



HEDONIC PRICE ANALYSIS OF NON-BARREN BROODMARES

BREE L. DORITY*, DAYNA LARREAU**, FRANK TENKORANG***

Abstract: *The current real average selling price of a thoroughbred broodmare is nearly half its peak value in 2000. While annual price changes are influenced by economic performance, different prices at an auction are influenced by physical and genetic characteristics of broodmares. We use auction data from the 2013 November Keeneland Breeding Stock Sales to estimate a hedonic pricing model. We find prices are positively influenced by earnings of the covering sire, earnings of the broodmare, pedigree, and the racing performance of broodmare progeny. Conversely, the age of a broodmare and the day on which the horse sold have dampening effects on broodmare prices.*

Keywords: broodmare, hedonic pricing, thoroughbred

JEL Classification: D46, L11, Q13

1. INTRODUCTION

The real average thoroughbred broodmare selling price doubled during the period 1990-2000, however, since peaking in 2000, the real selling price has nearly returned to its 1990 value (Keeneland Association; Neibergs 2001). Yearly fluctuations indicate that price cycles were recorded within the economy (i.e. during the 1990-1991 and 2001 recessions, real average broodmare selling prices fell about 7 % and 28 %, respectively; whereas during the Great Recession of 2007-2009, prices dropped 54 %. Price variability *within* a given year also shows that prices vary substantially from one broodmare to another. For example, during 2001-2014 November Keeneland Breeding Stock Sales, the minimum price

* Bree L. DORITY, Department of Economics, University of Nebraska-Kearney, 1917 W 24th St, Kearney, NE 68849, USA, dORITYBL@UNK.EDU

** Dayna Larreau, Department of Economics, University of Nebraska-Kearney, 1917 W 24th St, Kearney, NE 68849, USA, s-dlarrea1@UNK.EDU

*** Frank Tenkorang, Department of Economics, University of Nebraska-Kearney, 1917 W 24th St, Kearney, NE 68849, USA, tenkorangf1@UNK.EDU

registered yearly was \$ 1,000, whereas the highest price generally reached around \$ 4 million. The purpose of this research is to quantify the non-barren broodmare sale price relationship due to a wide range of measurable characteristics of the 2013 Keeneland Breeding Stock Sales.

Few studies exist on the price determinants of broodmares (Neibergs 2001; Maynard and Stoeppel 2007), and the data encompassed relates to prices from years prior to the Great Recession, when an unprecedented growth was recorded, almost reaching peak values, while the yearly price variability was disregarded entirely. Although breeders may hold their higher quality stock until better market conditions, the broodmare market environment has changed since the Great Recession (i.e. prices have plummeted to the 1990s value and reveal a higher yearly volatility).

The present article contributes to the existing literature by examining broodmares in foal and broodmare prospects. In the sample used, broodmares in foal are defined as those currently pregnant, whereas broodmare prospects relate to those who have not been exposed to a stallion. Additionally, barren broodmares are those who have been exposed but did not get pregnant and, thus, have not been included.

Neibergs (2001) includes all broodmares sold in 1996 (e.g., in foal, barren, and prospects), whereas Maynard and Stoeppel (2007) focus on only broodmares in foal sold in 2005. The latter argue that Neibergs' (2001) assumption that the marginal impacts of the price determinants are the same for barren and in foal broodmares is invalid, particularly for the stud fee variable, where a \$ 0 stud fee was assigned to barren broodmares. Consistent with Maynard and Stoeppel (2007), we assume the price of a broodmare is a function of attributes signaling the future racing performance of her foals. Therefore, barren broodmares were not considered given they are not presently producing foals, but they retain the future potential. The average prices of broodmares that are barren, in foal, and prospects are \$ 33,833, \$93,117, and \$ 192,280, respectively, indicating that, unlike broodmare prospects, barren broodmare prices are sharply discounted. This is most likely because of the increased production costs of maintaining an open mare and/or due to the risk of reproductive deficiency.

Finally, in order to control for the quality of the sire bred to the broodmare the covering sire's career earnings were included. Because broodmare prospects have not been exposed to a stallion, the present contribution is the usage of four

approaches to predict the covering sire's earnings for the stallion the broodmare prospect is likely to be exposed to. This approach is different from that of Neiberger (2001), who assigned a zero value to the sire's earnings for broodmare prospects. Overall, the results suggest that pedigree and the success of a broodmare's progeny are more important than the racing performance in determining the price.

