Regression coefficient	0·77	0·71
Std error	0·04	0·05
Constant	0·53	0·67
Probabilities 0·5 and less (gives minimum of 25 observations at any probability)		
N	48	48
R	0·98	0·98
R^2	0·96	0·97
Regression coefficient	0·84	0·78
Std error	0·03	0·02
Constant	0·16	0·22

Source: columns (1), (3) and (5) of Table 4.

in the bottom half of the table, indeed imply that the FP correlation in 1973 was as high as, if not higher than, the SP one and therefore raise serious doubts as to the significance of inside information. The main caveat that needs to be entered concerns the paucity of data in the odds-on range, where it might be argued that inside information is particularly relevant. Given the few runners in the shorter odds range, it would require many years, even decades, to get together enough observations to make the analysis feasible over this range by itself. The practical problems involved in a supplementary analysis of this sort are also quite massive but, granting the importance of the point, we are exploring ways of overcoming them.

This limitation does not however undermine the current exercise. Only 71 winners out of the total of 2,777, roughly 2½ per cent, were accorded an SP probability of more than 0·5, so that the "exploitation" involved could hardly dominate that in the more heavily populated odds ranges unless the total amount of such exploitation involved were relatively small, which is indeed the view we are canvassing. Without wishing to belittle the statistical limitations and deficiencies of the present exercise, we are fairly confident that it poses a genuine challenge to the conventional wisdom that betting markets are "strongly inefficient" while supporting, *a fortiori*, the more accepted/acceptable belief that they are reasonably "weakly efficient".

A final point. Even if the "outsider" has access to as good information as the "insider" it does not mean that he exploits it, or exploits it as effectively. We have shown only (with the above caveat) that outsiders (collectively) had *available* to them just as good information as insiders (collectively), not that they used it and so achieved equivalent returns—but then, ought not this, rather than the *ex post* equality of returns, be the criteria for equity?

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Winning Systems? Some Further Evidence on Insiders and Outsiders in British Horse Race Betting

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I

In an earlier paper (Crafts, 1985) I examined the relationship of the racecourse odds at the start of a horserace in Britain to the odds forecast in the morning racing press. The results showed that there is considerable potential for profitable insider trading in British horserace betting but that the adjustment of the odds to the starting prices is "weakly efficient" in the sense that bettors at starting price could not share in the exploitation of profitable opportunities. I also demonstrated the existence of "mug bets", a class of particularly poor value bets where horses listed in the morning as fancied runners lengthen markedly in the betting during pre-race trading. In other words I argued that insiders are able to profit at the expense of outsiders, a situation which appears to be acceptable to or regarded as inevitable by the authorities.

The resulted presented here give further support to this general view. It is shown that the decision rules embodied in "racing systems" on sale to the general public in Britain are distinctly unprofitable, although in many cases they have been continually advertised over a long period. I also indicate a particularly profitable form of information possessed by insiders; in this case, however, there does seem to be scope for outsiders to adopt decision rules allowing them to profit from the insiders' information, a result which involves a further departure from efficiency in the horeserace betting market. Unfortunately the investment of time involved in seeking to exploit this rule is such as to imply that this finding is unlikely to benefit many people.

II

Each week in Britain the sporting press carries advertisements for "racing systems"; the reader is encouraged to purchase a set of decision rules which it is claimed can be used to bet with profit using publicly available information. Many such systems are typically on offer and some have been advertised regularly for years. If such systems actually are profitable, this would obviously violate the conditions for an efficient market. If such systems were profitable prior to publication but not subsequently, this would suggest a less serious inconsistency with the efficient markets hypothesis but nonetheless would indicate that profitable decision rules can be discovered and that horserace betting markets are not always efficient.

Table 1 reports the results of an investigation into the profitability of three systems, researched by their proprietors in the 1970s and widely advertised in the 1980s. Each of the systems provides decision rules for betting based on readily available public information. Fineform and the Peter Smith Method are based on the recent form figures of horses in a race while Special Bets gives the formula which yields a list of horses to follow based on time and manner of a winning performance. These systems have been marketed at prices in the £10 - £15 range.

TABLE 1 : The Profitability of Three British Racing Systems

		Win Fraction	Return[a] (%)	Win Fraction [a,b] To Break Even	Win Fraction [a,b] To Make 10% Return
a)	Before Publication				
	Fineform (n = 249)	0.345	-7.1	0.372	0.409**
	Peter Smith Method (n = 349)	0.203	-18.5	0.250*	0.275*
	Special Bets (n = 254)	0.303	-12.1	0.345	0.379**
b)	After Publication				
	Fineform (n = 252)	0.333	-19.9	0.416**	0.458**
	Peter Smith Method (n = 341)	0.226	-12.9	0.259	0.285**
	Special Bets (n = 147)	0.272	-10.9	0.305	0.337*

Source: Derived using the rules proposed in Holt (1986) for maximum rated horses, in Smith (1986) for handicap races of up to 12 runners where all horses have raced at least 5 times (his most preferred category), and in Randall (1983) for flat racing only. Results were checked using daily newspapers drawing samples from 1978-9 and 1986-7, except for Special Bets where 1978-9-80 and 1984-6-7 were used.

Notes:

[a]All calculations are made for off-course punters paying the 10% betting tax; on course punters paid 4% tax until April 1987 and now bet tax free.

[b]The required win fractions are calculated on the basis of the average odds per winning bet in the sample; * and ** indicate that this proportion is significantly different on a one-tailed test from the observed proportion at the 5 and 1% levels respectively.

The results in Table 1 are straightforward to interpret and give rise to the following points.

1. The systems do not permit a 10% rate of return on stakes (likely to be the minimum acceptable to compensate for the time and risk involved in following such betting rules) either before or after publication.

2. Only in the case of Fineform does there appear to be any evidence of the market responding to publication by adjusting odds to the detriment of the rule, which may have been profitable for on-course backers in the 1970s.

3. If results before and after publication are pooled, then both Fineform and the Peter Smith Method show a win frequency below at the 1% level of statistical significance that required to break even the Special Bets is below at the 10% level.

