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Determinants of Thoroughbred Racehorse Stud Fees

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Abstract

Determinants of Thoroughbred Racehorse Stud Fees
By Rebecca Ruby Cameron

This paper seeks to establish the main determinants of Thoroughbred racehorse stud fees. The study looks at a collection of characteristics of the stallion and his progeny on which the data is available, yielding an unbalanced panel data set for the past ten years. Fixed effects and random effects regressions are used to model the data, and produce a Hedonic Price Index that can be used to establish the marginal effect of each individual characteristic on the stallion's fee. The study suggests that breeders prefer stallions that produce winners of stakes and graded stakes races, have high stallion ratings, have a pedigree dominated by speed, and are popular.

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TABLES

Introduction:

The racing industry is one that starts in the breeding shed, where every breeder is hoping to produce the next phenomenon that wins decisively at the track and continues to make a mark as a stallion. However, breeding a good Thoroughbred is a challenge in itself. Statistics indicate that, even from a top stallion, there is only a 3.9% chance the foal will be even a stakes winner. Those involved in the industry have been described as engaging in a game of genetic roulette. The chances of producing a successful racehorse are low, and the costs are high. It is an industry in which a breeder can spend hundreds of thousands of dollars and still be more likely to produce a third-rate claimer than the next Triple Crown winner.

In this game of roulette, most of the expense, and therefore the risk, is derived from the stallion's stud fee. A stud fee is a fee charged to the owner of a mare for the opportunity to breed her to a stallion. This fee is usually paid to the owner of the stallion upon the birth of a live foal. These fees exhibit a considerable amount of variance across stallions, even across stallions of seemingly similar characteristics. At the lower end of the spectrum stud fees hover around $5,000. They can rise as high as $250,000 when they are listed; however, some stallions are listed as Undisclosed or Private. In this case, the stud fee can be upwards of $500,000. The range of stud fees is wide, and horses that have some similar characteristics can have vastly different fees, indicating that there are many different factors that enter into determining a stallion's fee. For instance, Birdstone, who this year sired the Kentucky Derby winner Mine That Bird as well as the Belmont and Travers Stakes winner Summer Bird, has a stud fee of $30,000 for the coming year. In comparison, A.P. Indy, whose best runners this year were the Gazelle Stakes winner

Flashing and the Beldame Stakes winner Music Note, commands a stud fee of $150,000 for the coming year. The $120,000 difference between the stud fees of two stallions, who produced multiple stakes winners this year, indicates that there are many different factors that influence a stallions stud fee besides the most obvious characteristic: the performance of its offspring on the track. In this paper I hope to model the determinants of stud fees by focusing on what characteristics breeders look for when they decide on the stallion they are going to breed their mare to, and what stud fee they are willing to pay for those given characteristics.

Literature Review:

There are several other studies relating to the Thoroughbred racing and breeding industries. These studies examine a number of subjects ranging from adverse selection in auction markets to examining the influence of genetics in the breeding industry.

In their paper, *Roses or Lemons: Adverse Selection in the Market for Thoroughbred Yearlings,* Brian Chezum and Brad Wimmer look for the possible presence of adverse selection in the yearling auction markets because they argue sellers have a greater knowledge of the yearling they are selling than any buyer. Chezum and Wimmer use data from yearling sales to test their prediction. They find that the data confirms the existence of adverse selection in the yearling auction markets.

In the study, *Breeding Racehorses: What Price Good Genes?* by Alastair Wilson and Andrew Rambaut considers whether “there is genetic variation for success on the racecourse” (Wilson and Rambaut, 2007), and whether a stallion’s fee accurately reflects his ability to pass on these genetic qualities. Wilson and Rambaut conclude that while lifetime earnings are heritable (stallion’s can pass their winning ways on to their

offspring), stud fee's are not an indicator of a stallion's genetic quality, and therefore do not represent the likelihood that a stallion's offspring will be successful at the track.

Another study, *Estimation of Genetic Trend in Racing Performance of Thoroughbred Horses,* B. Gaffney and E.P. Cunningham investigate why winning times have not improved dramatically in recent years given that there is considerable selective breeding in the thoroughbred industry. They describe that, "despite intense directional selection, especially on the male side, and the generally high heritabilities of various measures of racing performance, winning times of classic races have not improved in recent decades" (Gaffney and Cunningham, 1988). In their paper they examine whether the failure of winning times to decrease is a result of a lack of additive genetic variance; however, they conclude through their study that this is not the case.

A fourth paper, *Associations Between Yearling Body Measurements and Career Racing Performance in Thoroughbred Racehorse*, by Adriana Smith, W. Burton Staniar, and Rebecca Splan researches whether certain body measurements on yearlings are indicators of their potential racing performance. They test if wither height, body length, distal limb length, cannon circumference, heartgirth circumference, and chest width are positively correlated with performance at the racetrack. Smith, Staniar and Splan find that the only body measurements that had no correlation with racing performance are the leg traits, and that wither height and hip height are particularly important indicators of future racing ability.

These four papers all consider different aspects of the Thoroughbred industry. The first study supports the existence of adverse selection in the auction market, while the other three take a more scientific route and examine the influence of genetics on

Thoroughbred breeding and the influence of body type on racing ability. This study, alternatively, aims to explain the economic motivations of the breeding industry and determine which traits of a stallion have the greatest impact on the stud fee he can command.

Theory:

Stud fees in the Thoroughbred racing industry are much higher than in other horse related disciplines, in part because the Jockey Club requires a live cover for any foal produced to be registered as a racehorse. The Jockey Club Rule Book names three breeding practices that are not acceptable by its standards, they are: artificial insemination, cloning, and embryo transfer or transplants. This prevents the use of artificial insemination (AI), which the rule book defines as, “the process of depositing semen into the reproductive tract of a broodmare in order to get a broodmare in foal (pregnant) without the physical mounting by a stallion” (Jockey Club Rule Book, 2010). AI is used for example in Standardbred breeding where a high stud fee is $20,000. AI is arguably much safer for the mares and less demanding of the stallions, but the requirement of live cover allows the Jockey Club to guarantee the quality of the Thoroughbred bloodstock, and keep the bloodline pure.

To understand why owners will pay to breed their mare to a particular stallion, it is necessary to understand why people breed racehorses in the first place. Understanding these motives will help explain what traits breeder’s value in a stallion, and therefore what they are willing to pay a higher fee for.

People breed racehorses for two main reasons. One is to raise the foal, race it, and perhaps breed it in the future after its racing career is over. The other is to sell the foal at

auction. Either of these goals indicates a certain set of characteristics that breeders would hope a stallion would pass on to its offspring. The great breeder Federico Tesio, who bred an astounding number of top class Thoroughbreds, described his goal as, "'… to breed and raise a racehorse who, over any distance could carry the heaviest weight in the shortest time'" (Hunter, 2006). To Tesio, performance at the track was of the utmost importance. He valued stallions that could pass on their speed, stamina, and determination onto their progeny. Along with their performance at the track, and their personality, stallions are valued for their build, and, perhaps most importantly, for the performance of their offspring both at the racetrack and in the breeding shed.

