Journal of Agricultural and Applied Economics, 29,2(December 1997):419–435

Price Expectations and Supply Response in the Thoroughbred Yearling Market

J. Shannon Neibergs and Richard Thalheimer

ABSTRACT

Limited information is available concerning price determination in the thoroughbred yearling market. A recursive model incorporating price expectations and biological constraints is used to estimate supply and demand functions for thoroughbred horses. Empirical results characterize a market with inelastic supply and elastic demand that converges to equilibrium under static conditions. Purses were identified as the most influential variable impacting price. Comparative statics illustrate the effectiveness of purses as a policy instrument for the thoroughbred industry. Federal tax policy also was found to have a significant impact on the decisions to breed or invest in thoroughbred yearlings.

Key Words: elasticity, parimutuel horse racing, price determination, price flexibility, purses, thoroughbred, yearling.

The thoroughbred race horse industry has a rich history as a form of recreation, and as a source of legalized gaming. In the United States, over $14 billion was wagered on parimutuel horse racing in 1995 (Christiansen and Cummings). Predominant states involved in the thoroughbred industry ranked by foal crop include Kentucky, California, Florida, Texas, and Oklahoma (The Jockey Club). Currently, the thoroughbred industry is undergoing structural change in response to speculative investment and disinvestment that has occurred in the breeding industry, an expansion in simulcasting races,[1] and increased competition from a proliferation of alternative gaming options.

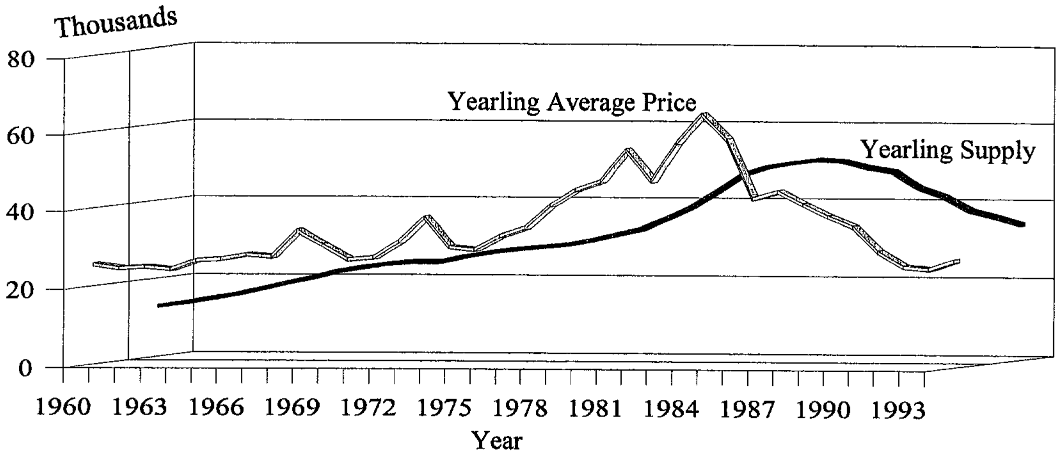
The thoroughbred industry can be roughly divided into five sectors. In the breeding sector, the primary focus is producing foals that are predominantly sold as yearlings.[2] This sector's investment in the industry includes the breeding stock of stallions and mares, and extensive fixed capital assets from which to conduct breeding operations. The second sector includes owners of yearlings and horses-in-training. They are investors who create the market demand for the breeding sector's production. Participants in this sector view horses as capital assets whose values reflect expected after-tax earnings from racing and breeding, plus the additional utility gained from directly

The authors are assistant professor and associate professor, respectively, with the Equine Industry Program, College of Business and Public Administration, University of Louisville, Louisville, Kentucky.

The helpful comments of Robert G. Lawrence and two anonymous reviewers are gratefully acknowledged.

[1] Simulcasting is where a track conducts a live race and simultaneously transmits the race via satellite to off-track wagering sites. Simulcasting has had significant effects on the geographical distribution of gross amount wagered and on-track attendance, and has changed a race track's market from a regional to a national and international basis.

[2] All thoroughbreds become yearlings on the first January 1 after they are foaled. Therefore, each thoroughbred has January 1 as its official birthday. The primary market for thoroughbreds is yearling auctions.



Source: The Blood-Horse, *Annual Auction Review.*

Figure 1. Average North America yearling sale price (deflated 1994 = 100) and supply, 1960–94

participating in a professional sport. The third sector includes racetracks who conduct parimutuel racing. The fourth sector is comprised of state governments which set regulations and tax requirements guiding the industry. Horse race bettors, who make up the fifth sector, provide (directly or indirectly) the source of funds for breeders, owners, race tracks, and governments. Demand for thoroughbred yearlings is a derived demand initiated by horse racing bettors investing in parimutuel wagering pools that fund the purses for which race horse owners compete.[3]

The principal objective of this study is to present a dynamic econometric model of the thoroughbred yearling market. The model is used to analyze (*a*) the effect of purses on the demand for yearlings, (*b*) the dynamic supply response to changes in the price of yearlings, (*c*) the importance of the export market as a determinant of demand, and (*d*) the impact of taxes on the yearling market.

A brief historical review of the thoroughbred industry is presented first to highlight important changes in the yearling market relative to specifying an econometric model. This is followed by a review of existing thoroughbred yearling market research. The next two sections specify the empirical model and present the results. Comparative dynamics are then analyzed with a specific emphasis on analyzing purse and federal tax policy impacts on the market. Potential impacts to breeders and yearling buyers from an evolving thoroughbred market are summarized and highlighted in the conclusions.

History of Thoroughbred Industry and Review of Literature

History

Impacts to the thoroughbred industry manifest their effects in the yearling market where the greatest number of horses are sold. The yearling market is the most significant source of revenue to breeders and depends on buyers' expectations of economic conditions in thoroughbred racing. Over the past 30 years, the thoroughbred yearling market has exhibited trend and cyclical behavior reflecting changes in the industry, as shown in figure 1.

The supply of yearlings in North America grew steadily from 1960 to 1975, rose rapidly from 1976 to peak at 51,293 yearlings in 1987, and declined to 37,108 by 1994. Average yearling prices were steady from 1960 to 1972, then grew rapidly from 1975 to a peak

[3] State statutes generally specify the minimum redistribution of gross parimutuel wagers to winning bettors, state taxes, race tracks, and purses.

of $65,015 in 1984.[4] The rapid rise in price was fueled by massive foreign purchases and domestic speculative investment (Hollingsworth). Many yearling buyers were willing to pay a premium above any realistic racing earnings on the theory that they would eventually recapture their investment through tax savings and the yearling's residual breeding value. This amounted to unsustainable speculation and, combined with federal tax reform, oversupply, economic recession, and decreased foreign expenditures, caused the market to decline rapidly from 1985 to 1992. The recent market recovery is the result of renewed foreign interest and increased potential race earnings due to larger purses funded primarily by the growth in simulcasting.

