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Prizes, Selection and Performance in Arabian Horse Racing

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"Prizes, Selection and Performance in Arabian Horse Racing."*

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I. Introduction

Much has been written in the theoretical literature about the incentive effects of tournaments.[1] There is also a growing empirical literature that tests the theory of tournaments.[2] The emphasis in the empirical literature is on testing the effect that tournament prize structures have on the absolute performance levels of the tournament participants. With the exception of Lynch and Zax (1997), the factors that influence the decision to enter a tournament receive little attention.

This paper examines the determinants of race selection in Arabian horse racing as well as the effect prizes have on both absolute and relative performance, conditional on selection. We find that the decision to enter a race is influenced by expected winnings and that the difference between prizes affects the absolute level of performance in the way predicted by the theory. However, our results only weakly support the hypothesis that larger prize differences increase relative performance.

We also examine the effect prize differences have on sorting. The theory of tournaments predicts that increasing the difference between prizes will induce tournament contestants to sort themselves into separate tournaments based on their ability. Our results support this hypothesis.

The paper proceeds as follows. Section II outlines the main results from the theoretical and empirical literatures on tournaments. Section III describes the data set

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[1] See, for example, Lazear and Rosen (1981), Green and Stokey (1983), Nalebuff and Stiglitz (1983), Rosen (1988), O'Keeffe, Viscusi, and Zeckhauser (1984), or for a nice survey of this literature see McLaughlin (1988).

[2] See, for example, Becker and Huselid (1992), Clive, Schotter and Weigelt (1987), Ehrenberg and Bognanno (1990a, 1990b) Knoeber and Thurman (1994) and Orszag (1994).

and sections IV-VI contain the empirical results. Concluding remarks appear in section VII.

II. Previous Theoretical and Empirical Literatures

The theoretical literature on tournaments is rich with testable hypotheses. First, Lazear and Rosen (1981) show that, while the decision to enter a tournament depends on the absolute level of prize money, the decision of how much effort to exert during the tournament does not. The level of effort depends, instead, on the difference between the prizes awarded to the various places.

Mixed tournaments, which match workers of different abilities, are inefficient. Here, if worker ability is known, both the high ability worker and the low ability worker will choose lower levels of effort (see McLaughlin 1988). There is little incentive to work harder because pay depends on rank only and everybody is fairly certain in advance who is going to win. Because mixed tournaments are inefficient, tournament organizers should either sort workers into different tournaments based on their ability or use some form of handicapping.

However, if the worker's ability is known to the worker but not the firm then the workers will not sort themselves into different tournaments based on their ability. Lazear and Rosen (1981) show that the low ability workers, the 'b's,' will want to enter the 'a league.' The prize spreads, that would be efficient if the a's and the b's played in their own leagues make the expected utility of the b's higher in the a league. A higher inefficient prize spread in the 'a league' would induce self-sorting but also induce the a's to put forth too much effort. A more efficient way of sorting is for tournament organizers to require credentials.

Tournaments produce moral hazards (see Dye 1984; Lazear 1989). Because workers are paid based on rank, they will be less likely to cooperate and may even engage in sabotage.

Empirical tests of the theory of tournaments yield mixed results. For example, using economics students as volunteers, Bull, Schotter and Weigelt (1987) found that players put forth the amount of effort predicted by the theory in even tournaments, where players are of equal ability. In uneven tournaments the disadvantaged players put forth too much effort.

Ehrenberg and Bognanno (1990a, 1990b) test the incentive effects of tournaments using data from the 1984 Men's PGA tour and the 1987 European Men's PGA tour. They find that the level and structure of prize money influences player performance. Controlling for the quality of players, the difficulty of the course and weather conditions, golf scores are negatively related to the amount of total prize money which is proportional to prize differentials. Ehrenberg and Bognanno also find that golfers perform better in the final round of a tournament if the marginal returns to improving their rank are high and fewer strokes separate them from their closest competitors.

Ehrenberg and Bognanno also report that exempt players were more likely than nonexempt players to enter tournaments that offered higher prize money.[3] This finding resulted from a two-stage sample selection correction technique. The emphasis of the paper, however, is not on how prizes affect the selection of tournaments but on how prizes affect effort within tournaments.

[3] An exempt golfer is one who has performed well enough in previous tournaments to be allowed to enter any tournament he wishes.

Using the Ehrenberg-Bognanno model and data from the 1992 PGA Tour, Orszag (1994) finds the effect of total prize money on final scores to be insignificant. Orszag, however, does not offer a convincing explanation for why his results do not support the theory of tournaments while most other studies do.

Like Ehrenberg and Bognanno (1990a,1990b) and Orszag (1994), Becker and Huselid (1992) test the theory of tournaments in a sports setting. They use data from National Association for Stock Car Auto Racing (NASCAR) and International Motor Sports Association (IMSA) to show that increasing the spread between the average prize money awarded to the top finishing positions and the average prize money awarded to the lower finishing positions increases driver performance at a diminishing rate. The authors also found limited evidence that driver safety is adversely affected by increasing the spread supporting the hypothesis that tournaments may produce moral hazards.

Knoeber and Thurman (1994) test the theory of tournaments outside of the context of sports. Growers of broiler chickens are paid using tournaments and linear relative performance evaluation (LRPE) schemes. LRPE schemes reward growers based on their performance relative to that of the average grower. Their analysis of the data describing broiler production supports the following hypotheses. First, changes in the level of prize money that leave prize differentials unchanged have no effect on grower performance. Second, in mixed tournaments growers of low ability choose riskier strategies or have more variable performances. Third, tournament organizers use handicapping and sorting to reduce the disincentive effects of mixed tournaments.

Lynch and Zax (1997) explicitly compare the incentive and sorting theories of tournament performance in road races. Regressions omitting controls for runner ability suggest that runners record faster times, the greater the loss they would suffer from finishing below their pre-race ranking. However, the relationship between prize money at risk and finishing time weakens or vanishes with these controls. Their results strongly suggest that races with large prizes record faster times because they attract faster runners, not because they encourage all runners to run faster.

With the exception of Lynch and Zax (1997), the previous empirical literature of tournaments has placed more emphasis on the effects of prize money on absolute performance and less emphasis on the role prizes play in tournaments selection. This paper will examine both as well as the effect prizes have on relative performance.

