



**AgEcon** SEARCH  
RESEARCH IN AGRICULTURAL & APPLIED ECONOMICS

*The World's Largest Open Access Agricultural & Applied Economics Digital Library*

**This document is discoverable and free to researchers across the globe due to the work of AgEcon Search.**

**Help ensure our sustainability.**

Give to AgEcon Search

AgEcon Search

<http://ageconsearch.umn.edu>

[aesearch@umn.edu](mailto:aesearch@umn.edu)

*Papers downloaded from **AgEcon Search** may be used for non-commercial purposes and personal study only. No other use, including posting to another Internet site, is permitted without permission from the copyright owner (not AgEcon Search), or as allowed under the provisions of Fair Use, U.S. Copyright Act, Title 17 U.S.C.*

*No endorsement of AgEcon Search or its fundraising activities by the author(s) of the following work or their employer(s) is intended or implied.*

## **Quarter Horse Supply and Demand: Welfare Analysis and Impacts of the Equine Processing Ban**

Mallory K. Vestal, M.S.  
Oklahoma State University  
Ag Hall 556  
Stillwater, Oklahoma 74078  
[mallory.vestal@okstate.edu](mailto:mallory.vestal@okstate.edu)  
806-367-1716

Jayson L. Lusk, Ph.D.  
Oklahoma State University  
[jayson.lusk@okstate.edu](mailto:jayson.lusk@okstate.edu)

Eric A. DeVuyst, Ph.D.  
Oklahoma State University  
[eric.devuyst@okstate.edu](mailto:eric.devuyst@okstate.edu)

Steven R. Cooper, Ph.D.  
Oklahoma State University  
[steven.cooper@okstate.edu](mailto:steven.cooper@okstate.edu)

Clement E. Ward, Ph.D.  
Oklahoma State University  
[clement.ward@okstate.edu](mailto:clement.ward@okstate.edu)

*Selected Paper prepared for presentation at the Agricultural & Applied Economics Association's 2012 AAEA Annual Meeting, Seattle, Washington, August 12-14, 2012*

*Copyright 2012 by Mallory K. Vestal, Jayson L. Lusk, Eric A. DeVuyst, Steven R. Cooper, and Clement E. Ward. All rights reserved. Readers may make verbatim copies of this document for non-commercial purposes by any means, provided that the copyright notice appears*

## **Abstract**

Despite the existence of over 2.5 million Quarter Horses in the U.S., there has heretofore been little information available on the structural parameters underpinning the Quarter Horse market. In this paper, we compiled a unique data set, merging together information on registrations from the American Quarter Horse Association and price data from a large regional horse auction. The data is used to estimate the supply of yearling Quarter Horses using biological production lags to identify the key structural parameters; we find an own-price elasticity of short- and long-run supply of 0.32 and 0.27. An inverse demand function is also estimated, and after accounting for endogeneity, we find a price flexibility of own-price yearling demand of -0.71. Results reveal that demand shifted inward following the horse processing ban, resulting in deadweight annual losses of over \$4 million in the yearling Quarter Horse market.

**Keywords:** *horse, harvesting, supply, demand, elasticity*

The American Quarter Horse Association (AQHA) has over 3 million horses registered worldwide. Of the 3 million Quarter Horses, 2.6 million are in the United States (U.S.). Further, Texas and Oklahoma are the top two states populated with Quarter Horses with 440,872 and 179,458, respectively (American Quarter Horse Association 2011). In 2011, over 91,000 Quarter Horses were registered, the next largest registration being Thoroughbreds at 27,000 (The Jockey Club 2012). These statistics quite convincingly demonstrate that the U.S. horse population is dominated by Quarter Horses. Economically speaking, the U.S. equine industry, as a whole, provides 1.4 million jobs and over \$39 billion directly to the economy (Deloitte Consulting 2005; Lenz 2009). The total impact on the U.S. Gross Domestic Product, including direct, indirect, and induced effects is estimated at \$101.5 billion (Deloitte Consulting 2005). Despite the industry providing billions to the U.S. economy, we know relatively little about it outside of a few hedonic studies.

In 1998, Lansford et al. focused specifically on yearling Quarter Horses in the race-horse industry applying hedonic theory to assess the price determinants. Maynard and Stoeppel (2007) and Neibergs (2001) conducted hedonic price analyses of Thoroughbred broodmares. Taylor et al. (2006) examined the price determinants of show quality Quarter Horses sold at auction while Lange et al. (2010) conducted a hedonic price analysis to study the 'lower end' segment of the horse industry by examining recreational and pleasure horses sold online. Although hedonic analysis provides insight and perspective into the price determinants of horses, it provides little information as to the structural parameters surrounding the industry.

Economic research, outside of hedonic price analysis, is very limited. In perhaps the only study estimating underlying structural parameters, Neibergs and Thalheimer (1997) estimated supply and demand functions associated with the Thoroughbred yearling market. By implementing a recursive model incorporating price expectations and biological constraints both supply and demand functions were estimated. The resulting model of Neibergs and Thalheimer support the conclusion that macroeconomic conditions along with production costs have an impact on the supply of Thoroughbred yearlings while expectations regarding return on investment is relevant to demand. Overall, their empirical estimates defined a market of inelastic supply and elastic demand that converges to equilibrium under static conditions.

With the recent legislation and court decisions halting the processing of horses for human consumption, the economic feasibility of the equine industry is at risk and merits economic evaluation. In 2007, the total U.S. horse population was estimated at 9.2 million, and in 2006 almost 105,000 horses were processed for human consumption (Cowan 2010). Due to the U.S. view of horses as a companion rather than a food animal, the demand for the meat lies abroad. In 2007, the three primary horse processing facilities (Beltex Corporation, Texas, Dallas Crown, Inc., Texas, and Cavel International, Inc., Illinois), ceased operation due to the passage of state regulations and court decisions (Cowan 2010). Although Texas and Illinois have state laws preventing processing, other states could not operate processing facilities due to the 2006 congressional decision to defund the inspection of processing facilities. Without the inspections, the meat could not be sold, therefore the processing was exported.