By the close of the 1980s, parimutuel wagering had been legalized in 36 states. But the 1980s and early 1990s also saw increased legalization of state lotteries and alternative gaming. Widespread state lottery expansion changed the public's perception of gaming from morally corrupting, dishonestly operated, and the source of negative social externalities, to a state-regulated source of funding, economic growth, and entertainment (Christiansen and Cummings). This growth reflects an acceptance by the public of gaming as a leisure time activity. The change in gaming's image and two developments in the late 1980s and early 1990s have created the potential for a wide proliferation of gaming. First was the 1987 U.S. Supreme Court decision (*California v. Cabazon Band of Mission Indians*) that opened the door for gaming on Indian reservations, as set forth in the subsequent Indian Gaming Regulatory Act of 1988 (Marfels). Second was the surge in riverboat gaming along the Mississippi River—authorized in Illinois, Indiana, Iowa, Louisiana, Mississippi, and Missouri. The negative substitution effect on thoroughbred wagering and attendance from lotteries (Thalheimer and Ali 1995a, c; Gulley and Scott; Simmons and Sharp) and casinos (Ali and Thalheimer; Thalheimer and Ali 1995b) has been well established.

[4] All prices in this study are deflated by the CPI, where 1994 = 100.

Alternative gaming affects the thoroughbred yearling market through purses. The negative substitution of alternative gaming for parimutuel wagering decreases purses in areas where there is direct competition between parimutuel and alternative gaming. Alternatively, some states (e.g., Delaware, Iowa, and West Virginia) use alternative gaming revenue to subsidize purses. In either case, purses are the active agent exerting influence on the thoroughbred market.

Review of Literature

Although the thoroughbred industry represents a large economic sector, its market and factors affecting price determination remain largely unexplored. Lawrence (1968) developed economic models analyzing price determination for the quarter horse and thoroughbred industries, and was the first to specify a recursive model for this industry. Several alternative specifications of single and simultaneous models were estimated. Results indicated that supply, quality, national income, and potential earnings had the greatest impact on average thoroughbred yearling price.

Karungu, Reed, and Tvedt tested the hypothesis that macroeconomic conditions affect thoroughbred yearling prices. Specifically, a trade weighted exchange rate, an intermediate term interest rate, a binary variable representing the 1986 Tax Reform Act, and purses were found to affect the median price of thoroughbred yearlings auctioned at the Keeneland (Kentucky) and Saratoga (New York) select sales.[5] Buzby and Jessup expanded on the work of Karungu, Reed, and Tvedt to include both macroeconomic variables and yearling-specific variables (sex, month foaled, Kentucky bred, stud fees, and past racing performance of the sire and dam) in a hedonic model that estimated individual yearling prices from

[5] A select sale is a public auction in which the entrants have been nominated and chosen based on criteria for pedigree and conformation. Select sales represent the highest quality yearlings in the market. Only a small portion of the yearling population qualifies for a select sale.

a time series of Keeneland select sales. The data for the Buzby and Jessup study consisted of 3,027 yearlings auctioned from 1980 to 1990. A binary variable representing the 1986 Tax Reform Act, the sire's stud fee, gross foreign purchases, month foaled, and the dam's past racing performance were found to significantly impact the price of individual yearlings.

The results from both the Karungu, Reed, and Tvedt, and Buzby and Jessup studies support the conclusion that macroeconomic conditions affect the yearling market, because they reflect the economic climate that encourages or discourages investors. However, results from these studies have limited application to industrywide analysis due to their focus on select sales. From 1980 to 1994, the number of yearlings sold at the Keeneland and Saratoga select sales represented on average only 5.1% of the total number of yearlings auctioned in North America, and their average price was 16 times greater than the average price of all yearlings auctioned. Consequently, the use of data limited to the select sales results in a small and biased representation of the true population. A second limitation of the two studies is that neither model addressed the impact of yearling supply. And third, the use of a binary variable to represent the 1986 Tax Reform Act allowed the regression models to incorporate a number of structural changes in the yearling market during this time period into one variable. In addition to tax reform, the effects of development and expansion in simulcasting, a decline in the number of live racing opportunities, variation in gross purse structure, and the dramatic increase in competition from alternative gaming could manifest their impacts in a binary variable representing this time period. From an industry perspective, these are the factors that must be addressed, and the potential range of their impacts must be determined to develop efficient policy recommendations.

Model and Econometric Specification

Economists have long recognized the importance of dynamics and price expectations in agricultural production. Ezekiel's 1938 work is a classic reference in the application of difference equations in specifying a cobweb model (sometimes referred to as a recursive model). More recently, progress has been made in analyzing managed animal populations under alternative dynamic and price expectation specifications. Chavas and Klemme specified an aggregate supply response model where population dynamics were characterized by difference equations defining the age distribution of breeding stock, and optimal control methods were used to derive efficient production conditions in a dynamic setting. The investigations of Rosen; Whipple and Menkhaus; and Foster and Burt are examples of subsequent managed animal population models specified under the basis of difference equations. Stein examined the presence of cobweb cycles in commodities without futures markets. Rosen, Murphy, and Scheinkman specified a structural model to examine cattle cycles, and concluded that a recursive structural model with long-run constant returns to scale is a good working approximation of the cattle market. Irwin and Thraen provide a review of agricultural commodity modeling under alternative price expectations specifications.

Economic analysis of the thoroughbred yearling market is different, in part, because thoroughbred horses are capital goods in comparison to livestock commodities which are typically modeled as consumption goods. Furthermore, a thoroughbred mare has a potential breeding life of over 20 years. The long breeding life and the lack of data classifying thoroughbred breeding stock precludes the development of a model specification based on age and quality distributions of thoroughbred breeding stock.

The thoroughbred breeding decision is between breeding the mare, or not breeding the mare and maintaining the mare on the farm. Rarely are thoroughbred mares culled and sent to slaughter. Therefore, a mare not bred one year can return to the breeding population in subsequent years depending on market conditions. The economic decision is dependent on the marginal costs of breeding a mare and producing a yearling versus the expected price of selling the yearling. Because thoroughbred mares are constrained to produce one foal per year, and there is little that can be done to increase productivity, the supply response originates from changes in breeding intentions.

The underlying model hypothesis is that breeders act in accordance with the information available to them when breeding decisions are made in a way represented by the interaction of a supply and demand model of thoroughbred yearlings. Breeding decisions are dependent on the expected price of yearlings. The expected price would result from the solution of the supply and demand model for price on the basis of information available when breeding decisions are made. By utilizing the expected price to explain breeding decisions, all information in the supply and demand model is brought to bear in determining breeding decisions.

The empirical specification is based on a simple model of intertemporal equilibrium with price expectations. Because there are biologically determined time lags between price discovery and the decisions to breed a mare, register the foal, and sell the produced offspring as a yearling, there is a natural dynamic model structure. The decision to breed a mare is made early in year t, which is followed by an 11-month gestation period, to produce and register a foal in year $t + 1$.[6] The foal matures for a year and is sold as a yearling in year $t + 2$. Therefore, supply decisions are based in part on breeders' price expectations two years in the future.