A stallion's performance at the racetrack has a large influence on his stud fee. Particularly, in his first three years at stud before his foals start their racing careers and his true value as a stallion is still unknown. Until his offspring race, the only known variable is the stallion's own record, and, if it is a good one, it can be used by his owner to raise his stud fee. A valuable stallion entering stud would be one that has demonstrated speed and stamina or staying power over considerable distances against top class competition. Moreover, it is preferable if he has established his record over a number of different surfaces such as synthetic, dirt, and turf. Kevin Conley[1] describes in his book, *Stud: Adventures in Breeding*,

> In the first year at stud, breeders ask, *How did he do at the track?* The second year, *How do his foals look?* The fourth year, *How do his yearlings look?* By the fifth year – when the breeders can open the *Racing Form* to see whether the babies can actually run – the fate of a stallion is essentially sealed. By that time,

[1] Kevin Conley is an editor at *The New Yorker* magazine who took an avid interest in the Thoroughbred breeding industry. In his book *Stud: Adventures in Breeding* he looks at the industry from many different perspectives, such as mare owners, stud farm managers, and veterinarians. His book documents the opinion of these participants on different quirks of the industry, as well as the industry as a whole.

> what a horse did at the track barely matters, and his stud fee starts to reflects the true market value of his offspring, at the track and in the sales ring. (Conley, 2002)

As Conley points out, after the three year grace period is over, a stallion is valued not only for what his past performance, but also for what his offspring achieve. Measures of his success at the track become less important, and measures of his progeny's success become increasingly important. Successful offspring fetch high prices at auction sales; they perform well at the racetrack demonstrating the same speed and stamina as their father; and finally, they are successful stallions or broodmares after they retire from racing. For a truly great stallion, these traits are consistently found in his offspring. One such stallion, Storm Cat, at the height of his career commanded a stud fee of $500,000; people were willing to pay this because,

> In 1999, and 2000, Storm Cat's offspring earned more than $21 million dollars at the track, almost $7 million more than anyone else's. Furthermore, several of Storm Cat's colts who have recently launched their own stud careers – Storm Boot, Hennessy, Forest Wildcat – have begun siring stakes winners and high-priced yearlings, justifying hefty hikes in their stud fees. (Conley, 2002)

The hikes in the stud fees of Storm Cat's sons, can be attributed to two different factors. As Conley mentioned they too produced stakes winners and high priced yearlings, but they also have an enviable pedigree. A horse's pedigree is something that it can without question pass on to its progeny. For Storm Boot, Hennessy, Forest Wildcat, and any other son of Storm Cat their great-grand sire is Northern Dancer who is known as one of the leading sire of sires in the world. An impressive pedigree is something people are willing to pay a premium for because they feel they are buying into leading bloodlines, and, perhaps if they are lucky, developing their own breeding dynasty. There are certain bloodlines that are more valued in the racing industry. These lines connect

back to certain “sires of sires.” Three such sires stand out amongst others—Northern Dancer, Mr. Prospector, and Seattle Slew. These sires are known as “sire of sires” because they have produced stallions that have also been successful at stud and who have produced sons that are also successful as studs. For example, Northern Dancer’s

> Claim to preeminence is in the great stallions he has sired; as was once said of the Godolphin Arabian, ‘his pedigree is written in his sons.’ Collectively, Northern Dancer’s sons led the English sire list sixteen times, the American sire list four times, the Japanese sire list ten times, and the French sire list nine times through 2004, Further, they have passed the magic on. Sons of Northern Dancer’s sons have been leading sires in Argentina, Australia, Brazil, England, France, South Africa, and the United States. … It is in the ongoing excellence of his sire line that Northern Dancer is perhaps unrivaled in Thoroughbred history. (Hunter, 2006)

Therefore, sire of sires are producing horses that are far more valuable than what they achieve on the racetrack as the real money in horseracing is made in the breeding industry. If a horse has these particular stallions in its bloodlines it is more likely that its offspring will be valuable beyond their racing years.

A stallion might also be valued for his build, or conformation. Factors such as his height, the slope of his shoulder, the length of his back, the slenderness and straightness of his legs can affect the mechanics of how he runs, his stride length, and his soundness. A horse built with good conformation will run more correctly than a horse with poor conformation and will expend less energy running, therefore having more energy to defeat competitors in the homestretch. A horse that is taller will have larger proportions, and more than likely have a longer stride than a shorter horse, meaning that horse can cover more distance with each step. Finally, a horse with good conformation places less strain on his body when he runs, and therefore is less likely to develop any lameness issues if placed in a strenuous racing schedule, as many top racehorses are. Therefore, a

stallion that has good conformation would be valued over a stallion that does not because he can pass these traits on to his progeny.

Another trait a stallion can pass on to his offspring is his personality. How tough, competitive, or high-strung a horse is can affect his performance at the racetrack. Like any other athlete, a more competitive aggressive horse is always the better runner, while a tougher horse might battle through soreness or even lack of ability to win. Some stallions are known for possessing these traits, and for passing them on to their offspring. For instance, Hard Tack, the sire of Seabiscuit, was known for being an immensely difficult horse both at the track and on the ground, but he was competitive and tough, and he passed these traits onto his son. Seabiscuit, famously, won races he should not have been able to from a soundness and talent perspective, but, in good part, due to his personality. Hence, a stallion with stronger personality traits can command a higher fee than one without.

A final factor that influences a stallion's fee, is where he is stabled during his time at stud. The breeding industry, and the horseracing industry in general, is very highly centralized in Kentucky. Conley argues that,

> Horses thrive in this land [Kentucky] for a few reasons. First, the limestone is rich in calcium, which finds its way into the bluegrass, and then into the bones of the Thoroughbreds. Horses grazing on such power pasture grow more quickly because of it, and when they get to the track, the theory goes, their calcium-rich bones tend to break down less. So they run more fearlessly and win more often than horses bred in places where the main vegetation is saguaro, say, or cranberry bogs. (Conley, 2002)

While these physical attributes of Kentucky may be the reason for the industry initially being founded in the Bluegrass area, it means that today there exist scale agglomerations for the breeding industry in Kentucky. Many of the best stallions are located in Kentucky,

because this is where the top stud farms such as Lane's End and Claiborne are found. Because these stallions are in Kentucky people have an incentive to keep their best mares in Kentucky where they can be bred to these top stallions. This creates a circle that feeds on itself as those top mares' foals stay in Kentucky and retire there after they race, starting the process all over again and meanwhile keeping the best Thoroughbred blood in the Bluegrass Region. Therefore, for any stallion located outside of the Kentucky area it is difficult to command as high a fee. Stallions in other states do not see the same quality or quantity of mares and, as a result, their offspring start off at a disadvantage. Conley describes how this disadvantage has affected the stud fee of Cee's Tizzy, a California based stud,

> Even though Cee's Tizzy's son (Tiznow) beat Storm Cat's son (Giant's Causeway) in the most important race of the year (the Breeders' Cup Classic) in 2000 (then became the only back-to-back winner in 2001), Cee's Tizzy will not get a tenth of what Storm Cat does. He won't get a twentieth. Cee's Tizzy is lucky to get $15,000. (Conley, 2002)

After Tiznow's success, things have improved for Cee's Tizzy, but his fee only leapt from $7,500 to $15,000, still lagging behind perhaps even lower quality stallions back in the Bluegrass Region.