III. The Data

The data used comes from the Arabian Jockey Club, a national organization that regulates and promotes Arabian Horse Racing. The original data set contains data on all Arabian horse races in the US and Canada in 1991-95. For each horse in each race the data set includes among other variables, the horse's name, the jockey's name, the horse's age, weight carried, finishing time, finishing place, winnings, and odds of winning. For each race the data include, the name of the race, the total amount of prize money, the name of the racetrack, track conditions, the distance of the race, race restrictions and the type of race.

There are several different types of races. The stakes race is the most prestigious type of race and pays the highest prizes. Allowance races pay lower prizes and are less prestigious then stakes races. Unlike stakes races, in allowance races the horses carry more or less weight depending on their age and gender. A handicap race also uses weight adjustments to make races more competitive. Here a weight adjustment is determined for each horse individually, considering more than the horse's age and gender. A claiming race is a race where all of the horses entered are for sale for a pre-specified amount. This type of race usually attracts lower quality horses. Finally, a maiden race is a race for horses that have never won a race. The horses in a maiden race are slower on average.

We restricted the sample used in the final analyses in this paper to 1995 allowance races, which represent 42.5% of all 1995 races, for the following reasons. The horses that enter maiden and claiming races, which also represent 42.5% of all 1995 races, are, on average, slower and generally do not also enter allowance races. Many of the stakes races, which represent 14.9% of all 1995 races, have gender restrictions and the data set does not provide the horse's gender.[4] We only used 1995 races because we used 1991-94 data to create the variables measuring expected performance that we then used in the final analyses.

Descriptive statistics for the horses in 1995 allowance races appear in Table 1. Each of the 1732 observations represents an appearance of one horse in one race. There are 491 horses and 277 jockeys in the sample. The odds of winning are expressed as the dollar return on a one-dollar bet.

The prize difference variable is the dollar amount of prize money a horse would lose if it finished one place lower than its pre-race ranking. The pre-race ranking is based on the odds of winning. For example, if horse i in race j is the most likely to win, according to the odds, then horse i is assigned a pre-race rank of one in race j. If first and second place prizes for race j are p_1 and p_2 respectively, then the prize difference for the

[4] The other 0.1% of races are handicap races. Also, of all the 1995 stakes races 53.7% had gender restrictions. Only 22.0% of 1995 Allowance races had gender restrictions.

horse ranked first in race *j* is p_1-p_2. The prize difference variable for the lowest ranked horse is zero.

Table 1 Descriptive Statistics for Horses and Jockeys in 1995 Allowance Races

Variable	Mean	Standard Dev.	Minimum	Maximum
Prize Difference	243.8	420.5	0	2275.
Weight Carried	118.7	3.644	103.0	135.0
Finishing Time (Seconds)	83.05	14.01	52.00	132.0
Odds of Winning	16.35	30.49	0.1000	870.0
Age of Horse	5.364	1.769	3.000	12.00
Days Since Last Race	42.27	82.26	1.000	1093.
Number of Previous Races by Horse	17.08	13.28	1.000	93.00
Number of Top Three Finishes by Horse	7.806	7.198	0	59.00
Number of Previous Races by Jockey	144.0	177.7	1.000	917.0
Number of Top Three Finishes by Jockey	60.80	82.02	0	439.0
N=1732				

The ‘days since last race’ variable measures the time elapsed since the last time the horse raced regardless of whether the last race was a 1995 allowance race. The variables ‘number of previous races by horse,’ ‘number of previous races by jockey,’ ‘number of top three finishes by horse,’ and ‘number of top three finishes by jockey,’ also include all races from the beginning of 1991 till the race in question .

Table 2 contains descriptive statistics for race-specific variables. There are a total of 236 races. The race distance is in furlongs. One furlong is one eighth of a mile. Forty eight percent of the races are six furlongs or three quarters of a mile. The Herfindahl index of prizes is the sum of the square of the percentage of total prize money awarded to each place. This index measures dispersion in the entire prize structure and is bounded by zero and one.

Table 2 Descriptive Statistics for 1995 Allowance Races

Variable	Mean	Standard Dev.	Minimum	Maximum
Total Prize Money	3210.	1514.	600.0	7000.
Winning Time In seconds	80.86	13.48	52.00	124.4
Distance in Furlongs	5.910	0.9064	4.000	9.000
Herfindahl Index of Prizes	0.3894	0.02841	0.3134	0.4795
Track Conditions				
Fast	0.9534			
Muddy	0.01271			
Sloppy	0.01271			
Good	0.01271			
Firm	0.004237			
Heavy	0.004237			
N=236				

The average winning time in Table 2 is 80.86 seconds which is 2.2 seconds lower than the average finishing time in Table 1.

The track condition variables are dummy variables. Ninety-five percent of the time the track conditions are fast.

IV. Expected Times

One of the hypotheses tested in this paper is whether the decision to enter a race is influenced by expected winnings. Expected winnings for horse i in race j depend on horse *i*'s expected performance in race *j*. The expected performance, in turn, depends on horse *i*'s expected time in race *j* as well as the expected winning time in race *j*. The formation of these expected times, by those who decide which races the horse enters, is the subject of this section.

The regressions in this section mimic the way an owner of a horse forms expectations about how fast his horse will run in a race, and what the winning time in that race will be, based only on what is known prior to making the decision to enter the race. We assume that the identities of the horses that will make up the field, as well as the horse's odds of wining, are not known before the entry decision is made.

The regressions in Table 3 show which variables are important determinants of a horse's expected time in a race and the expected winning time in a race. The expected horse time regression, in the middle column of Table 3, uses data from all races from 1991-94. The dependent variable is a horse's finishing time in seconds. The right-hand side variables are listed in the first column of Table 3. The right-hand side variables also include dummy variables for racetracks and track conditions.

Two variables that measure horse quality are 'number of previous races by horse' and 'number of top three finishes by horse.' According to Table 3, the more previous starts a horse has the slower the horse's time will be. The negative sign on the quadratic term indicates that when the number of previous starts increases the finishing time increases at a decreasing rate. One possible explanation for this relationship is that the number of top three finishes is being held constant. Therefore, the more races a horse has to enter to gain a given number of top three finishes the slower the horse is.