In general, then, the results are consistent with an efficient markets hypothesis and there is no evidence to support claims that rules have been discovered which have allowed off-course bettors to make profits. Fineform, however, was a system which may have produced a small positive return for on-course punters for a time and may therefore have uncovered an inefficiency in the horserace betting market during the 1970s. The results given in Table 2 suggest that racing systems generally, as well as the "ratings services" of longstanding private handicappers such as Raceform and Timeform who sell selections for races are substantially unprofitable tools for bettors, again much as the efficient markets hypothesis would predict.

TABLE 2 : The Profitability of Other Racing Systems and Ratings Services

	Win Fraction	Return (%)	Win Fraction To Break Even	Win Fraction To Make 10% Return
Nine Racing Systems (n = 638)	0.202	-28.5	0.283**	0.311**
Five Ratings Services	0.254	-22.6	0.306**	0.336**

Source: Derived from the results reported in Roberts and Newton (1987) using own calculations with methods as in Table 1. None of the ratings services showed a profit but one of the racing systems did - however, this method's results as given in Roberts and Newton were based on only 12 observations.

It seems reasonable to conclude that punters who buy racing systems in the hope of obtaining access to decision rules that will lead to profitable betting do so in vain - as a proponent of the efficient markets hypothesis would predict - despite the misleading claims made repeatedly in advertisements in the sporting press. The continued sale of these systems suggests that participants in British horserace betting include many gullible outsiders.

At the other extreme of the market are knowledgeable insiders, who, as my earlier paper showed

(Crafts, 1985), possess a better idea of the true odds against certain horses than do the bookmakers or the general public. These insiders have opportunities to profit in the market trading which establishes the starting prices at which offtrack bets are settled and at which the insiders' information would not be profitable. Crafts (1985, p.298) shows that where horses have a ratio of the win probability implied by the morning line odds to that of the win probability implied by the starting price (FP/SP) > 1.5 it would not be profitable to bet at SP (after tax rate of return = -12.6%) but it would have been very profitable to bet on them at FP (79.7% rate of return).

Preliminary analysis of these data suggested that there might be a category of horses where insiders were able to avail themselves of particularly valuable insider information. The category in question is that of horses racing after a long absence from the racecourse through injury, which are allowed under British rules of racing to return to racing without any previous public trial; relatively few of these horses win first time out and they are generally ignored by tipsters and the betting public. Over the five years since my initial sample I have collected data on the performance of horses who had not run since the season before last and had starting prices markedly shorter than the odds forecast in the morning press (FP/SP > 1.5). The results are shown in Table 3 for the 88 observations which have occurred in the period September 1982 to November 1987. If it had been possible to bet on these horses at FP, the rate of return would have been 261.9%!

TABLE 3 : Betting on Horses with a Marked Difference between FP and SP which had been Off the Course for a Long Period

Win Fraction	Return (%)	Win Fraction to Break Even	Win Fraction to Make 10%
0.318	+55.8	0.204**	0.225**

Source: Derived on the basis described in the text using the Sporting Life as in Crafts (1985) but including only horses with a starting price < 7/1 and making calculations on the same basis as for Tables 1 and 2.

Table 3 reveals that the information possessed by insiders in the case of horses off the course since the season before last is especially profitable as their bets would generally be struck at odds better than SP. The important difference from the results in Crafts (1985) is that backing these horses at SP is highly profitable with a 55.8% rate of return on stakes. Thus there is a possibility that outsiders, including off-track bettors, could adopt a profitable decision rule by following the insiders and backing horses at SP where they have been off the course since the season before last and market support has established an FP/SP ratio > 1.5.

The findings in Table 3 are not consistent with "weak efficiency" if that is taken to imply that SP odds are a good approximation to winning probabilities but FP odds are not. There is, however, a substantial cost to adopting the decision rule suggested by the results of Table 3, namely that on more than half of the racing days each year there is at least one runner which has not raced since the season before last and might turn out to qualify at the end of market trading as having an FP/SP ratio of > 1.5. In a period of five years only 88 bets would have resulted from a very substantial investment of time and effort in market observation in order to be able to place a bet just before the end of trading if the rule happens to be satisfied.

III

The evidence presented in this paper suggests that the British horseracing betting market is not a very equitable one and strengthens my earlier objections to Dowie's (1976) claim to the contrary. This market includes insiders with potentially highly profitable information not known to the hapless outsiders who buy racing systems which contain unprofitable methods of betting. The results do, however, offer encouragement to the view that it may be possible to generate profitable betting rules and thus that the betting market may not be even weakly efficient; if so, it may be better to look for profitable rules by selective following of insiders than by seeking to devise systems based on form figures or past times.

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An Examination of Market Efficiency in British Racetrack Betting

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The nature of the British racetrack betting market provides a distinctly different opportunity for testing market efficiency. On the basis of data from a single racing season, we compare the returns to two similar forms of betting: (1) starting price bets placed with bookmakers and (2) pari-mutuel tote bets. Our analysis indicates that tote returns are consistently higher than starting price returns, even though both betting forms are of similar risk and the payoffs are widely reported. The persistently higher tote returns suggest that the British racetrack betting market does not satisfy the conditions of semistrong efficiency. Our results also provide indirect support that the market fails to meet the conditions for strong efficiency.

I. Introduction

The notion of an efficient market was initially formalized in Fama's (1970) seminal work. A market is considered efficient if information is widely available to participants and all relevant and ascertainable information is reflected in prices. In general, studies on market effi-

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ciency have examined financial securities or commodities markets. Recently, researchers have considered whether or not the efficient markets hypothesis of Fama and others has application in different markets, including racetrack wagering (see Snyder 1978; Tuckwell 1983; Asch, Malkiel, and Quandt 1984; Crafts 1985).

Racetrack betting is a particularly interesting application for efficient market analysis because of its many similarities to financial markets. For instance, 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 cannot usually be guaranteed; that is, the return on an investment is uncertain. Further, the possibility of "insider information" closely parallels that in the stock market. Such similarities make racetrack wagering a logical choice for further considering the efficient market analysis begun utilizing stock market data.