Cee's Tizzy is based out of California, which is one of many states—New York and West Virginia are two others—that have installed an incentive program in an effort to reduce the difference between stud fees in their state and as compared to stud fees in Kentucky. These programs generally involve specific races with impressive purses for state-bred horses only, thereby making it lucrative to breed good horses in that state. In California, there is also a cash bonus for the California based stallion whose progeny has

the highest earnings. Incentives like these may eventually dilute the concentration of the breeding industry in Kentucky.

There are many other characteristics of a stallion that can influence a breeder's decision as to what stallion they would like to breed their mare to and what fee they are willing to pay for the opportunity to breed to that stallion. In general, breeder's will look for a stallion who has a good pedigree, has performed well at the track himself, and who clearly stamps his foals as his own. In other words, the stallion produces foals that have his conformation and his personality, who win at the track, and eventually who are successful as stallions themselves. If a stallion possesses all of these qualities, in theory, he should be able to command a higher fee than a stallion that only has some of these qualities.

Much of the above discussion on the determinants of a stallion's stud fee is based on general knowledge of Thoroughbred breeding and racing. What would be more useful is a quantitative measure of the impact of the characteristics of a stallion on his expected stud fee. This study tries to accomplish this goal by using data describing the characteristics of a stallion to predict the stud fee paid that stallion. In this approach we use regression analysis to estimate what is known in economics as a hedonic price index. This type of index estimates the marginal impact on the stud fee of each explanatory variable while holding the other explanatory variables constant. The resulting hedonic price index allows us to estimate marginal impact of each of the characteristics of a stallion on his stud fee.

Data:

The data set consists of the top 100 stallions ranked by progeny earnings from 1999 to 2009. *The Thoroughbred Times*[2] reports this information each year, and their reports are the primary source for this data set. There are 894 observations for which data on the stud fee are available; these data are organized into an unbalanced panel data set. For each of the observations data on measures of different characteristics is taken from *The Thoroughbred Times, The Blood-Horse,* and *Pedigree Query* website. These data are proxy variables that measure the impact of the various traits of the stallion on the stud fee he commands.

Stallions are ranked by their Progeny's Earnings. This is a yearly statistic, meaning that it is the sum of the stallion's progeny earnings at the racetrack in that year. We convert these earnings from a nominal value into real 2009 dollars. The minimum earnings recorded is $2,424,215 in 2009 dollars and the maximum earnings recorded is $16,000,000 in 2009 dollars, while the average earnings are $4,578,049 in 2009 dollars. Progeny Earnings is an indicator of the success of the stallion's offspring. If the progeny's earnings are higher, then they have performed better at the racetrack that year than the progeny of a stallion with lower earnings. An increase in progeny earnings will be expected to have a positive impact on a stallion's fee.

Another statistic that describes a stallion's offspring's earnings is the Average Earnings per Runner. This statistic, unlike Progeny Earnings, is a lifetime statistic. It indicates what a breeder can on average expect a foal from that stallion to earn as a racehorse. The maximum average earnings are $338,699 and the minimum average earnings are $4,887, while the average is $64,729.51. Because this is a lifetime statistic, it

[2] *The Thoroughbred Times* records the sop 100 stallions for every year. However, for 2002 there is only data on the top 50 stallions.

is less skewed than Progeny Earnings.[3] It takes into account the number of runners a stallion has, and prevents one particularly stellar runner from making the stallion look better than he actually is. Once again, an increase in the average earnings per runner will be expected to have a positive impact on a stallion's fee.

We include a dummy variable equal to one if the stallion is located in Kentucky and zero indicating if the stallion is located elsewhere. This dummy variable is meant to capture whatever positive impact being stabled in Kentucky has on a stallion's fee.

We use a second dummy variable to capture the influence of a horse's pedigree on his fee; this variable is hereafter referred to as "Pedigree." As previously mentioned, there are certain horses that are particularly valued, known as sires of sires. These horses are: Northern Dancer, Seattle Slew, and Mr. Prospector. Storm Cat is also included, because research indicates that he has established himself as a newer sire of sires. The dummy variable has a value of one if the subject stallion has any of these horses in his pedigree going back two generations on the sire side and one generation on the dam side; and a value of zero if these horses are not in present in his pedigree for those generations. The presence of these horses will be expected to have a positive influence on the stallion's fee, because their bloodlines will automatically make any offspring that have those bloodlines more valuable.

Career best Ragozin Numbers are recorded when available for each stallion. Ragozin Numbers are meant to indicate the speed the stallion demonstrated on the track, adjusted for several factors that influence a horses performance, such as surface type,

[3] The median lifetime earnings of the stallion's progeny would be a better variable to use because it reduces the effect of unusually successful progeny on this measure of the success of the progeny. We do not use it because it is not available.

wind speed, and track condition. The numbers are, “based on a system in which a lower number represents a stronger effort. A figure of 0 is akin to a perfect race, though horses can run slightly lower figures (less than 0) due to such factors as wind, distance raced off the rail, etc., that upgrade their performance.” (*Thoroughbred Times: Stallion Directory*, 2009) Therefore, a higher Ragozin Number indicates a slower horse and will have a negative impact on the stallion’s fee.

Several indices are recorded for every stallion. The first is a Racing Index (RI), which measures how well the stallion performed at the track. This index is,

> based on the average earnings per start of runners in North America and Europe. RI permits comparison of racing performance of horses regardless of year of birth or sex. RI takes into account inflation and lower earnings potential for females. RI is calculated determining the average per start for all foals of a given crop for each year that they race. Fillies are calculated separately from colts because of lower purse money available. After five years of racing, a runner’s RI does not change, not even if it continues to race. (*Thoroughbred Times: Stallion Directory*, 2009)

A higher value for a racing index indicates a better runner. Therefore, a higher value will be expected to indicate a higher stud fee, bearing in mind that after a stallions foals start running his own racing career becomes much less important, so while higher values may lead to higher fees, the effect may also be minimal.

Since the stallion’s offspring’s performance is far more pertinent to his stud fee than his own there are two indices recorded that are meant to gauge how good a particular stallion is as a sire. The first index is a Sire Index (SI). This index, “indicates the average racing class of foals sired by a stallion. SI is calculated by averaging the RI’s (Racing Indices’) of all the stallion’s foals that have started three or more times in North America and Europe” (*Thoroughbred Times: Stallion Directory*, 2009). This index is an indication of what a breeder can expect the average racing quality of a foal by the particular stallion

to be. A higher index indicates higher racing quality foals and a better stallion. Therefore, a higher index will have a positive influence on a stallion's fee.