Table 3 Expected Horse and Winning Times Regressions 1991-1994

Variable	Expected Horse Time Parameter Estimates	Expected Winning Time Parameter Estimates
Intercept	-14.73*** (6.623)	-22.66*** (4.792)
Number of Previous Races By Horse	0.1175*** (18.83)	
Number of Previous Races By Horse^2	-0.000505*** (5.037)	
Number of Top Three Finishes by Horse	-0.4389*** (39.31)	
Number of Top Three Finishes by Horse^2	0.007235*** (21.23)	
Days Since Last Race	0.003177*** (6.475)	
Days Since Last Race^2	-0.2123x10^{-5}** (2.290)	
Age	-0.2667*** (5.294)	
Age^2	0.01444*** (3.628)	
Distance	15.44*** (181.8)	15.15*** (87.06)
Distance^2	0.009613* (1.646)	0.002246 (0.185)
Total Prize Money/1000	-0.006109*** (2.973)	-0.01352*** (2.995)
Herfindahl Index of Prizes	122.3*** (7.165)	153.9*** (3.922)
Herfindahl Index^2	-325.8*** (6.591)	-417.8*** (3.697)
Herfindahl Index^3	266.3*** (5.690)	351.1*** (3.296)
Allowance	0.2643*** (3.894)	0.6713*** (5.087)
Claiming	0.2982*** (3.564)	0.9387*** (5.862)
Handicap	-0.2015 (0.719)	0.1268 (0.220)
Maiden	1.615*** (20.35)	2.238*** (14.93)
Adjusted R^2	0.9851	0.9911
N	20894	2965

Regressions include racetrack and track condition dummy variables.

If a horse has more top three finishes then its expected time will be lower. The negative sign on the quadratic term shows that this effect diminishes as the number of top three finishes increases. This quality control variable tells us that, holding constant the number of races entered, the horses with more top three finishes will run faster.

The coefficients on the linear and quadratic terms of 'days since last race' show that the longer it has been since the last time a horse has raced the slower the horse will run. This effect diminishes as the times since the last race increases. The magnitude of this effect, however, is small. An increase in time since last race of seven days, starting from the average which is 33.78 days, increases the finishing time by only 0.2123 seconds or 0.02435% of the average finishing time.

The coefficients on age and age squared indicate that horses get faster as they get older until they are about 9.2 years old. Then times increase with age.

The regressions include a linear and quadratic term for the distance of the race. Both coefficients are positive and the coefficient on the linear term is very significant indicating, unsurprisingly, that some of the variation in finishing times is due to the variation in race distances.

The variables 'allowance', 'claiming', 'handicap' and 'maiden' are dummy variables for the type of race. The omitted race type dummy variable is the stakes race. The coefficients on three of the four dummy variables are positive and significant indicating that the times in stakes races are relatively faster.

The variable 'prize difference' is not included in the regressions in Table 3 because the value of this variable can not be known prior to making the decision to enter a race. Recall that the prize difference variable is the dollar amount of prize money a horse would lose if it finished one place lower than its odds-based pre-race ranking. However, prior to entering a race, a horse's odds of winning are not known. Total prize money and the herfindahl index are two more general measures of the differences between prizes in a race. They are known prior to entering a race and, therefore, are included in the regression.

Total prize money serves as a proxy for the prize spreads. The higher total prize money is, holding the prize structure constant, the higher the prize spreads will be. Prize structure is held constant by including the Herfindahl index of prizes in the regression. The coefficient on total prize money is negative and significant but small in magnitude. An increase in total prize money of $1000 will reduce the finishing time by about 0.006 seconds. This result is consistent with the theory of tournaments, but suggests that incentive effects may be weak.

The coefficients on the cubic, quadratic and linear terms of the Herfindahl index indicate that, when the index is between 0.25 and 0.57, times fall as prizes become more disperse. This is consistent with the proposition from the theory that larger prize spreads induce greater effort. When the index is greater that 0.57, times increase when the index increases. This shows that if the prizes are too unevenly distributed, for example first place gets all the prize money, then many of the contestants give up. This may be why there are not many races with Herfindahl indices in this range. For example, the Herfindahl indices in all 1995 allowance races range from 0.3134 to 0.4795.

The adjusted R^2 of 0.9851 shows that the variables in the expected horse time regression explain almost all of the variation in horse times.

The results of the expected winning time regression appear in the third column of Table 3. The dependent variable in this regression is the winning time in 2965 races that occurred from 1991-94. Here the unit of observation is the race, therefore this regression excludes the horse-specific variables 'number of previous races by horse', 'number of top three finishes by horse', 'days since last race' and age.

The coefficients on distance and distance squared are similar to those in the expected horse time regression with the exception that distance squared is no longer significant.

According to Table 3 an increase in total prize money of $1000 reduces the winning time in a race by 0.0135 seconds. Recall that higher total prize money represents larger prize differences because the herfindahl index is also included in the regression. The magnitude of the effect of total prize money on finishing time is twice as large in the winning time regression as it is in the horse time regression. One possible explanation is that, on average, winning horses run close to the front where the prize differences are higher.

The coefficients on the cubic, quadratic and linear terms of the Herfindahl index give a similar result as in the expected horse time regression above. When the index is between 0.29 and 0.50, winning times fall as prizes become more disperse. Over ninety-five percent of the races in the 1991-1994 sample fall within this range. This direct relationship between effort and the dispersion of prizes is consistent with the theory of tournaments. When the index is greater that 0.50, winning times again increase when the index increases.

The adjusted R^2 of 0.9911 shows that the variables in Table 3 explain virtually all of the variation in winning times.

We used the coefficients from Table 3 to create an expected horse time for each horse for each race, as well as an expected winning time for each race, in the 1995 allowance race sample. These two variables are used in the empirical analyses in the following two sections.

V. Sorting at the Race Level

This section analyzes the relationship between prizes and sorting at the race level. In the theoretical literature on tournaments, Lazear and Rosen (1981) show that increasing the prize spread in high ability tournaments will induce contestants to sort themselves into separate tournaments based on their ability. This hypothesis is tested in the regressions in Tables 4A-4C.