Demand for thoroughbred yearlings can best be represented as a capital investment function. Profit maximization compels investors to be aware of factors affecting the earning potential of yearlings. Previous studies on thoroughbred yearlings (Karungu, Reed, and Tvedt; Buzby and Jessup) have established the importance of purses, taxes, and foreign purchases as demand determinants. The structural model is specified by the following three-equation system (with variable definitions provided in table 1):

Table 1. Variable Definitions

Variable	Definition
$RFOAL_t$	The number of registered foals in North America
P_t	The average price of thoroughbred yearlings auctioned in North America
MTB_t	The present value of tax benefits from a capital investment in a thoroughbred mare
FCI_t	A farm production cost index
$SFEE_t$	The average advertised stud fee in North America
YRL_t	The supply of yearlings in North America
YTB_t	The present value of tax benefits from a capital investment in a yearling
$PRSE_t$	The average purse per race in North America
GFP_t	The gross amount of foreign purchases of thoroughbred yearlings auctioned
EXR_t	The exchange rate of United Kingdom pounds for U.S. dollars
$GGDP_t$	The growth in gross domestic product
NR_t	The number of live races in North America

Note: All variables are annual data. Lagged variables are noted as $t - 1$ or $t - 2$ when appropriate.

(1) Supply of Registered Foals:

$$RFOAL_t = \alpha_0 + \alpha_1 RFOAL_{t-1} + \alpha_2 P_{t-2} + \alpha_3 MTB_{t-2} + \alpha_4 FCI_{t-2} + \alpha_5 SFEE_{t-2} + \mu_t;$$

(2) Foal-to-Yearling Transfer:

$$YRL_t = RFOAL_{t-1};$$

and

(3) Inverse Demand for Yearlings:

$$P_t = \beta_0 + \beta_1 YRL_t + \beta_2 YTB_t + \beta_3 PRSE_t + \beta_4 GFP_t + \beta_5 EXR_t + \beta_6 GGDP_t + \beta_7 NR_t + \nu_t.$$

[6] Thoroughbreds can be registered in years beyond $t + 1$, but would still be counted in the foal crop of year $t + 1$.

The Supply Model

Equation (1) represents a supply model of registered thoroughbred foals, $RFOAL_t$. Supply response to price is modeled where $RFOAL_t$ responds to national average price for thoroughbred yearlings lagged two years (P_{t-2}) to represent price expectations and reproductive constraints associated with breeding decisions, as previously discussed. Due to the high asset fixity associated with thoroughbred breeding investments and the long length of time associated with breeding decisions, the supply of thoroughbred yearlings changes gradually over time. This can be observed in the smooth supply response curve (as seen in figure 1). The stickiness in supply response is in part attributable to the large fixed capital investment associated with horse production that is not easily liquidated, the small difference in marginal cost between a bred mare versus a nonproductive barren mare, and the biological constraints of reproduction. Also, many breeders may not be price responsive due to their willingness to subsidize their thoroughbred investment through periods of nonprofitability. A partial adjustment process is represented by a one-period lag of the endogenous variable, $RFOAL_t$.

Because tax benefits are a primary consideration in thoroughbred investment decisions, changes in federal tax policy affect the thoroughbred yearling market. Tax benefits are a better indication than tax costs of federal tax policy impacts on the yearling market, since tax benefits apply equally to profitable and nonprofitable thoroughbred investment decisions. The effects of changes in federal tax policy can be captured through an index that measures the present value of tax benefits from a capital investment in a thoroughbred broodmare (Hall and Jorgenson). The mare tax benefit index (MTB_{t-2}) represents the present value of tax benefits generated from a fixed capital investment in a thoroughbred mare.[7] By modeling tax reform through MTB_{t-2}, the net effect on the marginal cost of breeding decisions from changes in marginal tax rates, depreciation schedules, and capital gains can be determined directly.

Costs of production are represented through the remaining two variables in the supply model. A farm cost index (FCI_{t-2}) represents input costs of production, and $SFEE_{t-2}$ represents the national average stud fee paid to breed a mare. A stochastic error term is represented by μ_t.

Foal-to-Yearling Transfer

Thoroughbred foals are registered with the Jockey Club as weanlings shortly after they are born, and become yearlings on the first January 1 after they are foaled. Equation (2) is an identity that transfers $RFOAL_t$ to the supply of marketable yearlings, YRL_t. Once a foal is registered, only death prevents it from becoming a yearling. Since death loss rates for thoroughbreds are unavailable, and presumed negligible and invariant over time, an identity is used to transfer foals to yearlings.

The Demand Model

Equation (3) represents an inverse demand function where the national average price of yearlings (P_t) is a function of the predetermined supply of yearlings (YRL_t) and a set of current exogenous variables. The price of a capital asset, a thoroughbred yearling being no exception, is related to its earnings potential.

---

[7] MTB_t is calculated for each year t in the time series 1960–94 as the present value of expected maximum tax benefits from a fixed capital investment in a thoroughbred breeding mare, projected over a seven-year tax recovery period required for a broodmare investment as follows:

$$MTB_t = \sum_{n=1}^{N} \frac{T_{tn} D_{tn}}{(1 + r)^n} + \frac{C_{tN}}{(1 + r)^N},$$

$$\text{for } t = 1960, \ldots, 1994,$$

where n is an annual index relative to year t, and N is the tax recovery period of a mare (which is seven years). T_n is the highest personal marginal tax rate; D_n is annual depreciation expense; C_N is the capital gains tax benefit when allowed, and 0 otherwise; and the discount rate r is fixed at 8%. Each tax policy variable is projected over the seven-year tax planning horizon as expected in year t.

For a thoroughbred yearling, those earnings are the purses for which it competes. The national average purse per race ($PRSE_t$) represents yearling earning potential.

The yearling tax benefit YTB_t represents the present value of the tax benefits generated from a capital investment in a thoroughbred yearling, and is calculated and defined in the same manner as MTB_{t-2}.[8] The importance of tax reform impacts on yearling price is noted in previous studies (Karungu, Reed, and Tvedt; Buzby and Jessup).

Foreign investment greatly influences the thoroughbred yearling market. The gross amount of foreign purchases of thoroughbred yearlings (GFP_t) and the exchange rate of United Kingdom pounds for U.S. dollars (EXR_t) are used to capture the export influences of demand on the thoroughbred market. Buyers from the United Kingdom led foreign purchasers for many years in the study. Gross foreign purchases were identified as the most influential macroeconomic variable in Buzby and Jessup's study of yearling price determinants.

While foreign investors are important for their large investments in individual thoroughbreds, domestic investors buy the majority of thoroughbreds and are heavily influenced by the state of the national economy. The growth in gross domestic product ($GGDP_t$), calculated as $\{GDP_t - GDP_{t-1}\}$, represents domestic economic conditions.

Live racing is important to all sectors of the industry. The breeding sector supplies horses to race, owners need to run their horses in races in order to earn purses, and race tracks need live racing as a source of on-track revenues and as a product to sell in the simulcast market. The number of live thoroughbred races is represented in the demand model as NR_t. A stochastic error term is represented by ν_t.