Following the closure of domestic processing facilities, an increasing number of horses intended for processing were transported to Mexican or Canadian processing facilities (Dinan 2011). In 2005, a little more than 11,000 horses were exported to Mexico for processing, this figure jumped to over 50,000 by 2008 (Simon 2011). In 2007, 58,000 horses were processed for meat in the United States (prior to closure in September 2007), 35,000 horses were exported to Canada for processing, and 45,000 were exported to Mexico for processing (Lenz 2009). In November of 2011, U.S. President Obama signed into law a bill which restored the possibility of U.S. horse processing. The agriculture spending bill dropped the prohibition on inspections and, should a domestic plant be opened, the meat would be fully inspected. However, to date, a domestic plant has not been opened, and horses intended for processing continue to be transported to Mexico or Canada (Dinan 2011). The result of the legal actions is the unwanted horse (Dawson 2008). Abandonment is alarmingly common likely due to the loss of buyers for slaughter horses. Prior to the ban, horses had a salvage value. The owners now face large disposal costs.

To date, relatively little economic analysis has been conducted regarding the impacts of the processing ban. To our knowledge, two studies have been conducted. In 2010, the Government Accountability Office (GAO) submitted a Report to Congressional Committees on Horse Welfare and in 2011, Vestal et al. (2012) conducted a hedonic analysis assessing the impacts of the processing ban on horse prices in Oklahoma. Both studies relied on hedonic analyses, and found prices fell from 5-44% after the ban, a finding consistent with the argument that closure of harvesting plants reduced the demand for horses. Due to the fact that there are no published estimates of supply and demand

parameters for this market it is unfeasible to evaluate the effects of a policy of this nature outside of hedonic analysis.

The primary objective of this research is to determine the structural parameters associated with the supply and demand for Quarter Horse yearlings. Another key objective of the research is to determine the extent to which demand for yearling Quarter Horses has been affected by the processing ban, and to determine the welfare impacts resulting from the halt in domestic horse processing. We contribute to the literature in two important ways. First, as previously mentioned only one other study analyzes the structure of supply and demand in the equine industry, but this study only focused on the Thoroughbred industry. This paper analyzes supply and demand for registered Quarter Horses, which is the largest breed registry of horses in the United States. Second, and perhaps more importantly, unlike previous work studying the effects of the horse processing ban, which relied on hedonic analyses to infer the effects, we use our estimated structural parameters to determine the welfare effects of the policy.

The next section presents a brief conceptual background. This section is followed by sections specifying the empirical models, data, and results.

## **Conceptual Background**

### *Yearling Supply*

Agricultural producers make production and breeding decisions given current and expected future market conditions (Rosen 1987). The dynamics of supply in these sectors results from producer expectations about the future along with biological production lags (Brester and Marsh 1983).

In terms of price expectations, it is argued that if more specific information is not available regarding future prices, it seems reasonable to assume that the price expected to prevail at some future date depends on what prices have been in the past or are at the time of production decisions (Nerlove 1956). The simplest approach, the use of lagged price, is based on theory that producers use naïve expectations, where next period's price is equivalent to today's price. Employing the assumption that current price at the time of the breeding decision is equivalent to expected price of the output at the time of sale is appropriate for supply analysis as the price expected by producers at the time when production decisions are being made, is the applicable variable (Gardner 1976).

When the goal is to determine both short-and long-run elasticities, Nerlove argued that supply estimation without using distributed lags can severely bias short- and long-run elasticities. Whenever it takes time for producers to adjust to changed conditions and whenever the period required for full adjustment exceeds the interval of observation, then statistical relationships among observation on the relevant variables tell us little about the long-run elasticity or any of the short-run elasticities. In the shortest of all short-runs most factors of production are fixed while, as time passes, more of these restrictions are removed. Short-run elasticities of supply for an individual firm are always less than or equal to the long-run elasticity. Since the long-run equilibrium output quantity cannot be observed, the estimation of long-run estimates require the incorporation of the lagged dependent variable. Therefore the long-run price elasticity of supply may be obtained by dividing the coefficient of price by one minus the coefficient of lagged quantity (Nerlove 1958).

Within the horse production function, the decision to breed a Quarter Horse mare is between breeding and producing a foal or maintaining the mare without breeding for use in a future decision to breed and produce a foal (Neibergs and Thalheimer 1997). The economic decision is therefore dependent upon the costs associated with the production of a foal, and the expected price garnered after the foal is sold as a yearling. Due to the 11 month gestation of horses, the yearling supply resulting in the marketplace is based on these historical, (approximately two years prior) breeding decisions. The primary market for Thoroughbreds is yearling auctions (Neibergs and Thalheimer 1997). The yearling market is the most significant source of revenue to breeders and depends on buyer's expectations of Thoroughbred racing (Neibergs and Thalheimer 1997). Within the general Quarter Horse market, different buyers purchase horses at different ages dependent upon the intended use of the horse. Buyers looking to compete in age-based three-year-old futurities can either purchase a yearling at a lower price with greater risk associated, or a more developed two-year-old with a few months of training at a higher price. To some buyers there lies an advantage with a yearling purchase over a two year old, as the training is moderately less and the yearling can be trained in the preferred manner of the buyer. Other buyers see the associated risk and opt for the two-year-old purchase. For buyers looking to compete in two-year-old events, the yearling market is clearly targeted. This being said the analysis of either the yearling or two-year-old Quarter Horse market is valid, as long as the appropriate lags are applied to the model.

Consider a profit maximizing horse breeder participating in a competitive industry. The indirect profit function,  $\pi$ , for a horse breeder is defined as

$$(1) \quad \pi_t(y_t, \mathbf{w}_t) = \max_{q_{t+2}, x} (y_t q_{t+2} - \mathbf{w}_t \mathbf{x})$$

$$\text{s.t. } q = q(\mathbf{x})$$

where  $y_t$  is the expected yearling price that will be obtained when the breeding decision ultimately materializes into sellable yearlings,  $q_{t+2}$  quantity of yearlings ultimately produced which reach the market two periods later,  $\mathbf{w}_t$  is a m-dimensional current price vector of inputs,  $\mathbf{x}$ , in time,  $t$ , and  $q(\mathbf{x})$  is the yearling production function. The supply of function of yearlings is determined via Hotelling's lemma by differentiating (1) with respect to the output price:

$$(2) \quad q_{t+2} = \frac{\partial \pi(y_t, \mathbf{w}_t)}{\partial y_t} = f(y_t, \mathbf{w}_t).$$

Therefore, the supply of yearlings is a function of both input and output prices. Due to these biologically determined time lags between the breeding decision and price discovery when the yearling is sold at market, a lag is applied to the supply model.