Table 4A OLS Estimates of the Effects of Prize Difference on Sorting
Dependent Variable=Maximum expected time-Minimum expected time

Intercept	119.4 (1.585)
Herfindahl index of prizes	-942.9 (1.637)
Herfindahl index of prizes^2	2482.* (1.693)
Herfindahl index of prizes^3	-2160.* (1.739)
Total Prize Money/1000	1.422** (2.496)
Total Prize Money^2/1000000	-0.491*** (2.780)
Total Prize Money^3/1000000000	0.05295*** (3.218)
Mean of Dependent Variable	2.355
Mean of Expected Winning Time	81.02
Adjusted R^2	0.1036
N	214

Table 4B OLS Estimates of the Effects of Prize Difference on Sorting
Dependent Variable=Variance in expected times

Intercept	71.04 (1.335)
Herfindahl index of prizes	-559.1 (1.374)
Herfindahl index of prizes^2	1449. (1.399)
Herfindahl index of prizes^3	-1240. (1.413)
Total Prize Money/1000	1.229*** (3.053)
Total Prize Money^2/1000000	-0.470*** (3.771)
Total Prize Money^3/1000000000	0.05330*** (4.585)
Square Root of Mean of Dependent Variable	0.8742
Adjusted R^2	0.1564
N	214

Table 4C OLS Estimates of the Effects of Prize Difference on Sorting
Dependent Variable=Variance in expected-actual times

Intercept	332.2* (1.767)
Herfindahl index of prizes	-2628.* (1.829)
Herfindahl index of prizes^2	6824.* (1.865)
Herfindahl index of prizes^3	-5838. (1.884)
Total Prize Money/1000	5.060*** (3.559)
Total Prize Money^2/1000000	-1.785*** (4.051)
Total Prize Money^3/1000000000	0.1827*** (4.449)
Square Root of Mean of Dependent Variable	1.614
Adjusted R^2	0.1437
N	214

In these regressions the unit of observation is the race.[5] The dependent variable in each of the three regressions in Tables 4A-4C is a different measure of variation in horse quality. The first measure, used in Table 4A, is the difference between the highest and lowest expected horse time in each race. Recall that the expected horse time is calculated using the coefficients from the second column in Table 3. The second measure, used in Table 4B, is the variance of expected horse times in each race. These first two measures are ex ante measures of the variability in quality. They rely on what is known about the horse up through the last time the horse raced. The third measure, used in Table 4C, is the variance of the difference between expected horse times and actual finishing times. This dependent variable measures the ex-post variation in the unobservable component of horse quality.

The explanatory variables include a linear, quadratic and cubic term for the Herfindahl index of prizes as well as a linear, quadratic and cubic term for total prize money.[6] These variables measure the prize spread and the level of prizes respectively.

If the hypothesis from Lazear and Rosen (1981) is correct we would expect to see less variation in horse quality in races where the prize dispersion is higher. The results are mixed.

In Table 4B the coefficients on the linear, quadratic and cubic Herfindahl index are insignificant. However, in Tables 4A and 4C when the Herfindahl index rises above

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[5] There are only 214 observations in these regressions even though there are 236 races in the sample. Some races have horses with no prior race records. An expected horse time can not be calculated for these horses because the variable 'time since last race' is missing. These races were not used in the regressions in Tables 4A-4C. However, the horses in these races that do not have missing values for the variable 'time since last race' are used in the later analyses.

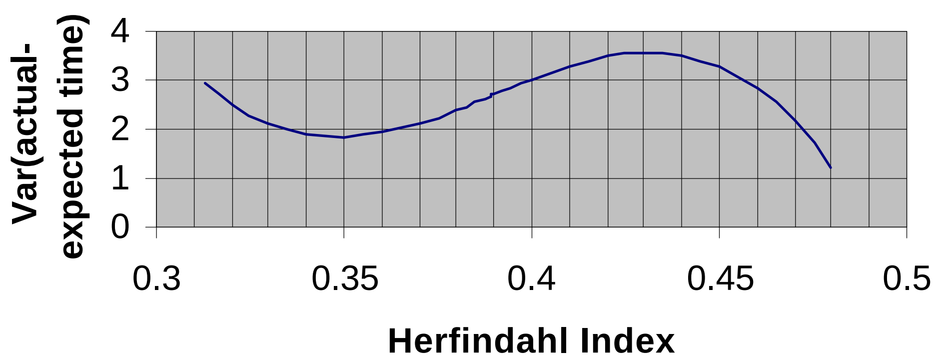
[6] The cubic specifications for total prize money and the Herfindahl index fit the data better than specifications with only a linear term or only a linear and quadratic term.

a certain threshold, around 0.43, the variability in horse quality declines when the Herfindahl index rises. This is consistent with the sorting hypothesis from the theory. However, only 10 of the 214 races in the sample have Herfindahl indices above this threshold. One reason that few races have Herfindahl indices this high is that very high herfindahl indices may discourage the contestants and produce slower times as demonstrated in Table 3. Below this threshold the variability in horse quality and the Herfindahl index are positively related.

As an example, Figure 1 shows the relationship between the Herfindahl index and the dependent variable in Table 4C, for the range of Herfindahl indices in the sample. In the sample the Herfindahl indices range from 0.3134 to 0.4795. The mean is 0.3891. In Figure 1 the level of total prize money is held constant at $3323.13, which is its average.

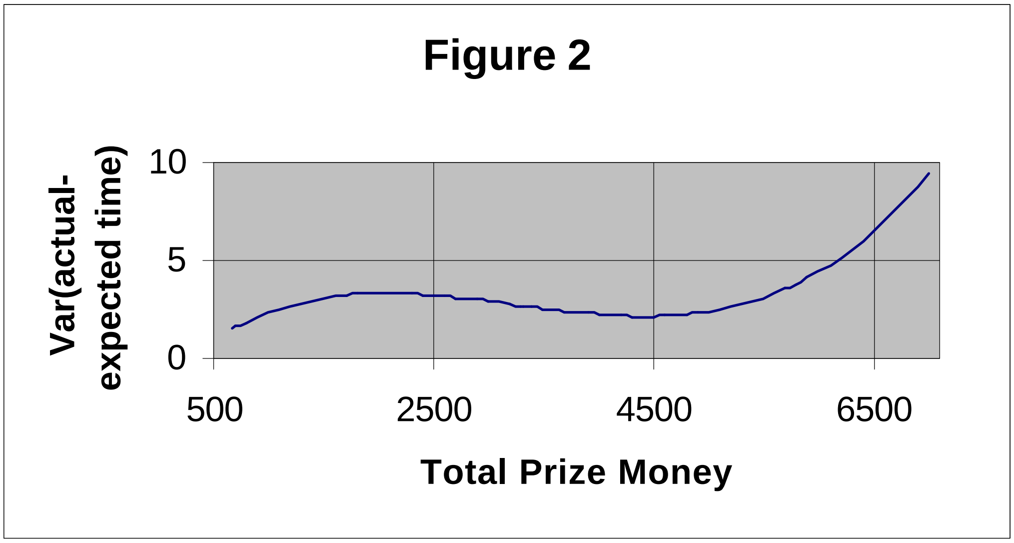
An increase in total prize money while holding the structure of prizes, or the Herfindahl index, constant can be viewed as both an increase in the absolute differences between prizes and an increase in the absolute level of prizes. The sorting hypothesis predicts that an increase in the differences between prizes will decrease the variation in horse quality while an increase in the level of prizes will increase the variation in horse

Figure 1



quality. Therefore, the relationship between total prize money and variation in horse quality will depend on which effect dominates

Figure 2 shows the relationship between total prize money and the dependent variable in Table 4C, for the range of total prize money in the sample. In the sample, total prize money ranges from $675 to $7000. The average is $3323. In Figure 2 the Herfindahl index is held constant at 0.3891, which is its average. Between $2100 and $4400 the variability in horse quality decreases as total prize money increases as the theory predicts. There are 76 races, out of 214 races in the sample, that fall in this range. However, when total prize money is above $4400, higher prize money increases the variability in horse quality. This is also consistent with the theory which predicts that horses of both low and high quality will enter races with higher prize money.