In a paper on betting market efficiency and equity, Dowie (1976) suggested three types of market efficiency tests differentiated by the definition of "available information" utilized. In his approach, tests of weak efficiency equate available information with historical prices and returns. Tests of semistrong efficiency add public announcements to the set of available information and focus on whether prices fully reflect them as soon as they are made. The third type of test, that of strong efficiency, considers the existence of specific subsets of market participants possessing monopolistic access to or control over specific information. Dowie chose to refer to this last set of tests as dealing with *equity,* apparently because of the differentiation in information accessibility: "In other words, we will talk of a market as *efficient* to the extent that it passes the weak and semi-strong tests and *equitable* to the extent that it passes the strong test" (p. 140). In the present paper we utilize a key aspect of the racetrack betting market in England, the ability to place either a bookie starting price or pari-mutuel tote bet, to analyze what Dowie refers to as semistrong efficiency. In doing this, we develop information relevant to, but not directly testing, the equity of this market. An additional test of market efficiency based on the work of de Leeuw and McKelvey (1984) and Zuber, Gandar, and Bowers (1985) is also provided.

Section II briefly describes the English thoroughbred betting market. Section III analyzes data on winning payoffs made during the 1978 racing season and discusses possible implications for market efficiency. As explained in more detail below, the 1978 season was chosen since it represented a period when electronic boards providing rapid odds updates for tote wagering were still rare in England. Section IV summarizes our analysis.

II. The Racetrack Betting Market in England

A typical English bettor ("punter") can utilize two general betting mediums. First, a bet can be placed on a horse through the totalizator—the "tote." The tote is similar to American racetracks' parimutuel betting systems. If a horse wins, the payoff made on a tote bet is based on the amount of money bet on the winning horse relative to the total bet in the winning pool. That is, once the takeout (taxes, track cut, owners' and trainers' cut) is removed, the winning pool is proportioned to those wagering on the winning horse. Each bet on a horse thus affects the odds paid if that horse should win. Though for small bets the impact may be almost negligible, large bets can have great marginal impacts on winning payouts. Because of the general absence of tote boards (electronic boards that update wagering and provide current odds) in England during the late 1970s (see the next section), tote bettors were betting with only minimal information (morning line odds or hand-calculated and "chalked" updates) about likely final odds for their betting choice.

A bettor also has the option of placing bets with a bookmaker. Bets with the book can be placed either at fixed odds, offered at the time of the bet, or at what is termed "starting price" odds. In the starting price bet, the odds are determined as the average of a set of the largest (or "ring") bookmakers at the racecourse just before the race starts. Starting price odds represent the "odds at which a 'sizeable' bet could have been made *on the course* just before the 'off' " (Dowie [1976, p. 140]; see also O'Neill [1971] for a more complete explanation). Starting price bets can be placed anytime prior to the race and remain available up until the start of the race. Though there is an almost infinite array of bets that can be made with a bookmaker (ante post, bar the fave, etc.), we needed to choose one that was sufficiently recorded to provide the data necessary for our analysis. Further, we wished to choose a bet that was not an insignificant part of the market.[1] At the time a bet is placed at the starting price, the bettor is uncertain about the amount to be received if a bet wins. Thus this type of betting shares a similarity with tote betting. A critical difference, however, is that the starting price odds reflect betting trends and bets made with bookmakers, while the tote odds reflect an aggregate measure of bettors' subjective winning probabilities based on a separate pool of funds. The final tote odds are determined by the total amounts in the pool bet on each horse, while the starting price

[1] Starting price betting constitutes a large amount of off-course betting. Dowie notes that "most off-course betting—95 per cent or more according to 'Michael Rolfe' of the *Sporting Life* (personal communication)—is at 'starting price'. This occurs despite the readily available option of off track TOTE wagers" (p. 140).

odds represent the last odds offered and reflect trends and the attempts of bookmakers to "round their books." Under either betting form, however, each bettor is uncertain of the exact odds he or she will receive until after the race starts. In terms of risk, starting price and tote bets are essentially equivalent. That is, both are defaultless, and the true likelihood that a particular horse will win and, thus, the odds of receiving a return for betting on that horse are identical. The difference in return from each is the focus of our analysis. Since the differing bets are two options for purchasing exactly the same item (a bet to win on a specific horse), we would expect the odds to converge. If, over time, tote odds (and thus payouts for a given bet on a winning horse) repeatedly exceed those of the corresponding starting price bet, we would expect bettor shifts to occur, leading to the tote and starting price odds being driven closer. If the betting market is semi-strongly efficient, then historical returns (payouts) from each betting type and differences in those payouts (published announcements following the outcome of the race) should be included in the market prices. Since the objects compared are identical (as explained below, a 10-pence bet on a winning race horse), the odds or returns from that object should be identical. If the market is equitable (or strongly efficient), then monopolistic or "insider" information should be absent. In the next section we investigate whether the returns on the two bet types show evidence of systematic differences and what, if any, implications exist concerning market equity.

III. Empirical Analysis

The data analyzed in this study are drawn from the 1978 thoroughbred racing season in England. We chose the year on the basis of a critical factor: the general absence of mechanical or electronic tote boards (as suggested by a letter from the Horserace Totalisator Board, London).[2] This placed the tote bettors in the position of having limited, if any, information on betting patterns or likely final odds for their betting choice. The sample consists of the first 1,427 flat races run in the 1978 season.[3] Information on the following variables was compiled for each race from the weekly race results published in the *Sporting Chronicle Handicap Book:* (1) the number of horses in each race, (2) the total (winning) purse in each race, (3) the type of race (e.g., maiden, claiming, stakes, etc.), (4) the track conditions, (5) the

[2] The letter, dated September 26, 1978, was received in response to an inquiry concerning the existence of electronic tote boards and the pool deductions (percentage) that affected tote wagering.

[3] The 1978 season includes a few scattered races occurring in late 1977. Our data run through June 1978.

TABLE 1

AVERAGE WINNING PAYOUTS PER 10-PENCE BET

	Number of Observations	Tote	Starting Price	Difference
All races	1,427	108.21 (270.27)	63.50 (52.33)	44.28* (251.27)

NOTE.—Standard deviations are in parentheses.