More specifically, the supply model is of the form:

$$(3) \quad \textit{yearling quantity}_t = f(\textit{yearling quantity}_{t-2}, \textit{yearling price}_{t-2}, \textit{production costs}_{t-2}, \textit{investment costs}_{t-2}, \textit{season}_t).$$

Equation (3) specifies the quantity of yearlings supplied as a function of the price of yearlings, production costs, and investment costs at the time of the breeding decision, which, in the case of horses is approximately two years prior to time  $t$ . The presence of *season* in equation (3) is intended to capture any seasonal variation in production.

Production costs primarily include the lagged mare price, and lagged feed price while investment costs are included in the model to account for any investment expenses (i.e. interest on a business loan) which would be incurred due to outside financing. The inclusion of the variables in the model is valid as seen in equation (2), supply is not only a function of output prices, but also input prices. Lagged price is included in the model as

the expected price of yearlings in the future, using naïve expectations; while the inclusion of the lagged quantity variable is for the determination of the short- and long-run supply elasticities.

### *Yearling Demand*

Similar to equation (1), buyers of yearling horses seek to maximize profit by purchasing yearlings for use managing livestock, training for re-sale, participating in competitive horse shows, or in recreational activities. Shephard’s lemma reveals that the derivative of these buyers’ profit functions with respect to the input price (i.e., the price of yearlings) yields the input demand for yearlings:

$$(4) \quad q = - \frac{\partial \pi(p_{h,t+n}, y_t, \mathbf{v}_t)}{\partial y_t} = g(p_{h,t+n}, y_t, \mathbf{v}_t),$$

where  $y_t$  is the yearling price,  $p_{h,t+n}$ , is the expected price of the horse sold  $n$  periods in the future, and,  $\mathbf{v}_t$  is a  $m$ -dimensional current price vector of remaining inputs,  $\mathbf{x}$ , in time,  $t$ . The input demand function is a function not only of the cost of the yearling but also associated costs incurred with changing the input into outputs (e.g., cattle, trained two-year olds, recreation) the following years.

Although equation (4) is specified as a quantity-dependent demand, it is more common to specify an inverse demand equation. Because of the aforementioned biological production lags, the quantity of yearlings available at any point in time is largely pre-determined, and as such it makes sense to think of price (or willingness-to-pay) as the endogenous variable and quantity was independent. We say “largely” because producers may have yearlings that they choose not to bring to market. Latter in

the econometric analysis, we discuss how we account for this potential endogeneity problem.

More specifically, the basic form of the inverse demand model is:

$$(5) \quad \textit{yearling price}_t = f(\textit{yearling quantity}_t, \textit{expected two - year - old price}_t, \textit{input prices}_t, \textit{investment costs}_t, \textit{ban}_t, \textit{season}_t, \textit{trend}_t).$$

Equation (5) specifies the price of a yearling as a function of the current (predetermined) supply, input/feed costs, investment costs, and a structural change variable for whether the horse processing ban is in place at the time of the yearling purchase. The presence of the *two-year-old* price variable is used to capture expectations about the future price of the yearling in one year as some buyers of yearlings will resell the horses a year later. As previously mentioned, legislation and legal rulings caused the closure of the only three horse processing plants in the U.S., and thus removed a major buyer for certain horses. The absence of the ‘killer’ buyers in the market place represents a downward demand shift that would, *ceteris paribus*, be expected to lower horse prices and be a structural change in the market captured by the variable *ban*. Also present in the demand model is the *season* variable to capture any seasonal variation in yearling price. *Trend* is used to capture any overall long-term time trend that could occur within the marketplace which is not accounted for in any other variable.

## **Data and Methods**

Availability of historical price information on Quarter Horses, to our knowledge, is largely unavailable. Presumably, large world class horse sales, such as the American

Quarter Horse World Show Sale, would have adequate historical data, however the horses marketed at such a high-caliber sale are not representative of the 'general' horse market. The goal of this study is to provide a framework to model the supply and demand of the average Quarter Horse yearling rather than a world champion prospect yearling. Summary sheets, including price and quantity information, were collected from an Oklahoma based horse auction company. The horse auction company conducts anywhere from six to eight consignment horse sales annually. At the conclusion of every sale, the company prepares summary sheets which break down the averages and associated quantities of the horses sold by gender (mare, gelding stallion), age (yearling, 2-year old, 3, 4, 5 year old, and 6+ years of age), and breed (Quarter Horse and Paint Horse). The summary sheets were collected for every sale conducted during the period 1997-2010. From the summary sheets, six annual sales were analyzed. These sales were held in January, February, April, June, August, and October. This provided 81 sale dates. Three dates were missing as sales were not conducted in August 1998, April 2003, and August 2010. The linear approximation, or average, of the sale held before and after the missing sale were averaged to generate a replacement observation. Failure to include these dates would have reduced the number of observations to 56.

Not only is national historical horse price information largely unavailable, but also national horse quantity data. In an effort to provide a framework to the Quarter Horse yearling market, data on the number of registrations to the American Quarter Horse Association were gathered. The monthly registrations provide insight into how many horses are in the marketplace.

Previous work has estimated that an unregistered or grade horse is discounted from 42% to 51%. (Vestal et al. 2012). This premium for registration far outweighs the \$25-\$50 yearling registration fee of the American Quarter Horse Association; therefore it is in the supplier's best interest to register all foals produced. This being said, the registration numbers should, in theory, be highly correlated with the actual national quantity available. The downside of the registration data is that there is no age or foaling date included in this figure. The monthly registration data from AQHA was lagged three months. Quite easily seen is the AQHA's attempt at motivating breeders to register foals prior to 12 months of age, when the registration fee increases 150% to \$125 per animal. Therefore the three month lag used should incorporate the interval between foaling date and registration date, this assumes foals are approximately 9 months old when they are registered. The authors acknowledge, this data limitation, however this has historically been one of the many barriers to estimation of the structural parameters. That being noted, this paper stands in solitary, and provides a truly unique, original contribution to literature.