To conclude, these results support the sorting hypotheses from the theory. Namely that races with the highest absolute levels of prizes attract both low and high quality contestants and that higher prize differences reduce the variation in the quality of contestants.

VI. Sorting at the Horse Level

This section uses a sample selection model to analyze the decisions to enter a race and how much effort to exert during a race once the race is entered. The complete sample selection model appears in equations 1-5 below.

The sample selection model consists of two parts. The race selection decision is modeled by a probit where the dependent variable is the unobserved variable Z^*. See equations 1-3 below. Z^* represents the difference between the marginal benefits and marginal costs of entering a race. We observe a horse being entered into a race, or $z=1$, when Z^* is positive. We observe a horse not being entered into a race, or $z=0$, when Z^* is not positive. V is a vector of explanatory variables that includes the expected horse time and the expected winning time variables created using the coefficients from Table 3. A list of all of the explanatory variables appears in the first column of Table 5A.

The second part of the sample selection model, for the horses that enter races, consists of the regression in equation 4. Here the dependent variable, Y, is the horse i's finishing time in race j. X is a vector of explanatory variables that includes horse i's age, weight carried, prize difference, odds of winning, expected horse time, number of previous races by horse i, number of previous races by the jockey, number of top three finishes by the horse i, number of top three finishes by the jockey, the distance of race j, racetrack dummy variables and track condition dummy variables. A complete list of these explanatory variables appears in the first column of Table 5B.

$$z^* = \alpha'\nu + u \quad (1)$$

$$z = 1 \text{ if } z^* > 0 \quad (2)$$

$$z = 0 \text{ if } z^* \leq 0 \quad (3)$$

$$y = \beta' x + \varepsilon \quad (4)$$

$$\varepsilon, u \sim N[0, 0, \sigma_{\varepsilon}, \sigma_{u}, \rho] \quad (5)$$

Equation 5 indicates that the errors in the probit and the regression may be correlated with correlation coefficient ρ. If so, OLS estimates of equation 4 would produce biased estimates of β. Simultaneous maximum likelihood estimates of the parameters in α and β and ρ will be consistent.

The likelihood function for a sample with only one race appears in equation 6 below.[7] The total number of horses is *n* and the number of horses that enter the race is *m*, where *n*>*m*. The term on the first line of equation 6 is for horses that enter the race. The term on the second line is for horses that choose not to enter. Φ and ϕ represent the normal cumulative distribution function and the normal probability density function respectively.

[7] Equation 6 is reproduced from Greene (1995), page 667.

$$L = \prod_{i=1}^{m} \phi\left[(y_i - \beta' x_i)/\sigma_\varepsilon\right] \cdot \Phi\left[\alpha' v_i + \frac{(\rho/\sigma_\varepsilon)(y_i - \beta' x_i)}{\sqrt{1-\rho^2}}\right] \cdot \prod_{m+1}^{n} \Phi\left[-\alpha' v_i\right] \qquad (6)$$

In the sample of 1995 allowance races there are 236 races. Therefore the underlying analysis would have consisted of 236 likelihood functions like equation 6. However, the plausible assumptions that α, β, ρ, and σ_ε are equal across races, allows us to form one multi-race likelihood function. In this multi-race likelihood function *n* is the product of the total number of horses and the total number of races, and *m* is the total number of observations were a horse enters any race. The results of the estimation of this likelihood function appear in Tables 5A and 5B.

There are 491 horses and 236 races in the sample. The total number of observations is 103001.[8] Table 5A contains the estimates of α. This probit half of the sample selection model does a good job of predicting the probability of entering a race. In the subset of observations where the horses do not enter the race the average probability of entering, predicted by the model, is 1.58%. The average estimated probability of entering for those horses that do enter is more than five times higher or 8.31%.

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[8] The product of 491 and 236 is 115876. The actual number of observations used is less. One reason is that a small number of races had age restriction that excluded 3 year-old horses. This reduces the set of possible races a 3 year-old can enter. Another reason is that the variables ‘distance from last race’ and ‘days since last race’ are missing until a horse races for the first time. Therefore, the first race for any horse is omitted.

Table 5A Sample Selection Model 1995 Allowance Races: Probit

Intercept	5.352 (0.551)
Distance From Last Race	-0.001802*** (29.92)
Distance From Last Race^2	4.240×10^{-7}*** (16.75)
Days Since Last Race	2.898×10^{-4} (0.384)
Days Since Last Race^2	-2.428×10^{-7} (0.368)
Number of Previous Races by Horse	0.05670** (2.173)
Number of Previous Races by Horse^2	-0.0002769** (2.341)
Number of Top Three Finishes by Horse	-0.2074** (2.076)
Number of Top Three Finishes by Horse^2	0.003331** (2.006)
Age	-0.03922* (1.822)
Distance	-13.15 (0.494)
Total Prize Money/1000	0.2209** (2.189)
Total Prize Money^2/1000000	-0.02179** (1.998)
Herfindahl Index of Prizes	6.848 (0.398)
Expected Horse Time	-0.1917 (0.804)
Expected Horse Time^2	-0.001943*** (4.313)
Expected Winning Time	1.054 (0.597)
Expected Winning Time^2	0.002082*** (4.394)

Includes racetrack dummy variables.

The variable 'distance from last race' is the distance, in miles, from the racetrack where the horse last raced. The average amount of total prize money in these races is only around 3200 dollars. Therefore, it is not likely that the horses will be transported all over the country to enter races. This is in fact the case. According to the results in Table 5A, an increase in the distance from the last race of 1000 miles decreases the average probability of entering a race from 1.69% to 0.50%.[9]

It would seem that it would be less likely for a horse to be entered into a race if the horse raced very recently. This is why the variable 'days since last race' appears in the probit. This variable, however, turned out not to be significant.