2. LITERATURE REVIEW

The American Horse Council Foundation estimated that \$ 26.1 billion was contributed to the national GDP by the horse racing industry, and, within the state of Kentucky, the horse industry produced goods and services valued at \$ 2.3 billion. Given such a considerable contribution, breeders, buyers, sellers, and others are interested in understanding the thoroughbred market. Previous studies have considered mostly yearlings and sires, since these account for a larger share of racing horses (Robbins and Kennedy (2001), Parsons and Smith (2008), Plant and Stowe (2013), Ng et al. (2013), Stowe (2013), Stowe and Ajello (2010)).

Thoroughbred yearling³ studies have been conducted using data from several countries. Robbins and Kennedy (2001) investigated the determinants of auction prices in a local market in British Columbia. Using a log linear hedonic price model and a sample of 1,581 yearlings from the Canadian Thoroughbred Horse Society for the period 1985-1997, they find that age, gender, birth month, stake race, sire characteristics (i.e. stud fee), and dam's characteristics (i.e. black type and progeny earnings) have a positive impact on yearling price.

Similarly, using British thoroughbred yearling auction data from 2004, Parsons and Smith (2008) examine price determinants of yearlings, while at the same time they focus on the British Horseracing Board's Owners' Premium initiative, designed to support the national breeding industry. Such a maneuver was expected to provide a premium for British sired and reared yearlings, however, the authors did not find sufficient evidence. Consistent with Robbins and Kennedy (2001), their other findings indicate that gender, month of birth, and stud fee impact yearling prices.

³ Yearlings are defined as horses between 1 and 2 years old, who have never been raced before the auction (Ng et al. (2013)).

Ng et al. (2013) and Plant and Stowe (2013) examine the pricing of yearlings using 2005 Australian Thoroughbred auction data and 2008 Keenel and auction data, respectively. The first find that age, gender, color, parents' and siblings' characteristics, and type of buyer (i.e. foreigner) are significant factors affecting prices and the results are robust to different specifications of parent and sibling characteristics. Plant and Stowe (2013) account for the impact of disclosures (i.e. eye, scope, and vet) on market prices, and find that such information decreases prices of low quality yearlings, but has no effect on prices of high quality yearlings.

Stowe and Ajello (2010) find that earnings, career wins, grade of races won, dam races, and stud fee of sire's sire positively affect freshman sire stud fees. For leading thoroughbred sires, their stud fees are influenced by yearling price and progeny performance (Stowe, (2013). Hansen and Saghalian (2015) studied the shift in stud fee from the time a sire enters the breeding shed to when it becomes established. Their results show that early in a sire's breeding career, it is its own racetrack record that determines its stud fee, but in later years, the leading factor is the progeny performance.

3. EMPIRICAL METHODS

Building on the work of Neibergs (2001), Maynard and Stoeppel (2007), and (mention all the main sources!), we construct an empirical hedonic pricing model where a non-barren broodmare price is a function of her breeding characteristics, racing characteristics, genetics, and market factors. Specifically, we estimate equations of the following form:

$$\ln(\text{price}) = \alpha + \sum_b^5 \beta_b x_b + \sum_r^4 \beta_r x_r + \beta_g x_g + \sum_m^{10} \beta_m x_m + \varepsilon \quad (1)$$

The dependent variable is the natural logarithm of the price the broodmare sold at auction. The breeding characteristics (x_b) capture the broodmare's expected ability to produce successful progeny, and include whether the broodmare is a prospect, the broodmare's age, the covering sire's total career earnings, and

whether the broodmare has produced any black type⁴ offspring and any graded stakes offspring. It should be noted that Neibergs (2001) and Maynard and Stoeppel (2007) included the sire's stud fee to control for the quality of the sire bred to the broodmare. Although the stud fee captures the market's valuation of the stallion's genetics, the sire's career earnings captures actual performance and may be a better signal of the future racing performance of the foals.

The racing characteristics (x_r) represent the broodmare's own ability as a racehorse, and include its previous earnings, as well as the number of races won, placed, and showed. Genetics (x_g) or the ability of the broodmare's parents to produce successful racehorses, is captured using a binary variable (= 1 if the broodmare's sire or dam is a black type producer). Market factors (x_m) include whether the broodmare was born in the U.S., whether the price was the reserve not attained value, and binary variables indicating the day on which the broodmare was auctioned during the 10-day sale.