Because there is no direct feedback from the demand equation to the supply equation, the specified model is recursive. In a recursive system, each of the endogenous variables can be determined sequentially. Given values for P_{t-2}, one can solve directly for $RFOAL_t$ in the supply equation. Then, knowing $RFOAL_t$, the value of P_t can be solved recursively in the demand equation. A recursive model structure can be tested for specification error against the hypothesis: $\rho(\mu_t, \nu_t) = 0$ (Pindyck and Rubinfeld).

Data

The model is fitted with annual data from 1960–94 for North America. This time frame covers the evolution of the industry from its era as a gaming monopoly to widespread competition from alternative gaming and the introduction of simulcasting. Data on $RFOAL_t$ were obtained from the Jockey Club's *1995 Fact Book: A Guide to the Thoroughbred Industry in North America.* Data on P_t and GFP_t were collected from various issues of the *Annual Auction Review* (The Blood-Horse) and represent an annual summary of yearling auctions in North America. Data on GFP_t are available only from 1973–94. Prior to 1973, foreign purchases were relatively insignificant and were not reported separately. Essentially, GFP_t is a variable with a constant value of zero assumed for years prior to 1973, and actual data used when GFP_t rose to a level of significance to be reported separately.

$PRSE_t$ and NR_t data were collected from various "All About Purses" articles (Lawrence) appearing in the *Thoroughbred Times.* MTB_{t-2} and YTB_t were calculated using data from *Standard Federal Tax Reports: 1993 Depreciation Guide* and the Internal Revenue

---

[8] YTB_t is calculated for each year t in the time series 1960–94 as the present value of expected maximum tax benefits from a fixed capital investment in a thoroughbred yearling, projected over a five-year tax recovery period with a fixed discount rate r as follows:

$$YTB_t = \sum_{n=1}^{N} \frac{T_{tn}D_{tn}}{(1+r)^n} + \frac{C_{tN}}{(1+r)^N},$$

$$\text{for } t = 1960, \ldots, 1994,$$

where n is an annual index relative to year t, and N is the tax recovery period of a yearling (which is five years). T_n is the highest personal marginal tax rate; D_n is annual depreciation expense; C_N is the capital gains tax benefit when allowed, and 0 otherwise; and the discount rate r is fixed at 8%. Each tax policy variable is projected over the five-year tax planning horizon as expected in year t.

Table 2. Thoroughbred Yearling Market Model Empirical Results

Supply ($RFOAL_t$)			Demand (P_t)		
Variable	Estimated Parameter	Significance Level[a]	Variable	Estimated Parameter	Significance Level[a]
Constant	−1,918.0	0.191	Constant	−82,927.8	0.000
	(1,430.6)			(18,138.6)	
$RFOAL_{t-1}$	0.876	0.000	YRL_t	−0.486	0.019
	(0.049)			(0.194)	
P_{t-2}	0.104	0.006	YTB_t	6.601	0.000
	(0.035)			(1.023)	
MTB_{t-2}	3.634	0.000	$PRSE_t$	7.860	0.000
	(0.671)			(1.233)	
FCI_{t-2}	−8.626	0.002	GFP_t	2.12E−4	0.000
	(2.452)			(1.89E−5)	
$SFEE_{t-2}$	−0.308	0.631	EXR_t	−2.479	0.919
	(0.635)			(23.997)	
			$GGDP_t$	10.535	0.097
				(6.120)	
			NR_t	0.141	0.396
				(0.164)	
Summary Statistics:					
No. Observations	35			35	
Adjusted R^2	0.994			0.951	
F-Statistic	1,066	0.000		97	0.000
Durbin-Watson	1.54			2.31	
Durbin-H	1.423			NA	
$\rho(\mu_t, \nu_t)$	−0.162	0.351			

Notes: Numbers in parentheses are standard errors.

[a] Represents the level of significance associated with the estimated regression parameters.

Code (Commerce Clearing House). Data on FCI_t were taken from various issues of the U.S. Department of Agriculture's *Agricultural Statistics.* The *Annual Stallion Register* (The Blood-Horse) provided data on $SFEE_{t-2}$. An annual average stud fee was calculated by averaging all advertised stud fees in the register per year. Over the study period, the average annual number of stallions advertised in the register was 2,321. Data on $GGDP_t$, EXR_t, and the consumer price index used to deflate data expressed in monetary units were obtained from the Citibase macroeconomic database. The sources of data for each of these Citibase data series are, respectively, U.S. Department of Commerce, Bureau of Economic Analysis; Board of Governors of the Federal Reserve System, Foreign Exchange Rates; and U.S. Department of Labor, Bureau of Labor Statistics, Consumer Price Index. (Descriptive statistics are presented in appendix table A1.)

Empirical Results and Discussion

Estimated results obtained from the data and specified model are presented in table 2. As appropriate for recursive systems, ordinary least squares was used to estimate parameters. Overall model results strongly support the suggested model specification and the conclusion that the thoroughbred yearling market follows a recursive market structure. Notably, the correlation between error terms of the supply and demand equations, $\rho(\mu_t, \nu_t)$, of −0.162 is not significantly different than zero. The adjusted R^2 is .99 and .95 for the supply and demand equations, respectively. The Durbin-Watson statistic in each case indicates the absence of serial correlation, suggesting that the equations are likely free of specification errors such as those caused by omitted variables or incorrect functional form. The Durbin-*H* calculated for the supply equation which contains a lagged endogenous variable is 1.423; when compared to the critical value of 1.645 (normal 0,1 distribution for a one-tailed test at the 5% level of significance), this supports the conclusion of an absence of serial correlation.

All coefficients in both the supply and demand equations have the anticipated signs. Each coefficient in the supply equation, except for the constant and $SFEE_{t-2}$, is significant at a level of 1%. The lack of significance in $SFEE_{t-2}$ may stem from problems with the original data which calculated the average stud fee based on the advertised price. In many cases, the actual stud fee paid is negotiated to a rate lower than the advertised fee. Also, stud fees are set relative to the strength of the yearling market and the quality of the stallion. Breeders historically have been willing to pay higher stud fees in times when the market was expanding.[9] Stud fee is assumed to be an important variable in breeding decisions and is left in the model despite its lack of significance.

Alternative specifications analyzing the lag structure of the supply model were estimated. A distributed lag specification for the lagged endogenous variable of $RFOAL_{t-2}$ and $RFOAL_{t-3}$, and alternative lags in the price response in addition to P_{t-2}, were estimated. Empirically these models did not perform well.