The remaining historical data in the analysis was gathered from several publically or membership exclusive databases. Historical Oklahoma City feeder cattle prices were gathered from the Livestock Marketing Information Center (Livestock Marketing Information Center 2012). The monthly mean prices of 500-600 lb and 600-700 lb pound steers were averaged and used in this analysis. Historical monthly average prices of oats, hay, and alfalfa hay prices were gathered from the United States Department of Agriculture Economic Research Service (U.S. Department of Agriculture 2012). Monthly prime interest rates were gathered from the Federal Reserve. This is the interest rate

posted by a majority of the top 25 insured U.S. commercial banks. The prime rate is one of several base rates used by banks to price short-term business loans (U.S. Board of Governors of the Federal Reserve 2012). Complete variable definitions are provided in table 1, and table 2 reports summary statistics on the data used in this analysis. All prices used in the analysis were inflation adjusted to 2012 dollars (U.S. Department of Labor 2012). The two models are specified as follows. Both supply and demand are specified in a log-log functional form. The primary goal of this study is to provide insight as to the sensitivity or elasticity of yearling supply and demand, therefore a log-log functional form is employed due to the constant elasticity and price flexibility quality.

We specify the structural model of yearling supply as

$$(6) \quad \ln q_t = \beta_0 + \beta_1 \ln q_{t-12} + \beta_2 \ln p_{t-12} + \beta_3 \ln mp_{t-12} + \beta_4 \ln ir_{t-12} + \beta_5 \ln cp_{t-12} + \beta_6 \ln ap_{t-12} + \sum_{b=1}^5 \beta_{7,b} \text{season}_{tb} + \varepsilon_t,$$

where  $\ln q_t$  is the quantity (or supply) of registered Quarter Horse yearlings,  $\beta_0$  is the intercept,  $\beta_1$  is the effect of the lagged quantity of registered Quarter Horse yearlings on natural log of quantity,  $q_{t-12}$  is the quantity available two years or 12 periods prior to period  $t$ ,  $\beta_2$  is the effect of lagged yearling price on natural log of quantity,  $p_{t-12}$  is the lagged natural log of average price received for Quarter Horse yearlings 12 periods prior to period  $t$ ,  $\beta_3$  is the effect of lagged mare price on natural log of quantity,  $mp_{t-12}$  is the lagged natural log of average price received for Quarter Horse mares 12 periods prior to period  $t$ ,  $\beta_4$  is the effect of lagged prime interest rate on natural log of quantity,  $ir_{t-12}$  is the lagged natural log of prime interest rates 12 periods prior to period  $t$ ,  $\beta_5$  is the effect of lagged average cattle price on natural log of quantity,  $cp_{t-12}$  is the lagged natural log of average Oklahoma City 500-700 pound feeder steer prices 12 periods prior to period  $t$ ,

$\beta_6$  is the effect of lagged average alfalfa hay price on natural log of quantity,  $ap_{t-12}$  is the lagged natural log of alfalfa hay prices 12 periods prior to period  $t$ ,  $\beta_{7,b}$  is the effect of season on natural log price,  $season_{bt}$  is the variable for season  $b$  (where 1 indicates January, 2 indicates February, 3 indicates April, 4 indicates June, 5 indicates August, and the intercept reflects an October sale), and  $\varepsilon_t$  is the error term.

The inverse demand of Quarter Horse yearlings is specified as,

$$(7) \quad \ln p_t = \alpha_0 + \alpha_1 \ln q_t + \alpha_2 \ln s q_t + \alpha_3 \ln twop_t + \alpha_4 \ln ir_t + \alpha_5 \ln cp_t + \alpha_6 \ln ap_t + \sum_{b=1}^5 \alpha_{7,b} season_{tb} + \alpha_8 ban_t + \alpha_9 trend_t + \varepsilon_t,$$

where  $\ln p_t$  is the natural log of yearling price at period  $t$ ,  $\alpha_0$  is the intercept,  $\alpha_1$  is the effect of the quantity of registered Quarter Horse yearlings on natural log yearling price,  $\ln q_t$  is the natural log of the quantity available in period  $t$ ,  $\alpha_2$  is the effect of quantity of yearlings present at the sale on natural log yearling price,  $\ln s q_t$  is the natural log on quantity of yearlings sold at the sale in period  $t$ ,  $\alpha_3$  is the effect of two year old prices on natural log yearling price,  $\ln twop_t$  is the natural log of average price received for Quarter Horse two-year-olds in period  $t+3$ <sup>1</sup>,  $\alpha_4$  is the effect of prime interest rate on natural log yearling price,  $\ln ir_t$  is the natural log of prime interest rates in period  $t$ ,  $\alpha_5$  is the effect of average cattle price on natural log of quantity,  $\ln cp_{t-12}$  is the natural log of average Oklahoma City 500-700 pound feeder steer prices in period  $t$ ,  $\alpha_6$  is the effect of average alfalfa hay price on natural log yearling price,  $\ln ap_t$  is the natural log of alfalfa hay prices in period  $t$ ,  $\alpha_{7,b}$  is the effect of season on natural log price,  $season_{bt}$  is the variable for season  $b$  (where 1 indicates January, 2 indicates February, 3 indicates April,

---

<sup>1</sup> The current-year two-year-old price is used to capture expectations about the future price of yearlings bought today. This assumes producers have naïve expectations regarding two-year-old prices: (next year's price is expected to be the same as this year's price). We have also considered models where we replace this variable with a prediction based on a distributed lag model, but it does not improve the model fit.

4 indicates June, 5 indicates August, and the intercept reflects an October sale),  $\alpha_8$  is the effect of the closure of horse processing facilities on natural log of yearling price,  $ban_t$  is the indicator variable (where 1 indicates closure of processing plants and 0 indicates intact domestic horse processing),  $\alpha_9$  is the effect of time on natural log yearling price,  $trend_t$  is time trend, period  $t$ , and  $\varepsilon_t$  is the error term. Due to biological production lags, the quantity is predetermined, to an extent; however a producer could retain a yearling, and does not have to bring them to market. The inclusion of the variable  $lnsq_t$ , is used to capture the effect of the actual quantity available at that particular sale on price, thus capturing any causality with could exist between this independent variable and the dependent price variable.