* The difference in average tote and starting price payouts is significant at the 1 percent level using a Wilcoxson matched-pairs signed-ranks test.

length of the race (in furlongs), (6) the totalizator payoff on the winning horse per 10-pence bet, (7) the date of the race, and (8) the starting price payoff per 10-pence bet.

As noted earlier, if the betting market is semistrongly efficient, then the expected returns to two bets of similar risk should be equal. However, if market inefficiencies exist, they may lead to a divergence between overall tote and starting price payouts. Thus a rough test of such market efficiency is simply to compare the average tote and starting price payoffs across races.

However, if the market is not equitable (not strongly efficient), some bettors would have inside information. We would expect them to place early fixed-odds bets with bookmakers. Since tote is parimutuel wagering in which odds are determined by the amount bet on individual horses, bettors with inside information would tend to avoid tote bets in order to place fixed-odds bets with bookmakers. If substantial accurate inside betting occurred as tote betting, tote payouts would be lowered. At the same time, if significant insider betting (based on good information) occurs with bookmakers, winning starting price payouts are driven downward. For example, if insider information is favorable on a horse that opens betting at 10 to 1 odds, bookmakers would receive substantial wagering. "Tick-tack" signaling (interbookmaker signaling) would tend to push the subsequent starting price odds below the early odds locked in by inside bettors. Hence, it is conceivable that insider betting may actually lower observed starting price payouts relative to tote payouts because the former are driven down as bookmakers react to the flow of insider funds.

Table 1 shows the mean payoffs and accompanying standard deviations from each of the two bet types and the average difference in payout for all winning horses in our sample period.[4] The table also includes the results of a Wilcoxson matched-pairs signed-ranks test

[4] The tote winnings are reported after the customary track takeout has been deducted. No similar deduction is made for starting price winnings.

for the difference in mean tote and starting price payouts. As indicated in the table, the average difference for a 10-pence bet (the common payout reporting base used in England) is 44.28 pence. That is, on average, over all races in the entire sample, the tote return exceeded the starting price return by 44.28 pence on a 10-pence bet. The average tote payoff was 108.21 (approximately 10 to 1) and the average starting price payoff was 63.50. Further, the Wilcoxson test indicated that the differences were significant at an extremely high level. These results indicate that the tote yielded a higher average payout, suggesting that the market fails to satisfy semistrong efficiency conditions. Further, the results are consistent with a lack of market equity and the presence of insider information, though, as noted earlier, the inferences here are only indirect.

It is still possible that the market really is efficient and that the results we find are due to factors that represent either aberrations or initial market conditions that get worked out over time. These possibilities lead us to consider the following two questions: (1) Since bookmakers generally limit offered odds (to avoid bankruptcy perhaps) and the tote odds are virtually unlimited (e.g., if only 10 pence in a £1,000,000 pool is bet on a horse that wins, the payoff rate would be rather large), could the findings of differences in average return simply reflect a few very large tote payouts? (2) Since bettors gain information over time (e.g., past race performances or past betting payouts), could it be that the differences are due to early race insider information? Once the season is well under way and more information is available on horses, jockeys, trainers, and betting returns, does the observed difference begin to disappear?

To address the first question, we ran our comparisons for a variety of subsets of our original data. Three new data sets were constructed by deleting observations that included tote payouts above specified odds level as follows:

Data Set	Observations Deleted if Tote Payout Odds Greater than
1	20 to 1
2	15 to 1
3	10 to 1

Even with observations deleted on the basis of the tote payout level, the tote payout average continued to exceed the starting price payout average. As detailed in table 2, the differences between the tote payouts and starting price payouts averaged 9.81 for data set 1, 6.86 for data set 2, and 3.13 for data set 3. Though, as we might expect, the

TABLE 2

AVERAGE WINNING PAYOUTS PER 10-PENCE BET

Races	Number of Observations	Tote	Starting Price	Difference
Tote ≤ 20 to 1	1,283	62.73	52.93	9.81*
		(43.5)	(35.22)	(32.33)
Tote ≤ 15 to 1	1,225	56.96	50.09	6.86*
		(35.13)	(31.18)	(27.43)
Tote ≤ 10 to 1	1,106	48.80	45.68	3.13*
		(25.64)	(25.89)	(21.89)

NOTE.—Standard deviations are in parentheses.
* Significant at the 1 percent level.

average difference declined as the level of payout declined, all three of the Wilcoxson matched-pairs signed-ranks tests were significant at the 1 percent level.

The issue raised by the second question suggested above concerns whether the observed differences tend to disappear over time. To address this issue, we performed our calculations and the Wilcoxson test for three different racing periods: (1) races up to and including April (533 races), (2) races run during May (509 races), and (3) races run during June (374 races). Dividing the periods up in this chronological order enabled us to examine whether the differences noted above diminished over time and whether the returns on the two betting types converged as bettors observed horse performance and betting returns. Tables 3, 4, and 5 present the tote and starting price return comparisons for each of the three periods. Each table includes mean payout comparisons for all races during the period and for

TABLE 3

AVERAGE WINNING PAYOUTS PER 10-PENCE BET FOR RACES PRIOR TO MAY 1

Races	Number of Observations	Tote	Starting Price	Difference
All	533	147.10	68.00	79.10*
		(415.43)	(55.86)	(393.80)
Tote ≤ 20 to 1	460	65.19	53.21	12.04*
		(45.37)	(34.47)	(33.12)
Tote ≤ 15 to 1	439	59.42	50.58	8.88*
		(35.59)	(31.91)	(29.55)
Tote ≤ 10 to 1	385	48.92	45.06	3.86**
		(26.05)	(25.28)	(22.66)

NOTE.—Standard deviations are in parentheses.
* Significant at the 1 percent level.
** Significant at the 5 percent level.