The second index is the Comparable Sire Index (ComSI). The Comparable Sire Index,

> indicates whether a stallion is improving his mares. ComSI is the average Racing Index (RI) of all foals out a mares bred to the subject stallion—except for those foals sired by the subject stallion. In other words, ComSI is the average RI of foals by other sires but out of the same mares the subject stallion has covered. Thus is the subject stallion's Sire Index (SI) is higher than his ComSI, then he is improving his mares. If not, then other stallions have done better with the same mares. (*Thoroughbred Times: Stallion Directory*, 2009)

This index is still looking at the racing quality of foals, but it rates the stallion in comparison to other stallions. A lower Comparable Sire Index indicates that other stallions are not producing as strong of offspring with the same mares, and that the subject stallion is the higher-quality stallion. Therefore, the Comparable Sire Index and the stud fee will have an inverse relationship, as the index increases there will be a negative impact on the stallion's fee.

The final two indices that are recorded are the Dosage Index and the Center of Dosage. Dosage in general is,

> a Thoroughbred pedigree classification system for owners, breeders and handicappers that expresses the elements of speed and stamina horse may inherit from selected key sires, or *chefs-de-race*, in its pedigree. These sires are classified in five aptitudinal groups: brilliant, intermediate, classic, solid and professional, covering the spectrum of brilliant speed to plodding stamina and reflecting the qualities the sires consistently pass along to their offspring. (Roman, 2002)

The distribution in this classification system of a horse's sire, dam's sire, grand sire etc. going back four generations determines a Dosage Pedigree (DP) that is calculated, with "points" indicating the number of stallions and the degree of relationship to the subject stallion in each category. This pedigree is then used to calculate the two

indices that are recorded. The first is the Dosage Index (DI), which indicates the ratio of speed to stamina in the pedigree. The Dosage Index is calculated,

> by dividing the DP into separate speed and stamina components. The speed component is defined as the Brilliant points plus the Intermediate points plus one-half the Classic points. Similarly, the stamina component is defined as one-half the Classic points plus the Solid points plus the professional points. (Roman, 2002)

The second index, the Center of Dosage indicates how stilted the subject stallion's pedigree is towards one side or the other, speed or stamina. This is calculated by, adding twice the Brilliant points plus the intermediate points minus the Solid points minus twice the Professional points and dividing that number by the total points in the DP" (Roman 40). Since basically the same information is used to calculate the Center of Dosage and the Dosage Index they are highly correlated, and therefore only one in used in the regression. The affect of dosage on a stallion's fee depends on what a breeder is hoping to produce. If they want a long distance runner then a breeder might pay more for a stallion with a dosage pedigree seeped in Solid and Professional sires. If, on the other hand, they prefer a sprinter that demonstrates intense burst of speed, they might pay more for a stallion whose pedigree has many Brilliant and Intermediate sires. The benchmark figures to determine if a stallion's pedigree indicates speed or stamina are, "a DI of 4.00 or less and a CD of 1.00 or less are considered to indicate stamina" (*Thoroughbred Times: Stallion Directory*, 2009), anything above those numbers indicates speed.

The number of crops a stallion has is included as a potential explanatory variable. This variable represents the number of years that a stallion has been at stud, another words: not racing. This variable will have an indeterminate impact on the stallion's fee. For instance, if the stallion is a very good stallion, then the more years he is at stud the

higher his fee will be because he will become increasingly popular thus raising demand for his offspring and his fee in return. However, if the stallion consistently produces foals that do not perform well at the track or as stallions themselves, then the number of crops he produces will most likely have a negative impact on his fee.

The average number of foals per crop is also included. This statistic is meant to capture if the horse bred selectively and rarely, or more often and less carefully. A horse bred more selectively will command a higher fee for two reasons. First, the increased selectivity regarding the quality of the mares he is bred to will mean that his foals will be of a higher quality. Second, withholding the stallion from the market will increase the fee people are willing to pay to breed to him. A good example of this is the stud fees of Seeking the Gold and Woodman. In 1995 their fees were the same, however, Woodman was one of the most actively bred stallions while Seeking the Gold bred rarely for a stallion (around 90 times). Six years later their fees were vastly different. Woodman cost around $25,000, while Seeking the Gold cost around $250,000 (Conley, 2002). Therefore, an increase in the number of times a horse is bred, which is modeled by a higher number of average foals per crop, will be expected to have a negative impact on the stud fee.

Several percentages are calculated measuring the performances of the stallion's offspring at the track. The first percentage is the number of foals that started a race. This percentage indicates the likelihood that a foal by the stallion will perform well enough in training to warrant entering him or her in a race. The average percentage of foals to start is 75%, while the minimum is 48% and the maximum is 92%. Given that a fairly high

percentage would probably start, this statistic will most likely have little impact on the stallion's fee.

The percentage of foals that won a stakes race is calculated. This statistic indicates the likelihood that a foal by the particular stallion will be a stakes quality runner. The average for this statistic is 6%, while the minimum is 1% and the maximum is 19%. It is a small percentage of foals produced by any stallion that prove to be talented enough to run in stakes races, therefore a higher percentage of foals by the stallion that are stakes quality will have a positive influence on his fee.

Foals that won graded stakes races is the third percentage calculated. This percentage shows the probability that a foal by the stallion will be talented enough to compete in graded stakes races, the top tier races in the country. For this statistic the average is 2%, the minimum is 0% and the maximum is 11%. Once again, for any stallion this percentage is low and a rise in this percentage will have a positive impact on the stallion's fee.

The ratio of the number of starters to the number of winners is recorded. This ratio represented the probability that a horse by a certain stallion that starts a race will win that race. This ratio ranges from 0.23 to 4.21, and averaged 1.98. The lower the ratio the better the stallion is because he has had more winners out of his starters, therefore, a rise in the ratio will have a negative influence on the stallion's fee.

The ratio of the number of stakes winners to the number of stakes wins is recorded for each stallion. This number attempts to capture the regularity of stakes winners by a particular stallion winning stakes races. Another words, if stakes runners are repeatedly winning the races they are entered in, and therefore demonstrating their high

quality; or if they win only one stakes race opening up the possibility that it is a stroke of luck or that the rest of the field is uncompetitive. The ratio ranges from 0 to 1, and averages 0.703. The lower the statistic, the more often each horse won a stakes race, and the higher the quality of the stallion, which will increase his fee.

The average winning distance for foals by a particular stallion is recorded. This distance is recorded in furlongs. This is meant to capture what type of runner a stallion tends to produce: a sprinter, a stakes horse, or a long distance horse. The most prize money is in stakes races, therefore the preferred average winning distance would be around 7 to 8 furlongs. This statistic ranges from 2.27 to 10.98 furlongs, and averages 7.19 furlongs. Because the preferred winning distance is expected to be around eight furlongs, the stud fee will be expected to rise to a certain point and then drop off.