Initially the models were estimated using ordinary least squares (OLS) estimation. Both models were subsequently tested for autocorrelation, a common problem with time-series modeling. The Durbin-Watson test statistic detected positive autocorrelation (10% significance level) of the fifth order in the demand model. The Durbin- $H$  test statistic was implemented to evaluate the supply model due to the lagged dependent variable making the Durbin-Watson test statistic no longer applicable. Autocorrelation was detected at the eighth order (1% significance level). With the presence of autocorrelation, the OLS estimates remain unbiased and consistent, however the estimate of the variance is biased, and therefore statistical tests are subsequently biased (Kennedy 2008).

Due to the detection of autocorrelation, an autoregressive error model (AR) was estimated. A subset autoregressive model was estimated by maximum likelihood for both supply and demand. A 5<sup>th</sup>-order subset model was estimated for the inverse demand function, while the supply model follows a 8<sup>th</sup>-order subset model.

Lastly the models were estimated simultaneously. When predicting the price in equilibrium, quantity supplied is endogenous. The area of primary concern in this model is that producers can hold back yearlings from the market based on changes in price. Common with the determination of demand and supply models, observed prices and quantities are simply a reflection of the intersection of these two models in each period. To this point, only single equation estimation methods have been employed, in an effort to better specify the parameters surrounding this market, a full-information method is used. The major advantage of employing a system approach is that the knowledge of all the zero restrictions in the system is evaluated, and therefore estimates have a smaller asymptotic variance-covariance matrix. While simultaneous estimation (SE) has positive aspects, the disadvantage lies in model misspecification. If the system is misspecified, the estimates of all the structural parameters are affected, rather than only the structural parameters of a single equation (Kennedy 2008). Full information maximum likelihood (FIML) estimation was used to estimate equation (6) and (7) simultaneously. FIML estimation accounts for any correlation between the errors of supply and demand and thus is more efficient. Due to the detection of autocorrelation, and the results of the stepwise regression, a subset autoregressive AR(1,5) demand model and an autoregressive AR(8) supply model was estimated.

## **Results**

Results of all models estimated are presented in tables 3 and 4. Over both models the adjusted  $R^2$  differs only slightly, ranging from 0.74 to 0.85 across all models estimated. Because the models are estimated in a log-log functional form, the interpretation of the coefficient estimates for continuous variables is the percentage change in the dependent

variable given a one percentage change in the respective independent variable. For indicator variables, the exact percentage effect can be obtained by converting the coefficient estimate,  $b$ , to a percentage effect,  $g$ , via the following formula provided by Taylor (2003):  $g = 100(e^b - 1)$ .

Consistent with the theory outlined, factors which impact production costs have a significant impact on the supply of Quarter Horse yearlings. Both *interest* and *alfalfa* are significant and negatively impact the supply. Alfalfa hay prices and interest rates are significant in all three estimation methods. For a 1% increase in the price of alfalfa hay the quantity of yearlings supplied decreases by 0.46% to 0.49% across the three methods. A 1% increase in interest rates causes a decline in quantity from 0.23% to 0.21% in the AR and SE models estimated. The seasonal variables *Jan*, *Feb*, *April*, and *June* are significant, this gives validation to the hypothesis that a seasonal effect could be present. Due to the monthly nature of the data rather than an annual model, seasonal variables are intended to capture any naturally occurring seasonal variation in quantity. Since a mare's estrous cycle is controlled by the photoperiod, the cycle commonly occurs during Spring and Summer months when the days are the longest. This would account for the positive relationship between the *April* and *June* variable and yearling quantity ( $\ln q$ ). Although naturally mares breed in the Spring and Summer months, many times mares are managed carefully and breed in earlier months of the year which explains the positive relationship between the *Jan* and *Feb* variable and yearling quantity ( $\ln q$ ). Many competitive events within the horse industry are age based, meaning they are designated only for horses of a specific age. Halter horses are shown as weanlings, yearlings, and aged horses, while several event specific organizations such as the National Reining Horse Association and

National Cutting Horse Association hold futurity (3-year old) and derby (4, 5, and 6 year olds) events. In order for a horse to be as developed as possible for their associated age based event, they need to be born as close to January 1 as possible. This being said many horses are managed and bred to foal in the early months of the year.

The variable of greatest interest,  $lnp$ , is shown to have a positive and consistently significant relationship with quantity. A 1% increase in the price of yearlings is correlated with a 0.25% to 0.32% increase in quantity supplied. Holding true with profit maximization theory, as the price of a product you produce increases the response would be to produce more. This variable's significance not only shows that producers of Quarter Horses are using the most current pricing information to make production decisions, but it also provides an estimate of the elasticity of the Quarter Horse yearling supply function. The short- and long-run elasticity estimates are presented in table 5. Over the short-run the supply elasticity estimates range from 0.25 to 0.32 which are representative of an inelastic supply. The long-run elasticities ( $\beta_2/1 - \beta_1$ ) range from 0.29 to 0.40. Our elasticities indicate a slightly more elastic supply function than the Thoroughbred supply function of Neibergs and Thalheimer which indicated a supply elasticity of 0.116 (Neibergs and Thalheimer 1997).

The results of the inverse demand function are included in table 4. Although only significant in the AR and SE models, but consistently negative across all models, the parameter estimate for the processing ban ( $ban$ ) is shown to decrease yearling prices as hypothesized. Yearling prices following the processing ban were approximately 22% lower on average than prices before the ban. It should be noted that the inclusion of the overall time trend variable in the model, strengthens the estimate of the processing ban as

the time trend captures any long-term decrease in price which could have been occurring alongside the policy change.

As expected, a negative relationship between quantity and price is shown in the results. This negative relationship is consistent across the three models and is significant in the AR model at alpha equal to 0.10 and in the SE model at alpha equal to 0.01, with a parameter estimate of -0.71 in the SE model. Therefore a 1% increase in quantity is associated with a price decrease of 0.71%. These price flexibilities specify an inflexible price structure. The reciprocal of the price flexibility forms the lower limit, in absolute terms, of the demand price elasticity, if the cross effects of substitution and complementarity are weak (Houck 1965). This yields an elasticity approximation of -1.41 for the SE model, indicating an elastic demand function.