TABLE 4

AVERAGE WINNING PAYOUTS PER 10-PENCE BET FOR RACES RUN DURING MAY

Races	Number of Observations	Tote	Starting Price	Difference
All	509	91.79	63.03	28.76*
		(124.15)	(48.39)	(92.67)
Tote ≤ 20 to 1	468	62.09	53.68	8.41*
		(41.33)	(33.07)	(31.08)
Tote ≤ 15 to 1	448	56.65	51.03	5.62*
		(32.89)	(29.13)	(26.26)
Tote ≤ 10 to 1	409	49.71	47.44	2.27**
		(24.73)	(25.25)	(21.91)

NOTE.—Standard deviations are in parentheses.
* Significant at the 1 percent level.
** Not significant.

races during the period in which the tote odds were no greater than 20 to 1, no greater than 15 to 1, and no greater than 10 to 1.

The results presented in tables 3–5 suggest some mild degree of learning over time by bettors; that is, there is some apparent reaction to information announcements. These mild adjustments, however, fall far short of immediate (and complete) reactions required for semistrong efficiency to hold. For example, there were generally lower average tote and starting price payoffs on winning horses during May and during June than in the earlier period running through the end of April. Further, there were generally lower differences in tote versus starting price payoffs in each of the later periods (May and June) compared with the earlier periods. As we might expect, additional information (e.g., announcements of results of previous races

TABLE 5

AVERAGE WINNING PAYOUTS PER 10-PENCE BET FOR RACES RUN DURING JUNE

Races	Number of Observations	Tote	Starting Price	Difference
All	374	75.51	58.26	17.26*
		(81.37)	(52.00)	(53.74)
Tote ≤ 20 to 1	353	60.52	51.77	8.75*
		(43.85)	(39.17)	(32.96)
Tote ≤ 15 to 1	336	54.28	48.39	5.90*
		(34.62)	(32.83)	(26.07)
Tote ≤ 10 to 1	310	47.57	44.30	3.27**
		(26.39)	(27.39)	(20.98)

NOTE.—Standard deviations are in parentheses.
* Significant at the 1 percent level.
** Significant at the 5 percent level.

in a given season) did tend to reduce the average payouts. What is surprising, however, is that, except for the "all race" category, this was not true when we compare May racing with June racing. In the all race category the difference went from 28.76 to 17.26. But for categories with high-tote-payoff races removed, this narrowing of difference failed to occur. In fact, the differences in June remained almost identical to those in May (see tables 4 and 5) with even actual slight increases (8.75 vs. 8.41, 5.90 vs. 5.62, and 3.27 vs. 2.27) in June. The one instance of a nonsignificant Wilcoxson matched-pairs signed-ranks test occurred in the May category for races with tote odds of 10 to 1 or less for the winning horse. All other such tests were significant at the 5 percent level or higher.

These results are consistent with a continued lessening of the occurrence of extremely high tote payoffs and with an ongoing presence of insider information leading to continuing differences between the returns on the two betting forms. Though there was a lessening of the difference from the early period of racing to the later two periods considered, the differences for races with winning tote odds of 20 to 1 or less stayed roughly the same from May to June. Further, even deep into the flat racing season in June, the differences remained statistically significant with no evidence of convergence.[5]

The statistically significant differences in average tote and starting price payouts presented in tables 1–5 cast doubt on the semistrong efficiency of British racetrack betting. We can extend our analysis further to incorporate an additional test based on recent literature in market efficiency. The formulation of this additional test is based on the following notion: If British gamblers use available information efficiently, then the starting price payout should be the best unbiased forecast of the tote payout (and vice versa). Following de Leeuw and McKelvey (1984) and Zuber et al. (1985), we can test this notion of efficiency by estimating the parameters of the following linear expression:

$$\text{TOTE}_i = \alpha_0 + \alpha_1 \text{SP}_i + \mu_i, \tag{1}$$

where TOTE_i is the totalizator payout in the ith race, SP_i is the starting price payout in the ith race, and μ is the error term.[6] The test for market efficiency based on equation (1) is the null hypothesis that

[5] Conventional t-tests were also conducted for the differences in average tote and starting price payouts. In all comparisons, tote payouts were significantly different from starting price payouts at conventional levels. The results of the Wilcoxson test for differences in means are reported since this test makes no underlying assumption about the distributions of tote and starting price payoffs.

[6] We are grateful to an anonymous referee for suggesting this alternative test for market efficiency.

$\alpha_0 = 0$ and $\alpha_1 = 1$ jointly (Zuber et al. 1985, pp. 800–801). As Zuber et al. note, ordinary least squares estimation of the parameters in (1) allows the null hypothesis to be tested using a standard F-test.

Table 6 presents the regression estimates for equation (1) for all the subsets of races presented in tables 1–5. The F-values indicate that the null hypothesis is rejected at conventional levels for every subset. Hence, this second statistical test provides additional evidence against the efficiency of the segment of the British racetrack betting market being studied here.

The presence of insider knowledge is consistent with our observation of lower starting price payouts: bookmakers attempt to balance their books on horses whose odds are firming at race time because of insider betting. However, if insider information exists, the market should assimilate this fact and agents in the market should integrate this information into their decision-making process. Rational starting price bettors should realize that insiders are benefiting at their expense. Hence, individuals who normally bet at starting price odds should tend to switch to the tote. This adjustment in betting patterns should lower tote payments because increased betting on a given horse will lower the odds. The reverse should occur for starting price odds as funds move out of this form of betting. Therefore, even with insider information, the starting price and tote payments to winners should converge. Yet, our empirical observations indicate otherwise.

One additional point adds further emphasis to our analysis. Tote payoffs represent "after-tax" payoffs. On the other hand, the starting price bettors must choose to pay a tax on the bet or pay a tax on the winnings, thereby escaping a tax on losing bets. In either case, the actual starting price payoff is less than the figures we utilized. Since we had no way to calculate how winners might have chosen to pay the tax, we ignored this in our calculations. Including this tax would further strengthen our results since this operates to reduce the true starting price return and increases the differences in payoffs we observed.[7]

IV. Summary

Under both types of tests utilized, our analysis of British racetrack betting provides evidence that conditions for semistrong efficiency are not satisfied. Tote payoffs were consistently greater than identical bets made at starting price odds. This result held true even when large tote payoffs (and even moderately high tote payoffs) are elimi-

[7] Including the 5 percent tax on either starting price bets or winnings did not alter our conclusions about higher average tote payouts.