Horses that have more race experience are more likely, and horses with more top three finishes are less likely, to enter races. One possible reason for this second effect is that the horses that do well in allowance races may be more likely to enter stakes races.

The distance of the race seems to have no effect on the probability of entering. The coefficient on age indicates that younger horses are more likely to enter races. A decrease in a horse's age by one year increases the probability of entering from 1.69% to 1.83%.

Increasing total prize money, holding constant the horse's expected time, the expected winning time and the herfindahl index, increases the probability of entering. This is consistent with the hypothesis that horses are entered in races where their expected earnings are the highest. An increase in total prize money of $1000 increases the average probability of entering from 1.69% to 1.88%.

The signs on the linear and quadratic terms of expected horse time and expected winning time are also consistent with the hypothesis that owners are out to maximize expected earnings. Holding constant the expected winning time in a race, a decrease in a

[9] The average probability of entering a race for the entire sample is 1.69%. We calculated the marginal effects in this section by increasing or decreasing the relevant independent variable and then recalculating the average probability of entering.

horse's expected time by one second increases the average probability of entering form 1.69% to 4.26%. In addition, holding constant the expected horse time, an increase in the expected winning time in a race of one second increases the average probability of entering from 1.69% to 14.62%. In other words horses are more likely to appear in races where their expected time, relative to the expected winning time, is low.

The estimate of ρ, the correlation coefficient between the error terms in the probit and the regression, appears at the bottom of Table 5B. It is significant and equal to 0.1373. In other words, unobserved characteristics of the horses that make horses more likely to enter races also makes them more likely to run slow. This type of sorting is at odds with the interests of race organizers who presumably would like to see faster horses enter their races. However, one explanation for this sorting may be that faster horses are more likely to race in the more prestigious stakes races, which are not included in the sample.[10]

Consistent estimates of β, for the horses that entered races, appear in Table 5B.[11] According to table 5B, older horses are slower. Increasing the age of the horse by one year increases the finishing time by 0.1848 seconds. The coefficient on distance is positive and significant indicating, naturally, that longer races take more time to finish.

According to Table 5B horses carrying more weight run faster. This may be due to the fact that the handicapping in allowance races is incomplete. The additional weight

[10] Horses, in our sample, with an average finishing place of 3rd or better in 1995 allowance races raced in an average of 3.087 allowance races and 2.103 stakes races in 1995. For horses with an average finishing place below 3rd these numbers were 3.827 and 0.8017 respectively.

[11] The biased OLS estimates of β are surprisingly similar in magnitude, sign and significance to the consistent estimates in Table 5B. For example the OLS estimate of the coefficient on the prize difference variable is –0.0813 with a t-statistic of 6.490.

that faster horses are required to carry may slow them down but it does not make them as slow as horses that are not required to carry additional weight.

Table 5B Sample Selection Model 1995 Allowance Races: Regression Results

Intercept	8.872** (2.018)
Age	0.1848*** (5.399)
Distance	8.563*** (5.682)
Weight	-0.03206* (1.767)
Prize Difference/100	-0.08043*** (5.384)
Odds of Winning	0.0071644*** (12.14)
Expected Horse Time	0.4413*** (4.550)
Herfindahl Index of Prizes	-14.80 (1.585)
Days Since Last Race	-0.0007239 (1.099)
Number of Previous Races by Horse	-0.001672 (0.152)
Number of Top Three Finishes by Horse	-0.07555*** (2.824)
Number of Previous Races by Jockey	0.001995 (1.086)
Number of Top Three Finishes by Jockey	-0.004368 (1.129)
Sigma	0.1889*** (65.94)
Rho	0.1373** (2.373)

Includes racetrack and track condition dummy variables.

Odds of winning and expected horse time are both controls for the horse quality. Both of these variables are significant and have the expected sign. Recall that the ‘odds of winning' is the dollar return on a one-dollar bet. Therefore, the higher this number is the less likely the horse is to win and the slower the horse is.[12]

The number of top three finishes by the horse is also a quality control variable. Holding the number of previous starts by the horse constant, an additional top three finish decreases a horse's finishing time by 0.0756 seconds.

The regression in Table 5B includes the variables 'number of previous races by jockey' and 'number of top three finishes by jockey' to control for the quality of the jockey. Surprisingly, the coefficients on both of these variables are insignificant. This result suggests that, unless the quality of the jockey is incorporated in the odds of winning variable, jockey quality does not matter in determining the finishing time.

Prize difference is the amount of prize money lost if a horse falls below its pre-race ranking. Recall that the pre-race rankings are based on the odds of winning. Even after controlling for horse and jockey quality, an increase in the prize difference of $1000 will reduce the finishing time by 0.8043 seconds. This result shows that greater prize spreads induce greater effort. These incentive effects are consistent with the theory of tournaments.

The prize difference only measures the loss resulting from dropping one place. The Herfindahl index of prizes represents the entire prize structure in a race. It appears in the regression to determine if the rewards to finishing several places higher, or the losses incurred from finishing several places lower, might also have an effect on finishing times.

[12] Holding odds constant, other variables that are known at the start of a race help predict finishing times. This implies that the betting market is 'inefficient' at least in regards to incorporating all known information that predicts horse speed.

The lack of significance here indicates that effort is influenced only by the risk of immediate losses that exist at the margin.

Table 5B shows that the relationship between prizes and effort works from the standpoint of the race organizer. Everything else being equal a race organizer would rather see faster times than slower times.

However, the race participants are primarily interested in their relative times since that is what determines their winnings. The next question left to answer is whether the incentives work from the standpoint of the contestants. Do higher prize differences produce higher places?

To answer this question we used a bivariate probit model. In the bivariate probit model, equation 4, the finishing time regression, is replaced with equation 7. Simultaneous estimation of equation 7 and equation 1, produce consistent estimates of γ.

$$z_1^* = g'x + \varepsilon \tag{7}$$

$$z_1 = 1 \text{ if } z_1^* > 0 \tag{8}$$

$$z_1 = 0 \text{ if } z_1^* \leq 0 \tag{9}$$

The dependent variable, z_1, is equal to 1 if the horse finishes at or above its pre-race ranking and zero otherwise. Recall that the pre-race rankings are based on the odds of winning. For example, if horse *i* is ranked second in race *j* then z_{1ij} is equal to one only if horse *i* finishes in first or second place in race *j*. Otherwise z_{1ij} is equal to zero.[13]

[13] The last ranked horse will always have a value for z_1 equal to one. Therefore, in an appendix, Tables A1 and A2 present the bivariate probit results omitting the last ranked horse.