The height of that stallion is recorded in hands (the typical measurement for horses), and then converted into inches. Height and stride length are shown to be correlated in Thoroughbreds (Smith, Stanair, and Splan, 2006). A horse with a longer stride will have a better chance of winning because he or she will cover more ground with each stride. Therefore breeders will prefer taller stallions that will pass those genes onto their foals, and those stallions will be able to command a higher fee.

Another variable that influences the stud fee of a stallion is the price that his offspring can fetch at auction. The nominal average auction price is recorded for the stallion each year that he appeared on the list of the top one hundred stallions. This is then converted into real 2009 dollars. The average for this statistic is $94,305.19 in 2009 dollars, the minimum is $2,998.29 and the maximum is $1,144,107 also in 2009 dollars. The average auction price will indicate to a breeder the possible return on their

investment. If they can get a higher price for a foal by a particular at auction then they will pay a higher fee for that stallion, therefore, as the average auction price rises the stud fee will be expected to rise as well.

Along with the average auction price, the number of offspring sold at auction that year is recorded. This indicates if the auctions are relatively flooded with foals by the stallion or not. The average for this statistic is 60 foals, while the minimum is 1 foal and the maximum is 210 foals. If a breeder is looking to sell their foal at auction, they may be interested in breeding to a stallion that is more popular at the auctions, therefore a stallion's fee will increase with the number of foals sold at auction.

Finally, the dependent variable is the stallion's stud fee. This is recorded for every stallion, in each year that the stallion appeared on the list. The stud fees are converted from a nominal fee into a real fee in 2009 dollars. In 2009 dollars, the maximum stud fee is $596,267.40, and the minimum fee is $3,219.34 with an average of $45,841.99.

Table 1. Summary of the variables in the data set.

Variable	Observations	Mean	Standard Deviation	Minimum	Maximum
ID #	894	141.3915	79.56495	1	277
Year of Observation	894	2004.178	3.216475	1999	2009
Year of Birth	894	1989.517	5.631185	1974	2001
Location	894	0.7550336	0.430308	0	1
Real Stud Fee	894	$51,680.22	$76,738.68	$3,219.34	$596,267.40
Nominal Stud Fee	894	$45,841.99	$67,962.58	$2,500	$500,000
Real Progeny Earnings	894	$5,101,615	$1,974,781	$2,914,003	$16,400,000
Nominal Progeny Earnings	894	$4,578,049	$1,863,520	$2,424,215	$16,000,000
Crop	894	7.741611	4.170406	2	20
Average Number of Foals in a Crop	894	70.80872	29.7058	23	214
Percentage of Foals that Start at the Racetrack	894	0.7530761	0.0652778	0.48	0.92
Percentage of Foals that Win a Stakes Race	894	0.0663311	0.0271441	0.01	0.19
Percentage of Foals that Win	894	.0239485	.0174063	0	0.11

a Graded Stakes Race					
Average Earnings Per Runner	894	$64,729.51	$24,014	$4,887	$338,699
Average Winning Distance	894	7.186924	0.6403502	2.27	10.98
Sire Index	891	1.929136	0.9036356	0	5.93
Comparable Sire Index	894	1.988277	0.8429523	0	5.75
Dosage Index	891	3.260303	1.436008	0.6	13
Center of Dosage	894	0.8026958	0.2632321	-0.25	1.5
Real Average Auction Price	894	$107,206	$122,377.80	$2,998.29	$1,144,107
Nominal Average Auction Price	894	$94,305.19	$104,432	$2,640	$1,014,601
Number of Offspring Sold at Auction	894	59.79083	30.7027	1	210
Number of Starters/Number of Winners	894	1.982844	0.329386	0.2308846	4.205883
Number of Stakes Winners/Number of Stakes Wins	894	0.7026773	0.1637577	0	1
Pedigree	894	0.5592841	0.4967509	0	1
Racing Index	843	46.39869	42.50517	0.22	217.24
Career Best Ragozin Number	560	3.170982	2.666274	-2	18.5
Height (Inches)	841	64.59156	1.245922	61	68

Table 2. Averages for the breed

Factor	All Foals 1991 – 2000	Foals by to 1% of sires
Starters/foals	67.6%	75.3%
Winners/foals (starters)	45.9% (67.8%)	58.9% (78.2%)
Repeat winners/foals (starters)	37.1% (54.9%)	52.3% (69.4%)
Stakes placed/foals (starters)	5.3% (7.9%)	9.8% (13.0%)
Graded SW/foals (starters)	0.6% (0.9%)	2.3% (3.1%)
Grade 1 SW/foals (starters)	0.2% (0.2%)	0.7% (0.9%)
Two-year-old starters/foals	32.2%	39.7%
Two-year-old winners/foals (2yo starters)	10.5% (32.5%)	15.1% (38.1%)
Two-year-old SW/foals (2yo starters)	1.0% (2.9%)	1.8% (4.5%)
Three-year-old starters/foals	56.6%	66.7%
Four-year-old starters/foals	45.3%	52.5%
Five-year-old and up starters/foals	29.4%	33.9%
Average career starts/foal	14	16
Average career starts/starter	21	22
Average winning distance in furlongs	6.74	7.01
Average winning distance turf in furlongs	7.96	8.10
Average earnings/starter	$40,675	$80,049

Average earnings/starter male (female)	$46,824 ($34,377)	$96,277 ($63,497)
Average earnings/start	$1,967	$3,702
Average earnings/start male (female)	$1,968 ($1,967)	$3,560 ($3,945)
Average Racing Index	1.10	2.01

Possible Sources of Bias in the Data:

There are two potential sources of bias in the data that should be acknowledged. The first is a selection bias arising from the manner in which the data was collected. The second is an endogenous variable bias arising from the relationship between some of the variables used in the regression.

The data is produced by ranking the top 100 stallions by progeny earnings, which opens that data up to selection bias, as the data points only represent about 10% of sires universally, and the top 10% at that. In a study completed by B. Gaffney and E.P. Cunningham, *Estimation of Genetic Trend in Racing Performance of Thoroughbred Horses*, they face a similar problem. They explain that in their regressions of offspring on sire, which are similar to the regressions in this study that include many of the offspring's characteristics as determinants of their sire's fee, a selection bias exists because, "highly rated stallions have very high stud fees, and their offspring receive above-average treatment, for instance, in the quality of the trainer" (Gaffney and Cunningham, 1988). These results do not apply to stallions who are not within the top 10%, and until there is an equation to determine if a stallion belongs in that top 10% care must be taken in using the results to determine a stallion's fee.

It is also possible the real average auction price and the real stud fee are endogenously related. The price that a particular stallion's foals can draw at auction will impact his stud fee positively. Theory and the regression results confirm this. However,

this might be a reciprocal relationship, in which the stud fee can also impact the auction price, making real auction price an endogenous variable. Further study, examining the determinants of real auction prices, could shed light on the complete relationship between the average auction price of a stallion's foals and his stud fee.