Table 1 provides variable definitions and the expected signs, and Table 2 presents means and standard deviations for all broodmares in the sample. Overall, the average price of broodmares in the sample is \$ 96,529, but prices range from \$ 1,000 to \$ 4 million. On average, the broodmares are slightly older than 9 years and have \$ 87,600 in career earnings. More than 6 % and 12 % of the broodmares are graded stakes and black type producers, respectively, and 97.3 % of the broodmares had a sire or dam which was a black type producer. The average earnings of the covering sire is nearly \$ 1.6 million.

Table 1 Variable definitions and expected signs

Variable	Description	Expected Sign
Dependent Variable		
Price	Broodmare selling price	N/A
Breeding Characteristics		
PROSPEC		
T	=1 if a broodmare prospect	-
AGE	Age of broodmare in years	-
S_EARN	Actual or estimated covering sire earnings (in \$10,000)	+
BT_PROD	Broodmare is a black type producer	+

⁴ Black type refers to boldface type used in sales catalogs to distinguish horses that have won or placed in a stakes race.

Variable	Description	Expected Sign
GS_PROD	Broodmare is a graded stakes producer	+
Racing Characteristics		
M_EARN	Broodmare's career race earnings (in \$10,000)	+
WON	Number of races broodmare won	+
PLACED	Number of races broodmare placed	+
SHOWED	Number of races broodmare showed	+
Genetic Characteristics		
	=1 if either of the broodmare's parents was a black type	
PT_BT	producer	+
Marketing Characteristics		
BIRTH	=1 if broodmare was born in the U.S.	+
RNA	=1 if reserve not attained	-
DAYi	Dummy variable for day of sale, $i = 3, 4, \dots, 10$	-

Table 2 Means and Standard Deviations

Variable	Non-Barren Broodmares		Pregnant Broodmares		Broodmare Prospects	
	Mean	St. Dev.	Mean	St. Dev.	Mean	St. Dev.
Dependent Variable						
Price	96,529	227,280	93,117	212,570	192,280	477,830
Breeding Characteristics						
PROSPECT	0.034	0.182	0.000	0.000	1.000	0.000
AGE	9.130	3.556	9.220	3.583	6.592	0.814
S_EARN	159.410	141.060	165.090	140.250	0.000	0.000
BT_PROD	0.122	0.328	0.127	0.333	0.000	0.000
GS_PROD	0.058	0.234	0.060	0.238	0.000	0.000
Racing Characteristics						
M_EARN	8.760	14.729	8.236	13.827	23.457	27.025
WON	1.938	2.296	1.842	2.229	4.612	2.532
PLACED	1.659	2.160	1.574	2.062	4.061	3.243
SHOWED	1.490	1.979	1.407	1.876	3.816	3.100
Genetic Characteristics						
PT_BT	0.973	0.163	0.974	0.160	0.939	0.242
Marketing Characteristics						
BIRTH	0.955	0.207	0.957	0.203	0.898	0.306
RNA	0.133	0.340	0.134	0.341	0.122	0.331

Approximately 3.4% of the sample are broodmare prospects, and the mean price of prospects is \$192,280, which is nearly \$100,000 more than the mean price of pregnant broodmares. Moreover, on average, prospects are younger than pregnant broodmares (6.6 years compared to 9.2 years), have higher career earnings (\$234,570 compared to 82,360), and have won, placed, and showed in more races than pregnant

broodmares. This is important because although broodmare prospects are not in foal, their average characteristics also differ from barren broodmares sold in 2013. For example, the average barren broodmare was 10.3 years old and sold for \$ 33,833. Unlike Maynard and Stoeppel (2007) who only examined broodmares in foal, broodmare prospects were retained in the sample because their price is not discounted due to factors associated with being barren (e.g., loss in earnings for not being in foal, risk due to lack of reproductive soundness, etc. (Neibergs (1997))). Thus, based on the selling price, it appears there is an expectation among buyers that broodmare prospects will produce successful foal in the future and/or continue to race successfully.

Also, we use four approaches to predict the expected covering sire's earnings for broodmare prospects in our sample. This is different from Neibergs (2001) who assigned a zero stud fee value to barren broodmares, and likely broodmare prospects, arguing that it reflects the expected value of the foal for a barren mare. Approach 1 ly uses the average covering sire's earnings for all pregnant broodmares (\$ 1.65 million) as the covering sire's earnings for the prospects. For Approach 2, we construct pregnant broodmare price quartiles, and use the average covering sire's earnings in the relevant price quartile for the broodmare prospects' covering sire earnings.