The explanatory variables in equation 7, *x*, are the same as those in Table 5B with the exception that the expected horse time is replace with the horse's pre-race ranking. The estimates of a in the race selection probit appear in table 6A.

Table 6A Bivariate Probit Results: Race Selection Probit

Intercept	0.2084 (0.022)
Distance From Last Race	-0.001799*** (30.03)
Distance From Last Race^2	4.222×10^{-7}*** (16.72)
Days Since Last Race	2.247×10^{-4} (0.298)
Days Since Last Race^2	-2.066×10^{-7} (0.307)
Number of Previous Races by Horse	0.05405** (2.088)
Number of Previous Races by Horse^2	-0.0002669** (2.297)
Number of Top Three Finishes by Horse	-0.1969** (1.986)
Number of Top Three Finishes by Horse^2	0.003157* (1.921)
Age	-0.03741* (1.756)
Distance	1.488 (0.057)
Total Prize Money/1000	0.1909** (2.031)
Total Prize Money^2/1000000	-0.02062** (2.007)
Herfindahl Index of Prizes	-2.745 (0.162)
Expected Horse Time	-0.1745 (0.740)
Expected Horse Time^2	-0.001902*** (4.327)
Expected Winning Time	0.06849 (0.040)
Expected Winning Time^2	0.002058*** (4.435)

Includes racetrack dummy variables.

The marginal effects of changes in expected horse time, expected winning time and prize money in Table 6A are similar to those in Tables 5A. These results support the hypothesis that higher expected earnings increase the probability of entering.[14]

The estimated correlation coefficient between the error terms in equations 1 and 7, ρ, appears at the bottom of Table 6B. It is –0.003342 and not significant. This means that the unobserved characteristics that make a horse more likely to enter are not correlated with unobserved characteristics that influence a horse's relative performance. Recall that the conclusion from ρ in Table 5B was that slower horses, *ceteris paribus*, were more likely to enter races. However if all of the horses are slower then relative performance may not be affected.

The estimates of γ in equation 7 appear in table 6B. Unlike Table 5B, where finishing time was the dependent variable, the coefficient on distance, in Table 6B is insignificant.

Horses carrying more weight are also more likely to drop below their pre-race ranking. An increase in weight of 1 pound reduces the average probability of not dropping from 62.08% to 61.11%. This demonstrates that handicapping is working too effectively since it affects relative performance.

Unlike Table 5B, the coefficient on prize difference in Table 6B is insignificant. Together these results show that the prize incentives, as measured by the prize difference

[14] The coefficients on the linear and quadratic terms for total prize money in Table 6A indicate that, when total prize money is above $4,629, the probability of entering a race actually declines when total prize money is increased. However, 78% of the observations in the sample have values of total prize money that are less than this amount. One possible explanation is that owners that are considering entering Allowance races with high total prize money might end up choosing a stakes race which is not included in the sample.

variable, work from the standpoint of the race organizers, who would like more effort, but not from the standpoint of the jockeys, who would like to increase their winnings.

Table 6B Bivariate Probit Results: Place Probit

Intercept	-1.6072 (0.506)
Age	-0.04021 (1.504)
Distance	-0.02360 (0.514)
Weight	-0.02966** (2.245)
Prize Difference/100	0.01668 (1.484)
Odds of Winning	-0.0005454 (0.279)
Expected Place	0.2490*** (9.543)
Herfindahl Index of Prizes	11.59* (1.773)
Days Since Last Race	-0.0004095 (0.840)
Number of Previous Races by Horse	0.004924 (0.794)
Number of Top Three Finishes by Horse	0.01380 (1.216)
Number of Previous Races by Jockey	-0.001213 (1.124)
Number of Top Three Finishes by Jockey	0.002529 (1.107)
Rho	-0.03342 (0.364)

Includes racetrack and track condition dummy variables.

However, the positive and significant coefficient on the Herfindahl index of prizes shows that horses are less likely to drop below their pre-race ranking when prizes are more disperse.[15] Increasing the Herfindahl index of prizes by 0.01 increases the average

[15] Here the linear specification for the Herfindahl index fit the data best.

probability of not dropping from 62.08% to 65.80%. Also, the coefficients for the prize difference variable and the herfindahl index are jointly significant.[16] Therefore, there is some evidence, to support the hypothesis that larger prize differences produce higher places.

The coefficient on 'odds of winning' is not significant. However the coefficient on expected place, which is a ranking based on the odds, is significant. This suggests that the odds values are overly precise. The ordinal rankings derived from them predicts outcomes more effectively than do the cardinal odds themselves.

The positive sign on the coefficient for expected places means that lower ranked horses are more likely not to drop below their pre-race ranking. In fact it is impossible for the last-ranked horse to drop below its pre-race ranking. Because of this we reestimated the model in Tables 6A and 6B without last ranked horses. These results, which appear in Tables A1 and A2 in an appendix, show that the coefficient on expected place is still positive and significant. The coefficient on prize difference is still insignificant.

We also redefined the dependent variable in the place probit to be equal to one if the horse finished above its pre-race ranking and equal to zero if it finished at or below its pre-race ranking. In this model the prize difference variable was also redefined to be the amount of prize money that would be gained if a horse finished above its pre-race ranking instead of the amount lost if the horse finished below its pre-race ranking. This model excludes first ranked horses because it is impossible for the first ranked horse to

[16] The test statistic, which has a chi-squared distribution, is 5.535 with 2 degrees of freedom. It is significant at the 10% level.

finish above its pre-race ranking. Therefore, in this model, the prize difference for first ranked horses is not defined.

These results, which appear in Tables A3 and A4 in an appendix, indicate that the coefficient on expected place is still positive and significant meaning that lower ranked horses are more likely to finish above their pre-race ranking. The coefficient on prize difference is still insignificant.

Table 7 Ordered Probit Results

Intercept	1.711 (0.7294)
Age	0.05264*** (2.830)
Distance	0.03974 (1.168)
Weight	0.009463 (1.001)
Prize Difference/100	-0.01107 (1.283)
Odds of Winning	0.001373 (1.405)
Expected Place	0.2149*** (12.84)
Herfindahl Index of Prizes	-7.301 (1.513)
Days Since Last Race	0.0004366 (1.385)
Number of Previous Races by Horse	0.002175 (0.4915)
Number of Top Three Finishes by Horse	-0.02591*** (3.186)
Number of Previous Races by Jockey	0.001785** (2.192)
Number of Top Three Finishes by Jockey	-0.003892** (2.248)

Includes racetrack and track condition dummy variables.