### *Welfare Analysis*

A barrier in determining the welfare effects due to the 2007 closure of the domestic horse processing industry is that the equine industry has never been examined to determine the structural framework. In this section, we will use the estimates generated to evaluate the very short-run welfare effects and the welfare effects with a more elastic supply function.

In the short-run, yearling supply is predetermined by breeding decisions of the past. Further, horses are not bred and raised in an attempt to fill the demand of the processing facilities. Therefore, even the impending closure of the processing facilities would likely have had little to no effect on the breeding decision. In the shortest run, supply is completely inelastic. Taking the demand equation estimated and a period with predetermined supply we can generate calculations of the consumer surplus (CS),

producer surplus (PS), and total surplus (TS). From the estimates generated (evaluating the remaining parameters at their associated means) gives the inverse demand function defined as  $D^1$  equal to  $lnp = 14.20 - 0.71 * lnq$ . The inverse demand function following the processing ban,  $D^2$ :  $lnp = 13.95 - 0.71 * lnq$ . Using these estimates, and the given quantity of yearlings supplied, welfare estimates can be generated. The quantity of yearlings in October 2007 (observation after the closure of the processing facilities) was 8,510. In terms of horse price, the model calculates  $p^1$  of \$2,368.47 and  $p^2$  (price after processing ended) of \$1,844.57. Taking this difference of \$523.90 (loss per head), and aggregating it across all 8,510 yearlings available yields a loss of \$4,458,389.00 for this period alone. This is representative of the loss suffered to producer surplus. In our data we have an approximation for quantity supplied over six periods in one year. In 2007, 73,901 yearlings were supplied; multiplying this quantity by the loss per head of \$523.90, yields a loss of \$38,716,733.90. The short run is presented graphically in figure 1, and the following discussion is illustrated graphically in figure 2.

By incorporating both the supply and demand estimates generated by the models, we can take into account the supply elasticity, rather than assume a perfectly inelastic supply curve. Note that the following equilibrium projections and associated welfare changes are representative of a partial equilibrium. Given the dynamic interchanging affects which would result from a policy change of this nature (i.e. changes in mare price and two-year-old price), an additional model was estimated without the inclusion of these two variables. From this model, a general equilibrium could be formulated. The results of these auxiliary estimations are included in the appendix and differ only slightly from the results used in this application. The structural supply model estimated (evaluating the

remaining parameters at their associated means) gives the supply function defined as  $S$  equal to  $\ln q = 7.36 + 0.27 * \ln p$ . Incorporating  $S$ ,  $D^1$ , and  $D^2$  yields an initial equilibrium price and quantity:  $p^1 = \$1,863.11$ ,  $q^1 = 12,088$  and a subsequent equilibrium price and quantity:  $p^2 = \$1,480.30$ ,  $q^2 = 11,384$ . Using these values we can see that the loss to producers is  $\$4,492,658.16$ , calculated by:  $[(p^1 - p^2) * q^1] - [(q^1 - q^2) * (p^1 - p^2)]/2$ . To calculate the deadweight loss we evaluate  $D^2$  at  $p^1$  to calculate  $q^3$  (8,434). The deadweight loss suffered is shown to be equal to  $\$699,393.87$ . This, in its most reduced form, is calculated by:  $0.5(q^1 p^1 - p^2 q^1 - p^1 q^3 + p^2 q^3)$ . The implied change in consumer surplus is  $\$3,793,264.29$ .

## **Conclusions**

Economic research commonly overlooks the equine industry. Previous empirical research has primarily focused on the racing industry, and the few studies conducted within the Quarter Horse market have only employed hedonic price analysis. By incorporating price information from a large regional horse auction company and registration data from the American Quarter Horse Association, the structural parameters surrounding supply and demand are estimated. After accounting for endogeneity, the results from this study characterize a yearling Quarter Horse market with relatively inelastic supply function coupled with a somewhat elastic demand. After the closure of the domestic horse processing market in 2007, a hypothesized structural change occurred in the market due to the removal of buyers of 'killer' horses. The study shows that after correcting for autocorrelation and endogeneity, a structural change is shown to be significant. The

autoregressive and specified simultaneous estimation methods show that the processing ban caused a significant structural change to the market and an inward shift in demand.

The price flexibility, supply elasticity, and structural change parameter estimates can then be used in welfare analysis. From the results of the structural framework of supply and demand we show that the Quarter Horse yearling market was negatively impacted, with the producers suffering the greatest loss. By using the structural demand model estimated, and assuming a completely inelastic supply function, the change in welfare from the very short-run is quantified. On average, the loss per head was \$524. Applying the loss per head to the quantity of yearling Quarter Horses supplied in October of 2007 yields a loss to producer surplus of \$4.4 million. In 2007, almost 74,000 yearlings were supplied, therefore the loss per head applied to the annual quantity supplied yields an annual loss in the very short-run of over \$38 million.

The welfare analysis is also quantified using both the supply and demand structural parameters estimated. The short-run supply elasticity is 0.27 for yearling Quarter Horses, coupling this result with the demand functions quantifies the deadweight and producer surplus losses. The deadweight loss for a single period is almost \$700,000 while the loss to producer surplus is over \$4.4 million. Annualizing the results yield a deadweight loss in excess of \$4.1 million dollars, while producers suffered losses of over \$26.9 million.