Variables EXR_t and NR_t in the demand equation are statistically insignificant, but have the correct sign. All other estimated demand coefficients are significant at the 1% level, with the exception of $GGDP_t$, which is significant at the 10% level. In considering the insignificance of EXR_t, only 1.8% of the number of yearlings auctioned are purchased by foreign buyers. Typically, these buyers have a relatively inelastic demand for a limited number of yearlings with specific pedigrees sold for high prices at select sales. Given the low number of foreign-purchased yearlings and the demand characteristics of foreign buyers, EXR_t was not found to significantly impact average yearling price. However, the importance to the market of foreign purchases is evidenced by the high significance in GFP_t. When foreign buyers are active in the market, it increases competition and the pool of money available for yearling investment. If, for example, a domestic investor loses the bid on a yearling to a foreign buyer, the domestic investor is likely to bid on a subsequent yearling in the sale, thus bolstering the overall market. Based on theoretical and empirical considerations, both GFP_t and EXR_t were retained in the model.[10]

The number of live races (NR_t) was a concern of the industry when simulcasting expanded greatly in the late 1980s. It was widely believed that simulcasting would negatively impact the industry by decreasing NR_t, which in turn would depress the demand for thoroughbred yearlings. The lack of significance for NR_t indicates that the market does not significantly recognize variation in the number of live races as a threat or an incentive to the earning potential of thoroughbred yearling investments. In sum, the model specification estimated in this analysis appears valid based on statistical and economic merits.

Supply and Demand Parameter Elasticities

The supply elasticities and price flexibilities presented in table 3 provide an indication of the price responsiveness and market characteristics of thoroughbred yearlings. The price elasticity of supply calculated at the mean is 0.116, indicating an inelastic supply response. Given the biological constraints, lack of alter-

[9] The correlation between $SFEE_{t-2}$ and P_{t-2} was tested for problems of multicollinearity. The variables are not significantly correlated (0.112 with a p-value of 0.511).

[10] Alternative demand models were estimated by dropping GFP_t or EXR_t from the demand model to evaluate potential multicollinearity between these two variables. When GFP_t was dropped, EXR_t remained insignificant. When EXR_t was dropped, the estimated coefficient and the significance level of GFP_t did not change. The variables are significantly negatively correlated (−0.601 with a p-value of 0.031).

Table 3. Short-Run Supply Elasticities and Demand Flexibilities at the Mean

Supply ($RFOAL_t$)		Demand (P_t)	
Variable	Elasticity	Variable	Flexibility
$RFOAL_{t-1}$	0.859	YRL_t	−0.426
P_{t-2}	0.116	YTB_t	0.536
MTB_{t-2}	0.262	$PRSE_t$	2.606
FCI_{t-2}	−0.200	GFP_t	0.520
$SFEE_{t-2}$	−0.019*	EXR_t	−0.015*
		$GGDP_t$	0.098
		NR_t	0.242*

* The estimated value is not significantly different than zero.

native uses, and the long life of broodmares, the high asset fixity associated with breeding thoroughbred mares, and the nature of investment in the industry, an inelastic supply response is expected. A comparison of estimated supply elasticities of registered foals across studies cannot be completed due to the lack of comparable studies. In comparison to other livestock species with similar biological lags in production, the supply of registered foals is more inelastic than the supply elasticity of dairy heifers with respect to milk price, 0.28 (Chavas and Klemme), and the supply elasticity of beef cow replacement heifers with respect to calf price, 0.35 (Foster and Burt).

Price flexibilities calculated from the inverse demand function identify an inflexible price structure for all price-determining variables with the exception of $PRSE_t$, which has a price flexibility of 2.606. The thoroughbred yearling price flexibility coefficient with respect to purses estimated by Karungu, Reed, and Tvedt is 1.28. Buzby and Jessup did not include purses as a determinant of yearling price. The difference in magnitude between the two price flexibility estimates is likely due to the difference in sales data. Karungu, Reed, and Tvedt used select sale prices and considered purses only at one Kentucky race track. Select sales may be considered breeding stock sales for yearlings with the most fashionable pedigrees. By expanding the data to North American sales, a greater quality range is encountered where the primary use of a yearling is for racing. This accounts for the difference in magnitude between the estimated price flexibility coefficients.

The price-quantity flexibility coefficient of −0.426 for YRL_t indicates that, as the supply of registered foals increases, the breeding sector's marginal revenue will be positive ceteris paribus, because the revenue gained from selling more foals is larger than the revenue lost from the price decrease associated with the expanded supply. The inverse of the price flexibility is a good approximation of the elasticity when the price elasticities of substitutes approach zero (Chen and Dharmaratne). This results in a price elasticity of thoroughbred yearling demand of approximately −2.347 (1/−0.426), which is highly elastic. The combination of inelastic supply and elastic demand forces market adjustments to occur primarily as price changes.

A comparison of the elasticity and flexibility coefficients within each model identifies the relative importance of each variable's impact on $RFOAL_t$ and P_t, respectively. As characteristic of an industry with a long adjustment process, the variable with the greatest impact on $RFOAL_t$ is the lagged endogenous variable, $RFOAL_{t-1}$, followed by MTB_{t-2}. The variable exerting the greatest overall impact on yearling price determination is $PRSE_t$. For each 1% change in $PRSE_t$, P_t changes 2.606%; this, in turn, would change $RFOAL_t$ by 0.302%, given a time lag of two years. All other demand variable flexibilities are less than one, with YTB_t, GFP_t, and YRL_t having flexibilities of approximately 0.50.

Equilibrium Condition

A recursive system of equations has three potential intertemporal adjustment processes to endogenous changes in price or supply. If the slope of the supply response to a change in price is greater than the slope of the price response to a change in supply, the system converges to equilibrium in the absence of exogenous shocks. If the slopes are equal, the system oscillates continuously. If the slope of the supply response to a change in price is less than the slope of a price response to a change in supply, the system diverges from equilib-

Table 4. Long-Run Comparative Statics

Long-Run Supply (*RFOAL*) Comparative Statics			Long-Run Demand (*P*) Comparative Statics		
Comparative Static	Supply Response[a]	Long-Run Elasticity[b]	Comparative Static	Price Response[a]	Long-Run Flexibility[b]
$\frac{\partial RFOAL}{\partial RPSE}$	4.673	1.734	$\frac{\partial P}{\partial PRSE}$	5.591	1.854
$\frac{\partial RFOAL}{\partial MTB}$	20.761	1.495	$\frac{\partial P}{\partial MTB}$	−10.082	−0.649
$\frac{\partial RFOAL}{\partial YTB}$	3.924	0.357	$\frac{\partial P}{\partial YTB}$	4.695	0.381
$\frac{\partial RFOAL}{\partial FCI}$	−39.351	−0.912	$\frac{\partial P}{\partial FCI}$	19.076	0.395
$\frac{\partial RFOAL}{\partial SFEE}$	−1.763	−0.108[c]	$\frac{\partial P}{\partial SFEE}$	0.856	0.047[c]
$\frac{\partial RFOAL}{\partial GFP}$	1.260E−4	0.346	$\frac{\partial P}{\partial GFP}$	1.510E−4	0.370
$\frac{\partial RFOAL}{\partial EXR}$	−1.474	−0.010[c]	$\frac{\partial P}{\partial EXR}$	−1.764	−0.010[c]
$\frac{\partial RFOAL}{\partial GGDP}$	6.263	0.065	$\frac{\partial P}{\partial GGDP}$	7.493	0.070
$\frac{\partial RFOAL}{\partial NR}$	0.084	0.162[c]	$\frac{\partial P}{\partial NR}$	0.100	0.173[c]