TABLE 6

REGRESSION ESTIMATES FOR EQUATION (1)

	Intercept	Slope	R^2	F^a
		Whole Season		
All races	−36.30	2.27	.193	77.02*
	(10.15)	(.12)		
Tote ≤ 20 to 1	18.29	.84	.465	81.11*
	(1.60)	(.03)		
Tote ≤ 15 to 1	14.50	.75	.441	96.54*
	(1.42)	(.02)		
Tote ≤ 10 to 1	19.88	.63	.408	141.77*
	(1.20)	(.02)		
		Races through April		
All races	−63.34	3.09	.170	37.31*
	(25.72)	(.29)		
Tote ≤ 20 to 1	17.04	.90	.474	33.15*
	(2.81)	(.04)		
Tote ≤ 15 to 1	20.68	.76	.424	36.42*
	(2.55)	(.04)		
Tote ≤ 10 to 1	20.54	.63	.375	46.74*
	(2.14)	(.03)		
		May Races		
All races	−30.70	1.94	.574	111.52*
	(5.88)	(.07)		
Tote ≤ 20 to 1	17.04	.84	.451	24.64*
	(2.70)	(.04)		
Tote ≤ 15 to 1	19.33	.73	.419	33.00*
	(2.39)	(.04)		
Tote ≤ 10 to 1	21.09	.60	.379	56.56*
	(2.05)	(.04)		
		June Races		
All races	6.18	1.19	.579	26.44*
	(4.11)	(.05)		
Tote ≤ 20 to 1	20.51	.77	.477	27.18*
	(2.81)	(.04)		
Tote ≤ 15 to 1	18.44	.74	.494	29.50*
	(2.40)	(.04)		
Tote ≤ 10 to 1	17.85	.67	.485	39.48*
	(2.05)	(.04)		

NOTE.—Standard errors are in parentheses.

[a] F-values for null hypothesis $\alpha_0 = 0$, $\alpha_1 = 1$, jointly.

* Significant at the 1 percent level.

nated from the data set. Further, the result continued to hold as the season progressed, despite increased information availability on horse performance and on differing tote and starting price payoffs early in the season. Although we did find a mild narrowing of the differences in tote and starting price payoffs when comparing early-season races with May or June races, the differences remained at absolute levels approximately equal to those earlier in the season.

Both types of bets are accessible to bettors, and the outcomes are published daily with weekly summaries of all race and payoff results. The fact that these differences persist leads us to a quandary. Are we observing an inefficient market or simply one in which the tastes and preferences of the market participants lead to the observed results? Is all relevant and ascertainable information reflected in the "prices," the market odds? In fact, is it ever possible to differentiate between the two, to separate an inefficient market from one in which the participants are pursuing the satisfaction of nonmonetary preferences?

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An Examination of Efficiency in British Racetrack Betting: Errata and Corrections

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Shortly after the publication of our paper in this *Journal* (Gabriel and Marsden 1990), we received a kind letter with several informational questions from Paddy Waldron, a graduate student at Wharton and long-time "punter" (bettor) in his native Ireland. One of Waldron's questions caused us to recheck the original source (*The Sporting Chronicle Handicap Book,* 1978) from which our data were gathered by research assistants. As his questions suggested to us, we discovered that a footnote had been overlooked and that the tote returns on Irish races included in the flat season (about 27 percent of all such races) are quoted as returns on a 20-pence bet (their minimum bet) rather than as returns on the 10-pence minimum used for reporting the other flat races. Thus we found that we had overstated the tote returns. We completely recollected all our data, making the necessary adjustments for Irish races and adding in eight races that had been reported out of sequence in the *Handicap Book.*

Using the corrected data, we still find that tote returns exceed starting price returns for all races in our period and for each subperiod (races through April, races in May, and races in June), though, of course, the differences are somewhat smaller than those reported earlier (see table 1). Further, all joint-hypothesis regression equation tests suggest the same conclusions as earlier, though three of the significance levels do differ, two going from .01 to .05 and one from .01 to .1.

We are indebted to Paddy Waldron for his interest and the questions that he raised. We are also indebted to the editor for this opportunity to remedy the error in our earlier computations. For brevity, only part of the revised figures are provided here. A complete set of revised tables is available from either author on request.

TABLE 1

AVERAGE WINNING PAYOUTS PER 10-PENCE BET

	Number of Observations	Tote	Starting Price	Difference
All races	1,435	81.55	63.37	18.18*
		(150.47)	(52.15)	(127.41)
Pre-May	535	102.51	68.17	34.3*
		(219.54)	(55.92)	(194.60)
May	514	74.78	62.76	12.0*
		(96.55)	(48.27)	(63.81)
June	386	61.52	57.53	4.0**
		(63.15)	(51.20)	(43.54)

NOTE.—Standard deviations are in parentheses.
* Significant at the 1 percent level.
** Significant at the 10 percent level.

One part of our earlier results, that dealing with restricting long-shot payoffs, needs revision. To this end, our original table 2 has been expanded to include restrictions using tote odds and restrictions using starting price odds. Originally we reported only the former since these were the stronger results. With the corrected data set, however, comparisons of restricted samples (tote $< 20:1$, $< 15:1$, and $< 10:1$) yield mixed results, though the "after-tax" nature of tote returns suggests that if starting price returns were adjusted for taxes, the earlier reported results might still hold. *Simply put, the corrected results are not as strong as those reported earlier.* Restricting observa-

TABLE 2

AVERAGE WINNING PAYOUTS PER 10-PENCE BET

Races	Number of Observations	Tote	Starting Price	Difference
Tote $\leq 20:1$	1,339	55.34	54.24	1.1**
		(40.21)	(36.09)	(23.74)
Tote $\leq 15:1$	1,296	51.02	51.64	−.6
		(32.91)	(32.05)	(19.62)
Tote $\leq 10:1$	1,202	44.70	46.92	−2.2*
		(24.45)	(26.02)	(16.18)
Starting price $\leq 20:1$	1,408	74.85	59.10	15.7*
		(140.17)	(41.78)	(122.93)
Starting price $\leq 15:1$	1,353	63.87	53.71	10.2*
		(117.35)	(32.49)	(106.55)
Starting price $\leq 10:1$	1,271	52.69	48.40	4.3*
		(42.86)	(25.48)	(29.85)