The results provided in this study provide an initial inference as to the structural framework surrounding the yearling Quarter Horse market. As previously mentioned, a study of this nature has not been previously conducted. Therefore, the results provide a significant contribution to the literature. The primary objective behind estimating the

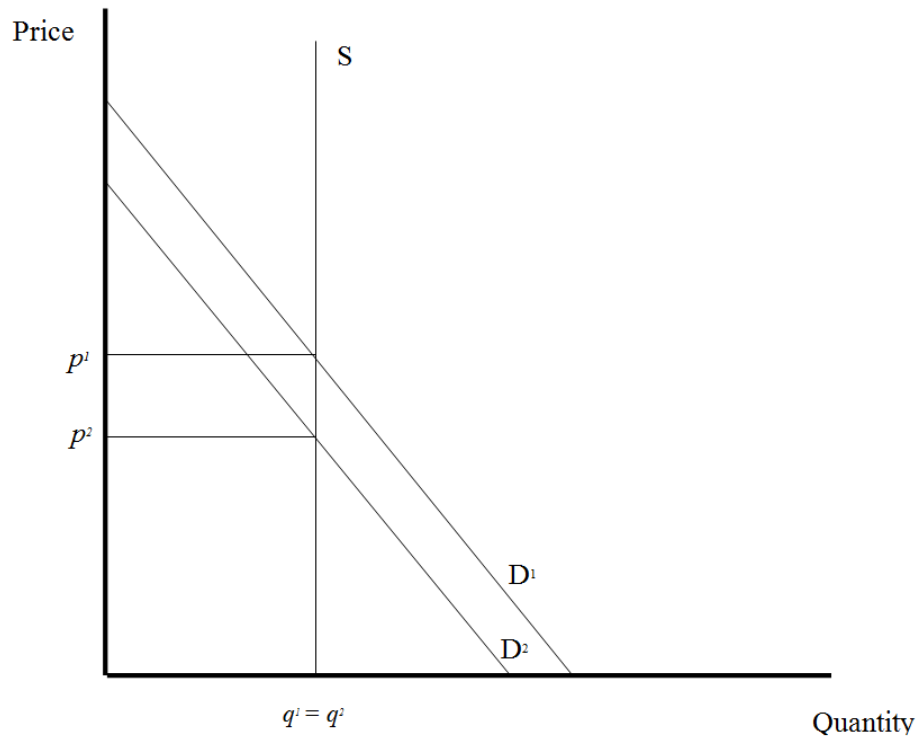
structural framework surrounding the yearling Quarter Horse market was to provide insight into the economic effect of the closure of horse processing in the United States. Horse processing for human consumption is a topic of great debate. Virtually no economic studies have been conducted to determine the economic impacts the equine industry has suffered as a result of court proceedings and decisions. By applying an alternative conceptual framework, we have provided validity to the previous hedonic studies which have addressed the horse processing issue. Likewise, we concluded that the closure of the United States horse processing market had a negative (multi-million dollar) impact on the equine industry.

Although the authors note the associated limitations of this study due to data availability, the structural parameters surrounding the Quarter Horse yearling market, to date, have never been estimated. This essay provides a model in which policies, such as the processing ban, can be evaluated and the associated welfare effects can be quantified.

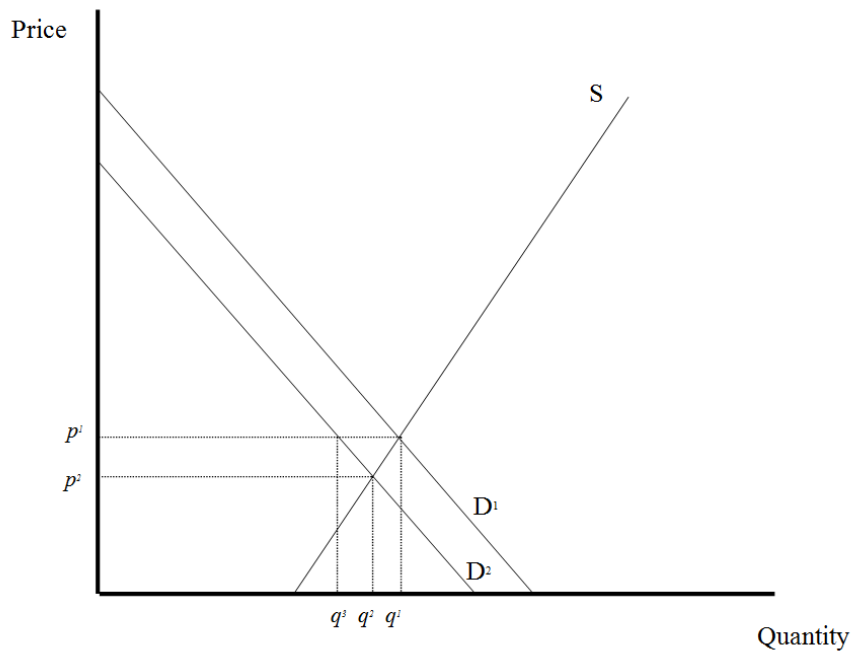
## References

- American Quarter Horse Association. 2011. *AQHA Annual Report, 2011*. Amarillo, Texas.
- Brester, G. W. and J.M. Marsh. 1983. "A Statistical Model of the Primary and Derived Market Levels in the U.S. Beef Industry." *Western Journal of Agricultural Economics* 8(1):34-49.
- Cowan, T. 2010. *Horse Slaughter Prevention Bills and Issues*. Washington DC: Congressional Research Service, CRS Report 7-5700.
- Dawson, P. 2008 "An Epidemic of Abandoned Horses." *Time Magazine*, May.
- Deloitte Consulting, LLP. 2005. *National Economic Impact of the U.S. Horse Industry*. Technical report prepared for The American Horse Council Foundation, Washington DC.
- Dinan, S. 2011. "Obama, Congress restore horse-slaughter industry" *The Washington Times*.
- Gardner, B.L. 1976. "Futures Price in Supply Analysis." *American Journal of Agricultural Economics* 58(1):81-84.
- Houck, J.P. 1965. "The Relationship of Direct Price Flexibilities to Direct Price Elasticities." *Journal of Farm Economics* 47(3):789-792.
- Kenndey, P. 2008. *A Guide to Econometrics*. Maine: Blackwell Publishing.
- Lange, K., J. Johnson, K. Wilson, and W. Johnson. 2010 "Price Determinants of Ranch Horses Sold at Auction in Texas." Paper presented at SAEA annual meeting, Orlando, FL, 6-9 February.
- Lansford, N.H., Jr., D.W. Freeman, D.R. Topliff, and O.L. Walker. 1998. "Hedonic Pricing of Race-Bred Yearling Quarter Horses Produced by Quarter Horse Sires and Dams." *Journal of Agribusiness* 16:169-185.
- Lenz, T. R. 2009. "The Unwanted Horse in the United States: An Overview of the Issue." *Journal of Equine Veterinary Science* 29(5): 253-258.
- Livestock Marketing Information Center. 2012. *Weekly and Monthly Oklahoma City Feeder Cattle Prices (Historical)*. Denver, Colorado.
- Maynard, L.J., and K.M. Stoeppel. 2007. "Hedonic Price Analysis of Thoroughbred Broodmares in Foal." *Journal of Agribusiness* 25(2): 181-195.