Results:

The hedonic index is estimated using semi-logarithmic random and fixed effects regressions. The horse ID number is used to indicate the cross-sectional unit and the year of the observation is used to indicate the time period. The natural log of the real stud fee is the dependent variable in each regression, and the variety of characteristics on which data is present, are the explanatory variables. The random effects model is fitted using the following equation:

$Ln(Real\ Stud\ Fee)_{it} = \beta_1 * (Characteristics)_{it} + v_{it}$.

While the fixed effects equation is,

$Ln(Real\ Stud\ Fee)_{it} = \beta_1 * (Characteristics)_{it} + u_i + e_{it}$.

A Sargan- Hansen test for fixed versus random effects is used to determine which model best fits the data, and for every variation of the model the test strongly indicates that the fixed-effects model is best. Therefore, the fixed effects models are used to analyze the different impacts of a stallion's particular traits on his fee.

Theory predicts that a stallion is valued by breeders for a multitude of characteristics, which pertain both to the stallion himself and to his offspring; however, the characteristics of his offspring should weigh more heavily on his stud fee than his own traits. The regression results support this.

Table 3. Fixed effects and random effects regressions with dependent variable log of real stud fee

Explanatory Variable	1	2	3	4
Characteristics of the stallion				
Location	0.43859* (0.10368)	0.32836* (0.06306)	0.43859* (0.10368)	0.33240* (0.06316)
Crop	-0.02923 (0.02047)	-0.04294* (0.01254)	-0.02923 (0.02047)	-0.04220* (0.012400)
Average Foals in a Crop	-0.00043 (0.00349)	0.00333 (0.00107)	-0.00043 (0.00349)	0.00328 (0.00107)
Number of Foals Sold at Auction	0.00400* (0.00130)	0.00612* (0.00106)	0.00400* (0.00130)	0.00602* (0.00106)
Sire Index	0.15148* (0.05005)	0.15503* (0.03651)	0.15148* (0.05005)	0.15302* (0.03625)
Comparable Sire Index	0.26297 (0.13449)	0.23586 (0.04783)	0.26297 (0.13449)	0.23752 (0.04821)
Dosage Index	0.0666746* (0.02543)	0.0306499* (0.01515)	—	—
Center of Dosage	—	—	0.23481* (0.08954)	0.25768* (0.10213)
Career Best Ragozin Number	—	-0.01522 (0.01228)	—	-0.01514 (0.01237)
Pedigree	—	-0.0550734 (0.06740)	—	-0.07357 (0.06757)
Racing Index	—	0.0000824 (0.00159)	—	-0.00005 (0.00154)
Height	—	-0.0063733 (0.02965)	—	-0.00156 (0.02950)
Characteristics of the stallion's foals				
Average Earnings per Runner	3.34E-06 (2.47E-06)	4.25E-06 (2.49E-06)	3.34E-06 (2.47E-06)	4.22E-06 (2.46E-06)
Real Average Auction Price	1.29E-06 (1.16E-06)	2.34E-06 (1.08E-06)	1.29E-06 (1.16E-06)	2.33E-06 (1.08E-06)
Percentage of Foals that have Won a Stakes Race	6.51514* (3.16044)	6.79565* (1.97050)	6.51514* (3.16044)	6.96528* (1.97870)
Percentage of Foals that have Won a Graded Stakes Race	9.82079 (5.05052)	10.40909* (3.40253)	9.82079 (5.05052)	10.15111* (3.36186)
Ratio of Starters to Winners	0.18758 (0.17474)	0.21542 (0.08949)	0.18758 (0.17474)	0.21134 (0.08965)
Ratio of Stakes Winners to Stakes Wins	0.35059* (0.13402)	0.24566* (0.09998)	0.35059* (0.13402)	0.24303* (0.09951)
Average Winning Distance	-4.697721 (3.91703)	-0.7307767 (1.62036)	-4.697721 (3.91703)	-0.6096407 (1.62701)
Average Winning Distance Squared	0.36218 (0.25590)	0.05182 (0.11444)	0.36218 (0.25590)	0.04510 (0.11480)
Constant	22.17593 (14.82687)	9.93351 (6.13474)	22.21123 (14.82535)	9.02485 (6.14270)
Number of Observations	541	541	541	541
Adjusted R^2	0.8687	0.7929	0.8687	0.7942
Fixed Effects	Yes	No	Yes	No
Random Effects	No	Yes	No	Yes
Sargan Hansen Test Statistic		0.0000		0.0000

* Statistically significant from 0 at the 5% level.

Traits of the Stallion:

Of the stallion's own traits, the fixed effects regressions indicate that his location, his dosage index, his center of dosage, the number of his foals sold at auction, and his sire and comparable sire indices are significant in determining his stud fee. The stallion's location has a considerable impact on his fee. In spite of the best efforts of the state bred programs to draw good mares to their stallions located outside of Kentucky, there is still a large premium available for the stallions of the Bluegrass region. According to the regressions, if a stallion is located in Kentucky he can command a 55 percent higher fee than a stallion located in any other state or country. The highly centralized nature of the breeding industry in part fuels this dramatic difference in fees. Conley observed that, "outside of the bluegrass there are no six-figure stud fees" (Conley, 2002). However, given that shipping a mare from Kentucky to California would only cost about $5,000, not including insurance, this difference appears somewhat unreasonable, and may expose some inefficiency in the market.

Speed and stamina are the principle determinants of a horse's performance at the track. If a horse possesses considerable speed he will perform better in different races than a horse that demonstrates considerable stamina. The stallion's center of dosage and dosage index measure speed and stamina as represented in his pedigree. According to the regression results a one unit increase in a stallion's dosage index and a one unit increase in a stallion's center of dosage lead to a 7 and 26 percent increase in his stud fee respectively. The larger value for the center of dosage coefficient reflects the fact that it requires a much greater change in pedigree to shift the center of dosage one unit than it does the dosage index. A rise in either index means that a stallion's pedigree is shifting

away from stamina towards speed. This indicates that in general breeders desire, and will pay a higher fee for, speed over stamina in a stallion's pedigree. This is consistent with the general observation that, "breeding has changed in the last century to emphasize speed over stamina (particularly in America) modern pedigrees are likely to lean toward brilliant-to-classic" (*Thoroughbred Times Stallion Register*, 2009). In addition, a stallion's pedigree is an important characteristic. It is one trait he can without a doubt pass on to his progeny. The center of dosage and the dosage index appear to be good proxies to measure the impact of a stallion's pedigree on his fee.