[a] The result is the evaluation of the comparative static using the estimated coefficients from the supply and demand equations.
[b] Elasticity and flexibility estimates are calculated at the mean.
[c] Estimated coefficient is not significant.

rium. The equilibrium condition is represented in equation (4), which indicates that the thoroughbred yearling market would converge to equilibrium in the absence of exogenous shocks $\{|1/0.104| > |-0.486|\}$:

$$(4)\qquad \left|\frac{1}{\frac{\partial RFOAL_t}{\partial P_{t-2}}}\right| > \left|\frac{\partial P_t}{\partial YRL_t}\right| = \left|\frac{1}{\alpha_2}\right| > |\beta_1|.$$

Long-Run Comparative Statics

The above model can be used to analyze economic adjustments of the thoroughbred yearling market over time by evaluating long-run elasticities and/or by simulating market adjustments in response to exogenous shocks. The derivation of the final form of the model by substituting the supply model, equation (1), into equation (3) takes into account the interaction of supply and demand simultaneously. If a disequilibrating change occurs in the form of a variation in an exogenous variable, the initial equilibrium will be upset. Endogenous variables (*RFOAL* and *P*) adjust relative to the new value of the exogenous variable, plus the recursive adjustments between *RFOAL* and *P* until long-run equilibrium is reached. The long-run supply elasticities and price flexibilities are presented in table 4. The long-run supply coefficients are greater in magnitude than the short-run coefficients, reflecting the greater ability of the market to adjust over time. The long-run price flexibilities are lower in magnitude than the short-run flexibilities, reflecting the feedback effects from the supply side of the market.

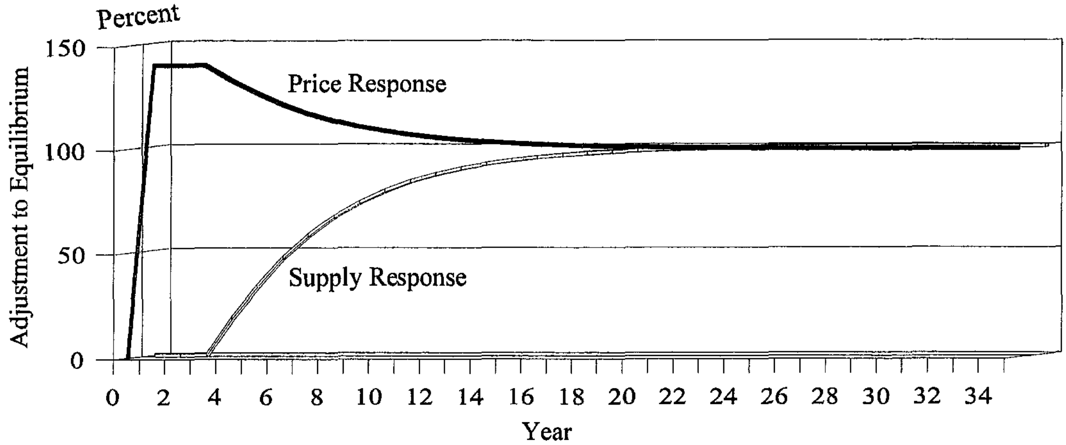


Figure 2. Time path of adjustment in response to a 10% increase in average purses

Variables with a long-run elastic response on *RFOAL* are *PRSE* and *MTB*, with long-run elasticities of 1.734 and 1.495, respectively. Adjustments in *RFOAL* in response to exogenous shocks originate from adjusting the size of the breeding herd. Changing the size of the breeding herd is a prolonged process due to the biological lags in production, constraints associated with asset fixity, and thoroughbred registration requirements that prohibit the use of artificial insemination and embryo transfer technology. The only variable with a long-run price flexibility response greater than 1.0 is *PRSE*, with a long-run flexibility of 1.854. This is a decrease from the short-run flexibility coefficient of 2.606, reflecting the feedback effects from supply adjustments in the market. In the short run, price can respond without any supply interaction because of the two-year biological lag in production.

The long-run adjustment in *RFOAL* is relatively small. This indicates that growth in the breeding industry is limited. The magnitude of the supply and price responses is a weighted combination of the size of the change in the exogenous variable, the relative importance of the exogenous variable to the market, the supply response to yearling price, and the yearling price response to supply. The high degree of inelasticity of thoroughbred yearling supply in combination with the inelastic nature of each of the supply model variables contributes to a long aggregate supply adjustment process.

Dynamic Adjustment to Equilibrium in Response to a Change in Purses

Purses were identified as the most influential variable in the thoroughbred yearling market. Purses cause the greatest magnitude of adjustment in both the average yearling price and the supply of registered foals. By generating positive economic incentives for all of its sectors, purses are potentially the most efficient policy instrument available to the thoroughbred industry. Purses have been used as a policy instrument for state breeder incentive programs. They also are used by tracks as an incentive for owners to improve the quality and number of horses running at their meet. An increase in purses has been shown to improve wagering (Ali and Thalheimer; Thalheimer and Ali 1995a, b, c).

Figure 2 illustrates the dynamic adjustment toward equilibrium of a 10% increase in $PRSE_t$ from its 1994 inflation-adjusted level of $10,910 to $12,001. The purse level is increased in year 1, and is held constant at $12,001 throughout the simulation. Holding all exogenous variables constant at their 1994 levels and allowing endogenous variables $RFOAL_t$ and P_t to respond iteratively results in an initial equilibrium foal crop of 28,997, and an average yearling price of $33,179. Average yearling price (P_t) responds immediately to the purse increase, and due to the lack of immediate supply response, P_t adjusts to 141%

Table 5. Dynamic Adjustment to a 10% Increase in Average Purses

Year	Change in Supply of Foals (No.)	Cumulative % Adjustment to Final Equilibrium	Change in Yearling Price ($1994)	Cumulative % Adjustment to Final Equilibrium
1	0	0.0	8,575	140.6
2	0	0.0	0	140.6
3	892	17.5	0	140.6
4	781	32.8	−433	133.5
5	684	46.2	−379	127.3
6–10	1,862	82.8	−1,127	108.8
11–15	598	94.5	−365	102.8
16–35	281	100.0	−171	100.0
Total	5,098		6,100	

of the long-run equilibrium and then declines slowly as *RFOAL* increases in response to the increase in P_t. By year 10, P_t has adjusted to 108.8% of long-run equilibrium, and 102.8% of the adjustment to long-run equilibrium is attained by year 15. In response to the 10% purse increase, the long-run equilibrium level of P_t increases from its initial level of $33,179 by $6,100, to result in a long-run equilibrium of $39,279.