For Approaches 3 and 4, we use the observed positive relationship between covering sire's earnings and pregnant broodmare prices and construct a sire earnings-to-broodmare price ratio, which shows how much larger the covering sire's earnings are compared to the selling price of the pregnant broodmare. We estimate how this ratio is related to information on the broodmares, and then use the results to predict the ratio for broodmare prospects. Finally, given the predicted ratio, we can predict the covering sire's earnings for the stallion the broodmare prospect is likely to be exposed to.⁵ Using OLS and Tobit, Approaches 3 and 4 involve estimating equations of the following form:

$$ratio_i = f(age_i, x_{r,i}, x_{g,i}, x_{m,i}) \quad (2)$$

where:

- *ratio* is the sire earnings-to-broodmare price ratio,

⁵ It should be noted that we may have introduced endogeneity into the model with Approaches 3 and 4. However, as shown in the results section, our findings are robust across all specifications suggesting that any bias is minimal.

- *age* is the broodmare's age, and
- x_r , x_g , and x_m are the racing characteristics, genetics, and market factors .

The subscript denotes pregnant broodmare *i*. Although 97.7 % of the sire earnings-to-broodmare price ratios for the pregnant broodmares are greater than one, using the OLS estimates, we obtain negative predicted ratios for 11 of the broodmare prospects in the sample. Tobit estimation used restricts the predicted ratios for the broodmare prospects to be positive. Overall, the average covering sire earnings for all non-barren broodmares ranges from \$ 1.65 million to \$ 1.95 million, compared to \$ 1.59 million for pregnant broodmares.

3.1. Data

Data on the broodmare was collected from the Keeneland website. The Keeneland Thoroughbred auctions are held in Lexington, Kentucky, where the Keeneland Association is located. Keeneland began in 1936 and has become the source of America's best thoroughbreds through its auctions and important races, including the first leg of the Triple Crown, the Kentucky Derby. Keeneland has sold more champions and stakes winners than any other selling company. The auctions attract buyers from nearly all U.S. state and 50 countries to Keeneland's four annual sales (Keeneland Association). The November Breeding Stock sale is where broodmares are bought and sold, and in November 2013, 1,474 broodmares were sold.

The data used includes the broodmare's sale price, age, career race earnings, number of races won, placed, and showed, place of birth, whether pregnant or a prospect, whether a black type and graded stakes producer, if either parents were black type producers, the day of sale and who the covering sire is. Data covering sire earnings was derived from the Blood-Horse Stallion Register, which covers information on more than 2,700 Thoroughbred stallions.

4. RESULTS

Table 3 presents the parameter estimates for several specifications and the estimated price flexibilities and marginal values for Approach 3 estimation.⁶

⁶ Given the limited printing space, results for Approach 3 were provided, although results for Approaches 1-4 are very similar (details can be provided upon request)

Specifically, column A shows the parameter estimates when the sample is restricted to only pregnant broodmares. This is analogous to Maynard and Stoeppel's (2007) approach. Column B presents the parameter estimates when we restrict the covering sire's earnings to be zero for broodmare prospects, which is an analogous approach to Neibergs (2001). Column C presents the parameter estimates using our Approach 3 outlined above, and the estimates in columns D, E, and F are based on the parameter estimates in Column C.⁷

Overall, the magnitudes and statistical significance of the parameter estimates are similar across the specifications, and the direction of the signs on all the estimated coefficients are as expected. The similar results despite differences in estimation of the covering sire variables may be because stud fee and sire earnings are highly intertwined (Stowe and Ajello (2010), Hansen and Saghaian (2015)).

4.1. Breeding Characteristics

Of the breeding characteristics, the earnings of the covering sire and whether the broodmare is a black type and graded stakes producer are positively related to her sale price. That is, if the covering sire's earnings increase by \$ 10,000, her sale price increases by 0.05 %. More importantly, compared to a non-black type and non-graded stakes producing broodmare, a black type and a graded stakes broodmare producer has a sale price that is 22 % and 47 % higher, respectively. Based on the estimated marginal values, this is an increase of approximately \$8,400 and \$18,600, respectively. Conversely, with each additional year the broodmare's selling price decreases by 7.7 %. It is important to consider the horse's age and its progeny performance together as Hansen and Saghaian (2015) found progeny performance became more important as the sire aged. Breeders and buyers will expect older broodmares to have successful progeny to insure their investment is worthwhile.