NOTE.—Standard deviations are in parentheses.
* Significant at the 1 percent level.
** Significant at the 10 percent level.

tions based on tote values eliminates those with high tote values and low starting price values (e.g., tote odds of 40 : 1 and starting price odds of 5 : 1 would be eliminated). Further, sorting by tote odds is based on unobservable values. Bettors can observe information on starting price odds through trends and firming in bookie odds. We resorted our restricted samples based on starting price odds ($< 20 : 1$, $< 15 : 1$, and $< 10 : 1$) and include the results for all races in table 2. *In all cases (table 2's entire period and the pre-May, May, and June groupings not shown here), the results of the Wilcoxon matched-pairs signed-ranks tests indicate that a bettor about to make a winning bet is, on average, better off making a tote wager (11 at a .01 or higher and one at a .05 level of significance).* Complete recalculations are available on request.

We apologize for any inconvenience that our oversight has caused. We hope that these corrections prove helpful and offer our thanks to Paddy Waldron for his inquiry, which led to the discovery of the data collection error on a segment of our observations.

Reference

Gabriel, Paul E., and Marsden, James R. "An Examination of Market Efficiency in British Racetrack Betting." *J.P.E* 98 (August 1990): 874–85.

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The Dr.Z Betting System in England[1]

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Abstract

The betting strategy proposed in Hausch, Ziemba and Rubinstein (1981) and Ziemba and Hausch (1984,1987) has had considerable some success in North American place and show pools. The place pool is England is very different. This paper applies a similar strategy with appropriate modifications for places bet at British racetracks. The system or minor modifications also applies in a number of other countries such as Singapore with similar betting rules. The system appears to provide positive expectation wagers. However, with the higher track take it is not known how often profitable wagers will exist or what the long run performance might be.

I. Introduction

At North American racetracks, the parimutuel system of betting utilizing electric totalizator boards in the dominant method of betting. Las Vegas and the other legal sports books may set odds on particular betting situations, but these fixed odds are not available at racetracks. In England and in other Commonwealth countries, such as Italy and France, odds betting against bookies is the dominant betting scheme. This fixed-odds system is introduced in Hausch, Lo and Ziemba (1994). They also indicate a tendency of higher (lower) returns for lower (higher) odds ranges. Thus, the favorite-longshot bias appears to exist in England (see e.g. Ali (1977), Busche and Hall (1988)).

This paper applies the betting system proposed by Hausch, Ziemba and Rubinstein (1981) and Hausch and Ziemba (1985) in England. This strategy is also called the Dr.Z system in the trade books Ziemba and Hausch (1984,1987) who discuss it more fully. The strategy utilizes the Kelly criterion (Kelly (1956)) which maximizes the expected logarithm of wealth. The Kelly criterion has several advantages. First, it maximizes the capital growth asymptotically. Second, it prevents bankruptcy. Third, the expected time to reach a specified goal is minimum when the goal increases. Fourth, it is superior to any different strategy in the long run. These properties were proved in Breiman (1961). See McLean, Ziemba and Blazenko (1992) for discussion of these properties.

II. The System

Instead of the North American parimutuel system of win, place, and show, the bets in England are to win and place. By "place" the British mean "finish in the money." This is what North Americans call show except for one important difference. The number of horses that can place in a particular race is dependent on the number of starters.

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[1] Modified from an Appendix in Ziemba and Hausch (1987).

Table 1. Relationship between number of horses that place and number of starters

Number of Horses that Place	Number of Starters
one: the winner	four or less
two: winner and second	five, six, or seven
three: winner, second, and third	eight to fifteen
four: winner, second, third, and fourth	sixteen or more

The place pools are not shown on the tote board, but the current payoffs for place bets for each horse are flashed on the screen. Bookies, on the other hand, simply pay a percentage of the win odds, as shown in Table 2.

There are many types of exotic bets as well. The tote jackpot corresponds to what North Americans call the pick six or sweep six. The tote placepot bet has no analogue in North America. The average rates of return on various bets on and off course against a bookmaker or the tote are listed in Table 3. The track take is 5% larger in the place pool than in the win pool. The tote take is larger than what the bookies make on average, and on-course betting takes are much less than off-course takes.

The races in England are on the turf for distances of generally at least a mile, except for some shorter races for two-year-olds. The season in southern England is unique in that races are run for about three days at each race course. The jockeys, trainers, and so forth then move on to a new course. After a month or so they return to the same course. Handicapping is very sophisticated in England. It has to be, with little information easily accessible (they have no analogue of the *Daily Racing Form*, although some past performances are available in newspapers) and all that moving from course to course.

The method of computing the place payoffs in England differs from that used in North America. In both locales, the net pool is the total amount wagered minus the track take. In North America, the cost of the winning in-the-money tickets is first subtracted to form the profit. This profit is then shared equally among the in-the-money horses. Holders of winning tickets receive a payoff consisting of the original stake plus their proportionate share of the horse's profits. This means that the amount of money wagered on the other horses in the money greatly affects the payoff. In England, the total net pool is divided equally among the horses that finish in the money. This means that the payoff on a particular horse depends upon how much is bet on this horse to place but not on how much is bet on the other horses. Since the minimum payoff is £1 per £1 wager, management is able to keep a control on betting for particular favorites. Once this minimum level is reached, it does not pay to wager on a given horse. This occurs whenever the percentage of the place pool that is bet on a given horse becomes as large as Q_p, which is the track take for place, divided by m, which is the number of in-the-money horses. In a race with 8-15 starters, if Q_p is about 0.735, and $m=3$, the just-get-your-money-back point is reached when the bet on a particular horse to place becomes 24.5% of the total place pool: 0.735/3 = 24.5%. Hence in England you will often see horses whose place payoffs are £1 or just slightly higher. This method of sharing the place pool tends to favor longer-priced horses at the expense of the favorites.