Due to the biological lags of yearling production, $RFOAL_t$ remains at the initial equilibrium level for two years as breeders respond to the new levels of P_t. A rapid growth in $RFOAL_t$ occurs from years 3 to 10, and accounts for 82.8% of the adjustment to long-run equilibrium. Over 94% of the long-run adjustment is attained by year 15. Table 5 shows that in response to the 10% purse increase, *RFOAL* increases from its initial level of 28,997 by 5,098, to result in a long-run equilibrium of 34,095.

Table 5 illustrates the expected rapid yearling price adjustment in response to a 10% increase in the average purse per race. In this example, it takes five years to attain 46% of the long-run adjustment, and an additional 10 years to attain 94% of the long-run adjustment in the supply of foals in response to the purse increase initiated in year 1.

These results illustrate the rapid price adjustment in response to purses and the opportunity for breeders to increase marginal revenue by increasing supply. But perhaps more importantly, the slow growth in $RFOAL_t$ will result in limited growth in services demanded and supplied by the breeding sector. From the racing sector's perspective, the slow growth in $RFOAL_t$ will not alleviate the problem facing some race tracks of not having an adequate supply of horses to maintain field size.[11] While other factors are sure to impact the industry over this time horizon, the comparative statics illustrate the effect of purses on the industry and their effectiveness as a policy instrument.

The adjustments to long-run equilibrium in *RFOAL* and *P* correspond to the response predicted by the comparative static results previously reported in table 4. For each dollar increase in *PRSE*, the comparative statics predicted a long-run increase of 4.673 and $5.591 in *RFOAL* and *P*, respectively. The purse increase of $1,091 would then result in an increase in long-run equilibrium of 5,098 in *RFOAL* (a 17.6% increase over initial equilibrium), and an increase in *P* of $6,100 (an increase of 18.4% over initial equilibrium).

The Impact of Federal Tax Policy on the Market

The Tax Reform Act of 1986 was a comprehensive overhaul of the federal income tax system. The act significantly changed incentives for investing by substantially reducing

[11] Field size is the number of horses in an individual race.

Table 6. Estimated Impact of Federal Tax Policy on the Thoroughbred Market, 1985–94

Year	Estimated Change in P_t	Change in YTB_t	Impact on P_t Due to YTB_t	Estimated Change in $RFOAL_t$	Change in MTB_{t-2}	Impact on $RFOAL$ Due to MTB_{t-2}
1985	−6,605	141	927	1,185	91	331
1986	−15,393	−324	−2,136	864	126	458
1987	2,006	−763	−5,034	−376	108	392
1988	−3,479	31	204	−1,701	−60	−218
1989	−3,078	147	971	−1,020	−648	−2,357
1990	−2,661	172	1,138	−4,103	−115	−418
1991	−6,364	143	941	−2,294	118	430
1992	−3,755	210	1,384	−3,542	139	504
1993	−571	110	725	−1,657	115	417
1994	2,182	100	659	−1,900	169	612

marginal income tax rates, and it broadened the tax base by eliminating many of the exclusions, deductions, and credits introduced into the tax code over the years. The key elements of the Tax Reform Act of 1986 affecting the thoroughbred market included reduced marginal tax rates, changed depreciation schedules, the elimination of capital gains, and the reduced ability to write off passive losses. The Tax Reform Act of 1986 is cited by many thoroughbred market analysts as contributing to the rapid decline in yearling price from 1986 to 1992 (Karungu, Reed, and Tvedt; Buzby and Jessup).

Federal tax policy is important to the thoroughbred market, because taxes affect both the marginal cost of breeding decisions and the marginal revenue of yearling investment decisions. Taxes are second in importance to purses when evaluating market-impacting variables. The long-run elasticity of *MTB* and *YTB* on *RFOAL* is 1.495 and 0.357, respectively (table 4). The long-run flexibility of *MTB* and *YTB* on *P* is −0.649 and 0.381, respectively.

Table 6 identifies the estimated impact to the thoroughbred market of the Tax Reform Act of 1986 through YTB_t and MTB_{t-2}. Table 6 indicates that the Tax Reform Act of 1986 had substantial impacts on P_t and $RFOAL_t$. An initial impact of the Tax Reform Act of 1986 on P_t was −$2,136 in 1986, while a negative impact of −$5,034 was estimated for 1987. A significant decrease in $RFOAL_t$ from the change in MTB_{t-2} was not felt until 1989 and 1990 due to the biological lags of production.

Conclusions

This study analyzed factors impacting price determination in the thoroughbred yearling market in North America. Yearling prices can be used as an indicator of horse values and the breeding sector's financial condition. Given the lagged time response associated with producing a yearling from the production decision to breed a mare to the date of sale, a recursive model specification was applied to the yearling market. This resulted in estimating a dynamic supply of registered foals equation, and an inverse demand equation of average yearling price. Model results indicate that the market structure for thoroughbred yearlings is characterized by inelastic supply and elastic demand with market adjustments occurring primarily as price changes. The supply of registered foals is found to have a more inelastic supply structure than livestock commodities with comparable biological production lags. This is primarily due to the asset fixity associated with thoroughbred investments and the willingness of many yearling breeders and buyers to subsidize their yearling investments through periods of nonprofitability.

Under static conditions, the model converges to an equilibrium. Yearling prices respond immediately to exogenous shocks, but the supply of foals has a prolonged adjustment process. In response to a change in average purses, average yearling price increases immediately to 141% of its equilibrium value, while supply response takes five years to achieve 46% of the equilibrium adjustment, and by the end of 10 years, 83% of the equilibrium adjustment occurs. It takes approximately 35 years to achieve full equilibrium supply adjustment from a change in purse levels. This market structure creates the opportunity for yearling breeders and buyers with predictive foresight on industry trends to take advantage of market fluctuations, due to immediate price response and a prolonged supply adjustment process. The inelastic supply structure for both short- and long-run outlooks indicates there will be limited growth in services demanded and supplied by the breeding sector. But perhaps more importantly, the resulting slow growth in the supply of foals reflects the need for long-term planning when considering policy factors, such as purses, which may be changed immediately through policy decisions.

The potential impacts to breeders and buyers from an evolving thoroughbred market are directly linked to trends in purses. Purses are currently increasing primarily from the expansion in simulcasting, and in some racing jurisdictions through the subsidization of purses from alternative gaming revenues. Recently, gross purses have been increasing slightly, but due to the declining number of live races, the average purse per race has been increasing between 5% and 10% per year. Purses are important to the industry because they create an elastic response in both the short and long run and for both the supply of foals and average yearling price. This indicates that policies targeting purse augmentation will be of the greatest benefit to the industry.

The decline in the number of live races is not viewed in the market as a statistically significant variable. The decline in live races is matched with a decline in the supply of foals, so the opportunity for yearling buyers to run their horses in races has not been constrained. The average field size has not changed appreciably from 8.95 at the start of the study period in 1960 to 8.31 at the end of the study period in 1994. The level of growth in field size ties all sectors of the industry together in a slow growth cycle. Field size determines the number of betting combinations available in a race. As field size increases, "handle," or the amount bet per race, is likely to increase. When handle increases, the potential payoff to winning bettors, purses, and track revenues also increase. However, due to the inelastic nature of supply, field size will be slow to increase, and some race tracks will continue to have difficulty maintaining the field size of their races, perpetuating a slow growth cycle in the industry.