Given the additional features, the price of a broodmare prospect is discounted by 27 % or about \$10,500 from that of a broodmare in-foal. Overall, the results are consistent with Neibergs (2001) and Maynard and Stoeppel (2007) despite the differences in estimation and time periods examined. Comparing price

⁷ Since the null hypothesis that the estimated coefficients are the same in two separate regressions (i.e. using only broodmares in foal or only broodmare) was not rejected, data has been pooled, one

flexibilities, a 1 % increase in age decreases the broodmare's selling price by 0.86 % according to Neibergs (2001), by 1.14 % according to Maynard and Stoeppel (2007), and by 0.70 % according to our estimation.

4.2. Racing Characteristics

The only racing characteristic that is statistically significant is the mare's career earnings, which suggests that if they increase by \$ 10,000 its selling price increases by 1.5%. This is consistent with Neibergs (2001) and Maynard and Stoeppel (2007) who estimated price flexibilities of 0.10 and 0.14, respectively, compared to our price flexibility of 0.13.

Comparing the 1.5 % per \$ 10,000 increase in price due to the broodmare's career earnings to the 7.7 % reduction due to age indicates that, for sellers, it would be worth it to breed and/or sell the broodmare early on if it is less talented, instead of holding onto it and hoping it will perform well in the following races. A yearly win of close to \$ 50,000 is needed to offset the age reduction. Overall, results suggest that untalented broodmares should be bred often from a young age in an attempt to produce a black type and/or graded stakes foal, which is estimated to increase its value by 22 and 47 %, respectively.

4.3. Genetic Characteristics

Although we find that the success of a broodmare's progeny is an important factor influencing her price, her pedigree is even more important. That is, compared to a broodmare with no black type producing parents, a broodmare with at least one black type producing parent has a sale price that is 108 % higher, or about \$ 21,000. Altogether, results are consistent with Neibergs (2001) and Maynard and Stoeppel (2007), suggesting that pedigree and the success of a broodmare's progeny are more important than the performance in determining its price.

When attending an auction, buyers and sellers alike focus on pedigree and progeny. It is very important to trace black type and/or graded stakes progeny through the pedigree in order to attempt to predict success in future foals, rather than sire earnings or stud fees. Broodmares with a line of repeatedly producing black type and/or graded stakes foals, whether or not they are winners themselves, will be more genetically likely to produce proven racers. Therefore, the broodmares that produce the most black type and/or graded stakes foals are more genetically disposed to proven progeny and, thus, are valuable.

4.4. Marketing Characteristics

The above results hold controlling for the birth place of the broodmare, the day on which it was sold, and whether the price was the reserve not attained value rather than the sale price. So far no evidence that the mare U.S.-born influences its price. However, consistent with previous studies, we find that each additional selling day had a statistically significant price discount with the largest discount occurring on day 10 (more than \$ 51,000)⁸. This indicates that if buyers are willing to wait, they may receive considerable discounts. On the other hand, the reserve not attained value (e.g., the last competitive auction price bid) was statistically significant, as opposed to Neibergs' (2001) perspective, suggesting that the last competitive auction price bid does not accurately reflect the broodmare value (e.g., the seller chose an unrealistic reserve price).

Overall, despite the change in the broodmare market environment since the Great Recession, we find that most valuable broodmares are those resulting from a black type producing parent, who already produced black type winners and graded stakes winners themselves. These results are consistent with Neibergs (2001) and Maynard and Stoeppel (2007) who examined price determinants of broodmares in the pre-Great Recession time period. If the broodmares with a valuable pedigree and successful progeny are bred with a high quality stallion, then, according to Robbins and Kennedy (2001) and Parsons and Smith (2008), the offspring will sell for a higher price as a yearling, and the winning genetics passed on will influence the yearlings' resale value and stud fee.

⁸ Since there was no significant price discount on Day 2 relative to Day 1, 8 rather than 9 binary variables representing the day on which the broodmare sold were included because.