The other variable included in the regression to assess the influence of pedigree is the pedigree dummy variable, which is meant to capture if a stallion has particularly good bloodlines that breeders will pay a premium for. This variable is omitted in the fixed effects regressions due to collinearity. A possible reason for this unexpected result can be traced back to the construction of the variable. Pedigree is a dummy variable that has a value of one if there were certain sires in the first two generations of the stallion's pedigree on the sire side, and the first generation on the dam side, and a value of zero otherwise. However, this may have not gone into enough detail regarding the stallion's pedigree. Going back further in the pedigree reveals that the one of the three sires of sires is in almost every subject stallion's pedigree, allowing that proximity to the subject stallion is of minimal importance this is not really a distinguishing feature between different stallions, and will not warrant a change in price. Conley explains the impact that a sire of sires can have on the breed, referring to Northern Dancer, he said, "when a sire's sons, too, become sires, the numbers – and the resulting genetic influence – can grow to be overwhelming. In the 2000 Breeders' Cup nearly 90% of all starters had Northern

Dancer somewhere in their pedigree. The ‘prepotent’ sire of sires recreates the breed in his own image” (Conley, 2002). The Breeders’ Cup races represent the top racehorse in the world, and if 90% of them have Northern Dancer somewhere in their pedigree, the likelihood that the other 10% have either Seattle Slew or Mr. Prospector somewhere in their pedigree is high, indicating that this is not as distinguishing a feature.

Certain stallions are more popular that other stallions, and their reputation can be expressed in the form of higher stud fees. The number of a stallion’s foals sold at auction is a proxy for the stallion’s popularity. The breeding industry goes through phases where everyone wants to own the offspring of a particular stallion. There was a time when everyone wanted a horse by Northern Dancer and his progeny flooded the auctions. More recently, Storm Cat has been very popular. However, his recent pension means that another stud will soon fill his shoes. According to the regression for each additional foal sold at auction the stallion’s fee rises 0.4 percent. While this variable does not have as sizable an impact as some of the other variables, it is significant, and indicates that a stallion’s popularity is an important factor in whether people want to breed their mare to him or not. This exposes another possible inefficiency in the market: A stallion can have the strong characteristics that breeders look for, yet his foals are unpopular at auction, and his fee will be lower expected.

The final two characteristics of the stallion that proved significant in determining his fee are the sire index and the comparable sire index. These two indices use the racing indices of the stallion’s foals to rate the stallion. According to the regressions a one unit rise in the sire index and a one unit rise in the comparable sire index yield a 16 and 30 percent increase in the stallion’s fee respectively. This indicates that a higher rating as a

sire increases a stallion's fee, but the most important rating of the two is the comparable sire index that compares the stallion to other stallions. These indices are easily understandable and comparable for breeders, and it is reasonable that they are an important factor in the determination of a stallion's stud fee.

Other characteristics of the stallion on which data is present prove insignificant or are omitted due to collinearity in the regression. The stallion's racing index, his height, and his career best ragozin number are omitted by the regression because of collinearity. The stallion's racing index and his career best ragozin number are meant to capture the impact of the stallion's own performance at the track on his fee, while his height is meant to capture if there are physical characteristics that might make a stallion more appealing to breeders and raise his fee. The high degree of collinearity may be due to the selection bias present in the data, yielding observations that are very similar for these variables. The number of crops the stallion has (the number of years he has been at stud), and the average number of foals in a crop (how many times per year the stallion is bred), and the average auction price of the stallion's offspring are all insignificant. The number of crops and the average number of foals in a crop are attempting to model the difference between an aged stallion and a young one, and the difference between a stallion that is selectively breed, and one that is breed more often. These variables may be insignificant because they are poor proxies for these characteristics of the stallion, because they are truly unimportant in determining the stallion's fee. The average auction price is included to model what portion of the stallion's stud fee breeders can on average expect to recoup by selling their foal at auction. The insignificance of this variable most likely reflects the endogenous relationship between the average auction price and the stallion's stud fee.

Traits of the Stallion's Progeny:

The performance of the stallion's offspring at the racetrack is an important determinant of his stud fee. People buy racehorses to win races, and therefore breeders want to breed to a stallion that is known for producing big winners consistently. Several variables in the regression attempt to capture this effect. The significant variables are the percentage of foals that have won a stakes race, the percentage of foals that have won a graded stakes race, and the ratio of stakes winners to stakes wins. According to the regression a one unit increase in each of these variables will raise a stallion's fee by 7, 10 and 42 percent respectively. If a stallion produces a high percentage of stakes winners that is good: His foals are performing well in respected races. If a stallion is producing a high percentage of graded stakes winners that is even better: His foals are winning in the highest class of races. Therefore, it is logical that there is a higher premium paid for an increase in the percentage of graded stakes winners compared to stakes winners. The final variable is the ratio of stakes winners to stakes wins, increasing this ratio produces a considerable rise in the stallion's fee. This result is contrary to theory, which predicts a decrease in stud fee associated with a rise in this ratio. This may reflect that breeders prefer not that each horse has won multiple stakes races, but rather that many horses have won a stakes race and that the stallion consistently "stamps" his success on in his foals. Therefore, a ratio closer to one is preferable as the regression suggests. Each of these variables are indicators to breeders of what they can expect to get from breeding their mare to a particular stallion, and are understandably an important determinant of that stallion's fee.

There are several other variables that are included in the regression to model different traits of the stallion's progeny, which are insignificant. These include: the average earnings per runner, the ratio of starters to winners, and the average winning distance of the progeny. The average earnings per runner variable is meant to capture how much of a stallion's stud fee a breeder could expect their foal to recoup at the racetrack. The ratio of starters to winners indicates the likelihood that a horse by a particular stallion will win. While the average winning distance is supposed to model what type of horse a stallion tends to throw, in theory breeders should prefer stallions that produce horses that like typical stakes race distances, where most of the prize money is. These variables may be insignificant because they are poor proxies for the characteristic being modeled. The variables may not be an important determinant of the stallion's fee. For instance, in the case of average winning distance, it is possible there is no preferred winning distance because there is good prize money available at every distance. The insignificance may be the result of other variables in the equation that are already modeling the effects of that characteristic. Breeders may only care about the percentage of foals that win stakes races and graded stakes races, rendering the ratio of starters to winners insignificant. Finally, the variables insignificance may be revealing some inefficiency in the market. The insignificance of the average earnings per runner indicates that breeders are not be taking into account the amount of money their foal is likely to earn at the track, unusual considering this is one of the chief means of recovering their investment in the stud fee.

The fixed effects regressions confirm that a stallion's fee is determined by his own traits as well as those of his offspring. The significant variables are: his location, his

sire index and comparable sire index, his dosage index and center of dosage, the number of his foals sold at auction, the percentage of foals that have won a stakes race, the percentage of foals that have won a graded stakes race, and the ratio of stakes winners to stakes wins. These variables are proxy variables that capture changes in the stallion's location, his pedigree, his popularity, and the racing quality of his foals, and indicate that these are significant characteristics for determining a stallion's stud fee.

Alternative Pricing Models in the Breeding Industry:

The results of this study can be used to determine a stallion's reasonable stud fee based on his own characteristics and the characteristics his offspring display. However, there is suggestion of other pricing models within the industry. Some stud farms alter their pricing to attract certain mares or even certain types of breeders. While the existence of these farms does not impact the regression results they are of interest as a clarification of motives and breeding tactics within the industry.