The role of taxes is important for both buyers and breeders. As tax benefits increase, buyers are willing to pay more for yearlings, and breeders are willing to supply more yearlings. Foreign purchases were found in this study to have a significant but inelastic impact on yearling price, indicating that on a national basis, the relative importance of foreign purchases is secondary in importance to domestic policies affecting purses and taxes.

The model specification for this study was limited to the yearling market. Much work remains to be done in the analysis of the thoroughbred market. The segregation of the market into quality groups would add to the precision and usefulness of the results. The expansion of the yearling market model into an industry-level model that directly incorporates the impacts of competition from alternative gaming and its flow-through effect on purses and the thoroughbred yearling market would be useful in the policy arena. Research is also needed to identify the exact relationships between simulcasting, its impact on live racing opportunities, and its impact on purses. Finally, the regionalization of market analysis is needed to develop industry information based on local conditions facing the thoroughbred industry.

References

Ali, M.M., and R. Thalheimer. "Transportation Costs and Product Demand: Wagering on Parimutuel Horse Racing." *Appl. Econ.* 29(1997): 529–42.

The Blood-Horse. *Annual Auction Review.* Lexington KY: The Blood-Horse, Inc. Various issues, 1960–94.

———. *Annual Stallion Register.* Lexington KY: The Blood-Horse, Inc. Various issues, 1960–94.

Buzby, J.C., and E.L. Jessup. "The Relative Impact of Macroeconomic and Yearling-Specific Variables in Determining Thoroughbred Yearling Price." *Appl. Econ.* 26(1994):1–8.

Chavas, J.P., and R. Klemme. "Aggregate Milk Supply Response and Investment Behavior on U.S. Dairy Farms." *Amer. J. Agr. Econ.* 68(1986):55–66.

Chen, D.T., and G.S. Dharmaratne. "Farm Price Response to Supply Shocks: A Comparison of Alternative Inverse Demand Structural Models." *Rev. Agr. Econ.* 18(1996):137–46.

Christiansen, E.M., and W.E. Cummings. "The United States 1994 Gross Annual Wager." *Internat. Gaming and Wagering Bus.* (1 August 1996):55–94.

Citibase Macroeconomic Database. Dexter MI: FAME Information Services, 1994.

Commerce Clearing House, Inc., Tax Law Editors. *Standard Federal Tax Reports: 1993 Depreciation Guide.* Chicago IL: Commerce Clearing House, Inc., 1993.

Ezekiel, M. "The Cobweb Theorem." *Quart. J. Econ.* 52(1938):225–80.

Foster, K.A., and O.R. Burt. "A Dynamic Model of Investment in the U.S. Beef-Cattle Industry." *J. Bus. and Econ. Statis.* 11(1992):419–26.

Gulley, O.D., and F.A. Scott. "Lottery Effects on Parimutuel Tax Revenues." *National Tax J.* 42(1989):89–93.

Hall, R., and D. Jorgenson. "Tax Policy and Investment Behavior." *Amer. Econ. Rev.* 57(1967):391–414.

Hollingsworth, K. "More for Less." *Annual Auction Review, 1984.* Lexington KY: The Blood-Horse, Inc., 1984.

Irwin, S.H., and C.S. Thraen. "Rational Expectations in Agriculture? A Review of the Issues and the Evidence." *Rev. Agr. Econ.* 16(1994): 133–58.

The Jockey Club. *1995 Fact Book: A Guide to the Thoroughbred Industry in North America.* New York: The Jockey Club, 1995.

Karungu, P., M. Reed, and D. Tvedt. "Macroeconomic Factors and the Thoroughbred Industry." *J. Agr. and Appl. Econ.* 25(1993):165–73.

Lawrence, R.G. "All About Purses." *Thoroughbred Times.* Various issues.

———. "An Econometric Analysis of Changes in Quarter Horse Prices, 1950 Through 1967." Unpub. Ph.D. dissertation, Texas A&M University, College Station, 1968.

Marfels, C. "Casino Gaming." *The Structure of American Industry,* eds., W. Adams and J. Brock. Englewood Cliffs NJ: Prentice-Hall, Inc., 1995.

Pindyck, R.S., and D.L. Rubinfeld. *Economic Models and Economic Forecasts,* 3rd ed. New York: McGraw-Hill, Inc., 1991.

Rosen, S. "Dynamic Animal Economics." *Amer. J. Agr. Econ.* 69(1987):547–57.

Rosen, S., K.M. Murphy, and J.A. Scheinkman. "Cattle Cycles." *J. Polit. Econ.* 102(1994): 468–92.

Simmons, S.A., and R. Sharp. "State Lotteries' Effects on Thoroughbred Horse Racing." *J. Policy Analysis and Manage.* 6(1987):446–48.

Stein, J.L. "Cobwebs, Rational Expectations, and Futures Markets." *Rev. Econ. and Statis.* 74(1992):127–34.

Thalheimer, R., and M.M. Ali. "The Demand for Parimutuel Horse Race Wagering and Attendance." *Manage. Sci.* 41(1995a):129–43.

———. "Exotic Betting Opportunities, Pricing Policies, and the Demand for Parimutuel Horse Race Wagering." *Appl. Econ.* 27(1995b):689–703.

———. "Intertrack Wagering and the Demand for Parimutuel Horse Racing." *J. Econ. and Bus.* 74(1995c):369–83.

U.S. Department of Agriculture, Statistical Reporting Service. *Agricultural Statistics.* Washington DC: Government Printing Office. Various issues, 1960–94.

Whipple, G.D., and D.J. Menkhaus. "Supply Response in the U.S. Sheep Industry." *Amer. J. Agr. Econ.* 71(1989):126–35.

Appendix

Table A1. Summary Statistics of Variables in Model System, 1960–94

Variable	Mean	Median	Std. Dev.	Minimum	Maximum
$RFOAL_t$	32,059	30,636	12,009	12,901	51,293
$RFOAL_{t-1}$	31,417	28,809	12,455	12,240	51,293
P_t	35,882	31,857	11,089	24,383	65,015
P_{t-2}	35,923	31,587	11,051	24,383	65,015
NR_t	61,759	68,822	13,314	37,661	82,726
FCI_{t-2}	743	671	353	335	1,244
YTB_t	2,915	3,016	914	1,630	4,569
MTB_{t-2}	2,308	2,424	711	1,401	3,732
$SFEE_{t-2}$	1,973	2,021	635	1,662	3,705
$PRSE_t$	11,899	11,957	699	10,482	13,031
GFP_t	87,950,627	86,911,825	47,887,797	22,361,185	182,238,233
EXR_t	212	212	50	130	281
$GGDP_t$	335	331	127	91	588

Notes: All monetary data have been deflated by the consumer price index, where 1994 = 100. GFP_t summary statistics are calculated using nonzero data from 1973–94.