Table 3 Regression results

Variable	Approach 3 Estimation					
	Pregnant Broodmares	Neibergs (2001) Approach	Parameter Estimates	Transformed Para. Est. ^a	Price Flexibility	Marginal Value
	[A]	[B]	[C]	[D]	[E]	[F]
PROSPECT		-0.237 ** (0.106)	-0.308 *** (0.098)	-0.268		-10,584
AGE	-0.077 *** (0.007)	-0.077 *** (0.007)	-0.077 *** (0.007)		-0.702	-3,042
S_EARN	0.0004 *** (0.0001)	0.0004 *** (0.0001)	0.0005 *** (0.0001)		0.083	20
BT_PROD	0.196 ** (0.076)	0.197 ** (0.077)	0.198 ** (0.076)	0.215		8,436
GS_PROD	0.399 *** (0.099)	0.393 *** (0.099)	0.393 *** (0.099)	0.474		18,602
M_EARN	0.014 *** (0.004)	0.015 *** (0.004)	0.015 *** (0.004)		0.131	592
WON	0.008 (0.02)	0.009 (0.018)	0.010 (0.018)		0.020	398
PLACED	0.013 (0.013)	0.008 (0.012)	0.008 (0.012)		0.013	307
SHOWED	-0.016 (0.013)	-0.016 (0.012)	-0.017 (0.012)		-0.025	-661
PT_BT	0.693 *** (0.116)	0.741 *** (0.111)	0.738 *** (0.111)	1.078		21,055
BIRTH	-0.030 (0.094)	-0.013 (0.088)	-0.007 (0.088)	-0.011		-288
RNA	-0.141 ** (0.058)	-0.140 ** (0.057)	-0.139 ** (0.057)	-0.131		-5,232
DAY3	-0.872 *** (0.09)	-0.878 *** (0.087)	-0.878 *** (0.087)	-0.586		-25,524

Variable	Approach 3 Estimation					
	Pregnant Broodmares	Neibergs (2001) Approach	Parameter Estimates	Transformed Para. Est. ^a	Price Flexibility	Marginal Value
	[A]	[B]	[C]	[D]	[E]	[F]
DAY4	-0.938 *** (0.086)	-0.939 *** (0.083)	-0.938 *** (0.083)	-0.610		-26,730
DAY5	-1.544 *** (0.081)	-1.548 *** (0.078)	-1.546 *** (0.078)	-0.788		-39,046
DAY6	-1.571 *** (0.084)	-1.568 *** (0.082)	-1.567 *** (0.082)	-0.792		-37,192
DAY7	-1.961 *** (0.083)	-1.965 *** (0.08)	-1.961 *** (0.08)	-0.860		-42,592
DAY8	-1.977 *** (0.101)	-1.989 *** (0.099)	-1.983 *** (0.099)	-0.863		-38,923
DAY9	-2.817 *** (0.101)	-2.820 *** (0.099)	-2.815 *** (0.099)	-0.940		-50,604
DAY10	-2.963 *** (0.108)	-2.983 *** (0.105)	-2.973 *** (0.105)	-0.949		-51,428
CONSTANT	12.002 *** (0.158)	11.944 *** (0.152)	11.923 *** (0.151)			
R-squared	0.67	0.68	0.68			
n	1375	1424	1424			

Heteroskedasticity-consistent standard errors are in parentheses.

*p ≤ .10. **p ≤ .05. ***p ≤ .01.

^a Binary variable coefficients transformed according to Kennedy (1981).

5. CONCLUSIONS

The present study uses a hedonic pricing model and Keeneland data from 2013 to examine specific factors related to thoroughbred broodmare prices. In order to control for the quality of the sire bred to the broodmare, the covering sire's career earnings were included, compared to Neiberghs (2001) and Maynard and Stoeppel (2007) who used the sire's stud fee. Although the latter captures the market's valuation of the stallion's genetics, the sire's career earnings captures actual performance, potentially better signaling the foals' future racing performance of the foals. Overall, the impact of the sire's career earnings on broodmare prices is smaller than the impact of the stud fee on broodmare prices. However, both impact broodmare prices by a far smaller amount than the pedigree and progeny performance variables (e.g., a 1 % increase in either the stud fee or the sire's career earnings increases broodmare prices by less than 1 %).

Although market conditions were different in 2013 compared to the period 1996-2005, on which the previous research focused, the present results are consistent with earlier ones. Thus, it is suggested that pedigree and the success of a broodmare's progeny are more important for determining its price than the racing performance. Specifically, the genetics variable had the greatest impact on price, followed by whether the broodmare herself was a graded stakes producer.

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