Certain stud farms offer discounts to owners of certain mares in return for boarding those mares at their farm, and breeding to their stallions. Some mares, often times called "blue hens," are particularly good broodmares and tend to have foal after foal that performs well at the track. A classic example of this is Better than Honour. She is the dam of 2006 Belmont Stakes winner Jazil, by Seeking the Gold, 2007 Belmont Stakes winner Rags to Riches, by A.P. Indy, who defeated eventual Horse of the Year Curlin to earn that victory, as well as 2008 Peter Pan Stakes winner Casino Drive, by Mineshaft. As a broodmare, Better than Honour's record is one of the best. In three years she produced three top class racehorses by three different stallions. Clearly, it would be in any stud farm's best interests for a mare such as Better than Honour to be boarded with

them and to be bred to one of their stallions. Looking at 2006 through 2008 the chances that one of her foals would be a success at the track is 100%, and the success of that foal would improve its sire's ratings and increase his fee. Some stud farms may offer incentives to owners of top class mares so that those owners will breed their mare to one of the farm's stallions. It is a win-win situation. The owner of the mare can breed their mare to good bloodstock for a reduced fee or free boarding, and the stud farm increases the chances that their stallions foals will be successful and the track, which can increase the public fee that they charge to other mare owners wishing to breed to the stallions. Conley describes one example of this between Claiborne Farm, a stud farm known for breeding such great thoroughbreds as Secretariat and Forty Niner, and the Phipps family:

> The farm has benefitted from its long-term associations – especially with the Phipps family, New York racing bluebloods whose mares, among the most coveted in the world, have boarded with Claiborne for more than seventy years. The combination of Claiborne stallions and Phipps mares creates the sort of virtuous circle that breeders pay to be a part of: boarder mares, like the Phippses', get first crack at the stallions, and those superior mares foal stakes-winning horses that burnish the reputation of their sires. In the next generation, the best stakes-winning horses retire to Claiborne, for the chance to breed to mares like the Phippses'. It's the bloodstock version of the rich getting richer, and it relies not on an old-boys network but on an old-mares network. (Conley, 2002)

As Conely describes the Phipps and Claiborne have a special relationship that breeds success.

While there might be some economic advantage for the Phipps to stabling their mares with Claiborne, other breeder's have to pay a hefty fee to breed their mare to a Claiborne Stallion. This is not the case for all stud farms though. Some farms appear to keep their fees low, opting to breed their stallions more often. These farms market themselves to the more "journeyman" breeder, who perhaps cannot afford the large fees of Claiborne stallions, and does not have a mare that a stud farm would offer incentives

to breed their stallion to. One farm in particular that does this is Crestwood Farm, which as Conley describes, has built a sire list that includes similar bloodstock to the top priced stallions for less money:

> Crestwood's success with Storm Boot has attracted other stallion owners, and now the McLean's have a tidy little list, full of the sort of studs that Pope McLean has always preferred: leading sire look-alikes and big-bang-for-your-buck horses, with a stud fee that costs less than your car. For $7,500 you can book Petionville, a son of the leading sire Seeking the Gold, who stands at Claiborne for $250,000. For $6,000, you can get Dixieland Heat, son of the $75,000 stallion Dixieland Band. (Conley, 2002)

The farm offers breeders the same bloodlines for cheaper, and often times this works just as well. For example Xtra Heat, by Dixieland Heat, who, "passed through the auction block three times – selling for $9,100; $4,700; $5,000, in one sale after the other; then she went to the track and won seventeen of twenty races, earning well over a million dollars, more than a hundred times her daddy's stud fee" (Conley, 2002). Farm's like Crestwood and Claiborne take different approaches to the breeding industry, both of which work well for them.

Conclusion:

Racehorse breeding is a gamble, and the stakes are high. Raymond Woolfe observed that, "the science of genetics is a far from exact one, and often the most carefully planned matings produce nothing that resembles the better qualities of either parent" (Woolfe, 1974). Bearing this in mind, a breeder can spend a significant amount of money on a stallion's stud fee to breed to his best mare and still not produce a winner. Most of the risk for the breeder is connected to the stud fee, and the goal of this study is to better understand which qualities have the greatest impact in determining a stallion's fee.

The beginning of this paper mentions the drastic difference of $120,000 in the fees of two seemingly similar horses: A.P. Indy and Birdstone. These stallion's offspring both performed impressively at the racetrack last year, winning some of the top races in the country. However, this study suggests that this is not the only determinant of a stallion's fee. The regression results indicate that the following variables are important in determining a stallion's fee: his location, his sire index and comparable sire index, his dosage index and center of dosage, the number of his foals sold at auction, the percentage of foals that have won a stakes race, the percentage of foals that have won a graded stakes race, and the ratio of stakes winners to stakes wins. Both A.P. Indy and Birdstone are located in Kentucky, so this variable should have no impact on the difference between their fees. A.P. has a much higher percentage of foals that are graded stakes winners and stakes winners (an 8 percent and 4 percent difference respectively). He also rates higher than Birdstone on his sire index and comparable sire index. A.P. Indy's pedigree is slightly more dominated by speed than Birdstone's. Finally, he has more foals sold at auction, indicating that of the two stallions A. P. Indy is the more popular. The only trait on which Birdstone rates higher than A.P. Indy is the ratio of stakes winners to stakes wins. Given that A.P Indy outperforms Birdstone in so many of the characteristics that the regression suggests are important to breeders, the $120,000 difference in their stud fees no longer seems quite so dramatic.

Ultimately the results of this study conclude much of what is to be expected, with some small surprises. Breeders prefer and will pay a higher stud fee for a stallion that has more winners in big races, has higher stallion ratings, has a pedigree dominated by speed, and is popular. These results are logical considering that owners of mares are either

breeding their mares to produce a racehorse for themselves that they hope will win big at the track, or to produce a foal that can fetch a high price at auction. While those results are to be expected, some of the results are not and may indicate that there is some inefficiency in the market for stud fees. For instance, the positive impact that being located in Kentucky has on a stallion's fee. While the industry is highly centralized in the Bluegrass region, there is good bloodstock and good racing to be had outside of that area. Cee's Tizzy proved this when his son Tiznow beat Storm Cat's son Giants Causeway in the Breeders' Cup Classic. Further two variables are surprisingly insignificant: the average earnings per runner, and the average auction price of a stallion's foals. It seems these variables should have a positive and significant impact on the stallion's fee, yet they are insignificant. These variables should capture how much of a stallion's fee a breeder can expect to recoup by either racing his foal or selling it, and this should impact how much he is willing to pay to breed to a stallion. The insignificance of the average auction price can be traced to the endogenous relationship between this variable and the stud fee itself. Therefore, further study into the determinants of auction prices could clarify this relationship, and the true impact of auction price on the fee a stallion can command. The insignificance of the average earnings per runner is slightly more concerning, indicating that breeder's decisions may not be entirely driven by cost-benefit analysis. Perhaps more weight is placed on tried and true stallions such as Storm Cat or A.P. Indy, while some less popular but demonstratively successful stallions such as Cee's Tizzy or Birdstone remain out of vogue. This may provide an opportunity for breeders. The science and art of breeding Thoroughbred racehorses is significantly driven by logical factors but there is a material element of subjectivity.

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