To further test the hypothesis that the prize structure affects relative performance we estimated an ordered probit model with a dependent variable equal to the finishing place. These results appear in Table 7.[17] The explanatory variables in Table 7 are the same as those in Table 6B.

Like Table 6B, the coefficient on odds is not significant indicating that odds are not a good predictor of relative performance. However, the odds-based variable ‘expected place’, an ordinalization of odds, is positive and very significant and, therefore, a good predictor of how well a horse will run.[18]

The coefficient on the prize difference variables is insignificant indicating, again, that prize differences do not affect relative performance.[19]

However, the variable ‘number of top three finishes by jockey’ is significant and negative. This variable is not significant in Table 5B. Together these results show that good jockeys do not produce faster times but they do produce higher places. This makes sense given that their pay is based on relative, not absolute, performance.

VII. Conclusions

This paper examined the role of prizes in Arabian horse racing. Like previous empirical analyses of tournaments this paper finds a positive relationship between the prize spread and the absolute level of performance. We also find some support for the hypothesis that larger prize spreads increase relative performance. Together these two results indicate that the prizes work for the tournament organizers, by inducing greater effort, as well as for the contestants who wish to improve their finishing places.

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[17] Because of the lack of significance of ρ in the previous bivariate probits we did not simultaneously estimate a race selection probit in Table 7.

[18] Nevertheless, if bettors consider all available information about the horses before betting then expected place should be the only significant variable in Table 7. It is not. However, the analysis of the efficiency of the betting market is a topic for future research and not the focus of this paper.

[19] The prize difference variable and the herfindahl index are also not jointly significant.

Unlike previous empirical tests of the theory of tournaments this paper also focuses on the determinants of tournament selection. Expected winnings, which is a function of total prize money, the dispersion of prizes, and a horse's expected relative performance, is positively related to the probability of entering a race.

We also examined the relationship between prize differences and sorting at the race level. Our results support two hypotheses from the theory. Races with the highest prizes attract contestants of varying ability and higher prize spreads will induce contestants to self-sort into tournaments based on their ability.

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Table A1 Bivariate Probit Results Without Last-Ranked Horse: Race Selection Probit

Intercept	0.8065 (0.080)
Distance From Last Race	-0.001768*** (28.18)
Distance From Last Race^2	4.167×10^{-7}*** (15.84)
Days Since Last Race	2.348×10^{-4} (0.301)
Days Since Last Race^2	-2.831×10^{-7} (0.408)
Number of Previous Races by Horse	0.04286 (1.598)
Number of Previous Races by Horse^2	-0.0002296* (1.847)
Number of Top Three Finishes by Horse	-0.1729* (1.684)
Number of Top Three Finishes by Horse^2	0.002956* (1.737)
Age	-0.04719** (2.118)
Distance	1.147 (0.041)
Total Prize Money/1000	0.1936** (1.940)
Total Prize Money^2/1000000	-0.02102** (1.928)
Herfindahl Index of Prizes	-3.642 (0.201)
Expected Horse Time	-0.1617 (0.660)
Expected Horse Time^2	-0.001943*** (4.083)
Expected Winning Time	0.07788 (0.042)
Expected Winning Time^2	0.002099*** (4.188)

Includes racetrack dummy variables.

Table A2 Bivariate Probit Results Without Last-Ranked Horse: Place Probit

Intercept	0.06198 (0.018)
Age	-0.05586** (2.000)
Distance	-0.03450 (0.729)
Weight	-0.03137** (2.275)
Prize Difference/100	0.01110 (0.939)
Odds of Winning	-0.01555*** (3.893)
Expected Place	0.2705*** (7.800)
Herfindahl Index of Prizes	8.888 (1.244)
Days Since Last Race	-0.0005659 (1.082)
Number of Previous Races by Horse	0.003153 (0.477)
Number of Top Three Finishes by Horse	0.01877 (1.588)
Number of Previous Races by Jockey	-0.0008654 (0.782)
Number of Top Three Finishes by Jockey	0.001959 (0.837)
Rho	-0.05947 (0.621)

Includes racetrack and track condition dummy variables.

Table A3 Bivariate Probit Results Without First-Ranked Horse: Race Selection Probit

Intercept	0.2680 (0.025)
Distance From Last Race	-0.001793*** (27.84)
Distance From Last Race^2	4.255×10^{-7}*** (15.77)
Days Since Last Race	3.289×10^{-4} (0.419)
Days Since Last Race^2	-2.990×10^{-7} (0.427)
Number of Previous Races by Horse	0.06489** (2.370)
Number of Previous Races by Horse^2	-0.0003013** (2.316)
Number of Top Three Finishes by Horse	-0.2230** (2.138)
Number of Top Three Finishes by Horse^2	0.003313* (1.901)
Age	-0.02549 (1.150)
Distance	1.632 (0.054)
Total Prize Money/1000	0.1944* (1.928)
Total Prize Money^2/1000000	-0.02131* (1.948)
Herfindahl Index of Prizes	-3.296 (0.168)
Expected Horse Time	-0.2092 (0.839)
Expected Horse Time^2	-0.001911*** (4.112)
Expected Winning Time	0.09326 (0.047)
Expected Winning Time^2	0.002076*** (4.223)

Includes racetrack dummy variables.

Table A4 Bivariate Probit Results Without First-Ranked Horse: Place Probit

Intercept	-2.099 (0.662)
Age	-0.03248 (1.242)
Distance	-0.06298 (1.359)
Weight	-0.02722** (2.009)
Prize Difference/100	-0.01837 (1.544)
Odds of Winning	-0.0003274 (0.252)
Expected Place	0.1616*** (6.290)
Herfindahl Index of Prizes	12.18* (1.889)
Days Since Last Race	-0.0003729 (0.721)
Number of Previous Races by Horse	-0.002300 (0.363)
Number of Top Three Finishes by Horse	0.02602** (2.106)
Number of Previous Races by Jockey	-0.001579 (1.357)
Number of Top Three Finishes by Jockey	0.003871 (1.563)
Rho	-0.06188 (0.654)

Includes racetrack and track condition dummy variables.