Table 2. Bookmakers payoff for place bets

Number of Runners	Type of Race	Fraction of Win Odds Paid on Place Element	Horses Regarded
Two to five		No place betting	
Six or seven	Any	$\frac{1}{4}$	First and second
Eight or more	Any except handicaps involving twelve or more runners	$\frac{1}{5}$	First, second, and third
Twelve to fifteen	Handicaps	$\frac{1}{4}$	First, second, and third
Sixteen to twenty-one	Handicaps	$\frac{1}{5}$	First, second, third, and fourth
Twenty-two or more	Handicaps	$\frac{1}{4}$	First, second, third, and fourth

Source: Rothschild (1978).

Table 3. Rates of return on different types of bets in England on thoroughbred and greyhound racing

Type of Bet	Rate of Return (%)
On-course bookmaker	90
Off-course bookmaker	81
Single bet to win with off-course bookmaker	85
Double bet to win with off-course bookmaker	78
Treble bet to win with off-course bookmaker	72
ITV Seven bet to win with off-course bookmaker	70–75
Computer straight forecast with off-course bookmaker	65
Greyhound forecast with off-course bookmaker	76
Greyhound forecast double with off-course bookmaker	58
Place element of each-way with off-course bookmaker	80
Ante-post betting with off-course bookmaker	96
Horse race tote win pool (on course)	80
Horse race tote win pool (off course)	77
Horse race tote place pool (on course)	75
Horse race tote place pool (off course)	72
Horse race tote daily double pool (on course)	74
Horse race tote daily double pool (off course)	71
Horse race tote daily treble pool (on course)	70
Horse race tote daily treble pool (off course)	67
Horse race tote daily forecast pool (on course)	70
Horse race tote daily forecast pool (off course)	67
Horse race tote jackpot pool (on course)	70
Horse race tote jackpot pool (off course)	67
Horse race tote placepot pool (on course)	70
Horse race tote placepot pool (off course)	67
Greyhound tote pool betting, average	83.5

Source: Rothschild (1978).

The current track take to win is about 20.6% and to place is 26.5%, and the breakage is of 10c variety, or more properly 10p, for pence[2]. These track takes are much higher than those in North America. Since the track paybacks to win and place are different, we call the former, $Q_w=0.794$, and the latter, $Q_p=0.735$.

It is easy to apply the Dr.Z system in Great Britain, although with its much higher track takes, there may not be many Dr.Z system bets, see Mordin (1992) for a discussion of this. We utilize the substitution that $q_i=Q_w/O_i$, where O_i are the odds to win on the horse under consideration.

The expected value per pound bet to place on horse i is

$$EX\text{Place} - \text{(probability of placing) (place odds)} - \text{(Prob) } (PO_i). \tag{1}$$

In (1), PO_i refers to the odds to place on horse i. Prob, the probability of placing is determined as follows.[3,4]

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[2]We can calculate these track takes as follows: The payoff on horse i if it wins is $Q_w W_i/W$, where Q_w is the track payback to win, and W_i and W are the bet amount of horse i and the total bet amount, respectively. So let $q_i = W_i/W$, the efficient-market assumption. Let B be the average breakage, namely, 4.5p. Since breakage can be 0,1,2,...,,9 pence, its average is 4.5p. Then the payoff on i is Q_w/q_i-B, which equals the odds O_i, since the odds are based on total return (not return plus original stake as in North America). So $q_i = Q_w/(B+O_i)$. Summing over all n horses gives

$$\sum_{i=1}^{n} q_i - 1 - Q_w \sum_{i=1}^{n} \left(\frac{1}{B+O_i}\right),$$

since some horse must win. Hence

$$Q_w - \frac{1}{\sum_{i=1}^{n} (B+O_i)}.$$

For place, there are one, two, three, or four horses that are in the money, depending upon the number of starters. So

$$Q_p - \frac{m}{\sum_{i=1}^{n} (B+O_i)},$$

where $m=1,2,3$ or 4.

With the above formulas, $Q_w \simeq 0.794$ and $Q_p \simeq 0.745$.

[3]These equations were developed using the 1981-1982 Aqueduct data to relate probability of in-the-money finishes to q, the probability of winning and n, the number of horses. Equations (2), (3) and (4) had R^2 of 0.991, 0.993 and 0.998, respectively. These equations are valid when q ranges from 0 to 0.6

With $n=5$ to 7 horses, the first 2 horses place and

$$\text{Prob} = 0.0667 + 2.37q - 1.61q^2 - 0.0097n. \tag{2}$$

With n=8 to 15 horses, the first 3 horses place and

$$\text{Prob} = 0.0665 + 3.44q - 3.47q^2 - 0.0049n. \tag{3}$$

With n=16 or more horses, the first 4 horses place and

$$\text{Prob} = 0.0371 + 4.47q - 6.29q^2 - 0.00164n. \tag{4}$$

Figures 1,2, and 3 determine Prob directly using only O_i, the win odds on the horse in question. Figure 1 applies when there are five, six or seven horses. Figure 2 corresponds to equation (3) and applies when there are eight to fifteen horses. Finally, Figure 3 corresponds to equation (4) and applies when there are sixteen or more horses.

The optimal Kelly criterion bet is to wager (Prob PO_i-1)/(PO_i-1) percent of your betting wealth[5]. We can determine the optimal fraction of your wealth to bet indicated by equation (5) using Figure 4.

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for (2), from 0 to 0.45 for (3), and 0 to 0.3 for (4), which should be the case in most instances. However, Figures 1,2 and 3 are valid for any q.

[4]In a race with $n=2,3$, or 4 horses, only one horse places, the winner. Such races are rare. Also, it is unlikely that the win and place pools would then become so unbalanced as to yield a Dr.Z system bet. However, one would occur when PO_i/O_i was at least 1.44, for a track payback of 0.794 and an expected-value cutoff of 1.14, since 1.14/0.794 is 1.44. In such a case, one would have a good bet.

[5]We have assumed that your bets will be small and hence will not affect the odds very much. Thus to determine the optimal bet b for betting wealth w_0, you maximize Prob $\log[w_0 + (PO_i\text{-}1)b] + (1 - \text{Prob})\log(w_0 - b)$, whose solution is equation (5).