- Neibergs, J.S. 2001. "A Hedonic Price Analysis of Thoroughbred Broodmare Characteristics." *Agribusiness* 17(2):299-314.
- Neibergs, J.S., and R. Thalheimer. 1997. "Price Expectations and Supply Response in the Thoroughbred Yearling Market." *Journal of Agricultural and Applied Economics* 29(2):417-435.
- Nerlove, M. 1956. "Estimates of the Elasticities of Supply of Selected Agricultural Commodities." *Journal of Farm Economics* 38(2):496-509.
- Nerlove, M. 1958. "Distributed Lags and Estimation of Long-Run Supply and Demand Elasticities: Theoretical Considerations." *Journal of Farm Economics* 40(2):301-311.
- Rosen, S. 1987. "Dynamic Animal Economics." *American Journal of Agricultural Economics* 69(3):547-557.
- Simon, S. 2011. "Horse Slaughter is Reconsidered." *Wall Street Journal*, January, pp. A3.
- Taylor, L.O. 2003. "The Hedonic Method." In P.A. Champ, K.J. Boyle, and T.C. Brown, ed. *A Primer on Nonmarket Valuation*. Norwell, MA: Kluwer Academic Publishers, pp. 331-386.
- Taylor, M.R., K.C. Dhuyvetter, T.L. Kastens, M. Douthit, and T.L. Marsh. 2006. "Show Quality Quarter Horse Auctions: Price Determinants and Buy-Back Practices." *Journal of Agricultural and Resource Economics* 31(3):595-615.
- The Jockey Club. 2012. *2012 Online Fact Book*. New York, New York.
- U.S. Board of Governors of the Federal Reserve System. 2012. *Selected Interest Rates-Bank Prime Loan*. Washington, DC.
- U.S. Department of Agriculture, Economic Research Service. 2012. *Hay: Average Prices Received By Farmers, United States (database)*. Washington, DC.
- U.S. Department of Labor, Bureau of Labor Statistics. 2012. *CPI Inflation Calculator*. Washington, DC.
- U.S. Government Accountability Office, Report to Congressional Committees. 2011. *Horse Welfare: Action Needed to Address Unintended Consequences from Cessation of Domestic Slaughter*. Washington DC, June.
- Vestal, M.K., J.L. Lusk, C.E. Ward, S.R. Cooper. 2012. "What Are the Consequences of United States Government Slaughter Policies on Horse Prices?" *in submission*.



**Figure 1. Short-Run Impact of Processing Ban**



**Figure 2. Long-Run Impact of Processing Ban**

**Table 1. Variable Definitions**

Variable	Definition
$lnq_t$	Three month lagged AQHA registration numbers
$lnp_t$	The natural log of the average price in dollars of registered Quarter Horse yearlings sold at sale during period $t$
$lnmp_t$	The natural log of the average price in dollars of registered Quarter Horse mares sold at sale during period $t$
$lnir_t$	The natural log of the average monthly prime interest rate in period $t$
$lncp_t$	The natural log of the average price (\$/cwt) of 500-700lb steers at Oklahoma City Market in period $t$
$lnap_t$	The natural log of the average price (\$/ton) of alfalfa hay in period $t$
$Jan_t$	1 if sale was held in January, 0 otherwise
$Feb_t$	1 if sale was held in February, 0 otherwise
$April_t$	1 if sale was held in April, 0 otherwise
$June_t$	1 if sale was held in June, 0 otherwise
$Aug_t$	1 if sale was held in August, 0 otherwise
$Oct_t$	1 if sale was held in October, 0 otherwise (base variable)
$lnsq_t$	The natural log of the quantity of registered Quarter Horse yearlings sold at sale in period $t$
$lntwop_t$	The natural log of the average price in dollars of registered two year old Quarter Horse sold at sale in period $t$
$ban_t$	0 if sale year is 2001- August 2007 (processing allowed), 1 if sale year is October 2007-2010 (closure of horse processing facilities)
$trend_t$	Time trend (Each observation is numbered in sequential order)

Note: All price variables are inflation adjusted to 2012 dollars. Lagged variables are noted as  $t-1$ ,  $t-2$ ,  $t-12$  corresponding to a 1, 2 and 12 period lag respectively.

**Table 2. Summary Statistics, 1997-2010 (N=84)**

Variable	Mean	Std. Dev.	Min. Value	Max. Value
Log yearling quantity ( $lnq_t$ )	9.35	0.35	8.68	9.96
Quantity	12,249.39	4,241.66	5,880.00	21,215.00
Log yearling price ( $lnp_t$ )	7.48	0.36	6.13	8.29
Yearling price	1,877.49	650.17	745.08	3,985.94
Log mare price ( $lnmp_t$ )	8.07	0.29	7.44	8.71
Mare price (\$/hd)	3,327.77	979.47	1,709.76	6,053.63
Log interest rate ( $lnir_t$ )	1.78	0.36	1.18	2.25
Interest rate	6.37	2.09	3.25	9.50
Log cattle price ( $lncp_t$ )	4.81	0.10	4.62	5.05
Cattle price(\$/cwt)	123.40	12.65	101.47	156.41
Log alfalfa hay price ( $lnap_t$ )	4.85	0.14	4.61	5.25
Alfalfa hay price (\$/ton)	129.02	18.89	100.32	189.74
Log sale quantity ( $lnsq_t$ )	4.08	0.62	2.08	5.14
Sale quantity	69.70	36.63	8.00	171.00
Log 2 year old price ( $lnwop_t$ )	7.92	0.34	6.98	8.49
2 year old price (\$/hd)	2,898.79	902.95	1,074.82	4,868.92
Season ( $Jan_t$ )	0.17	0.37	0	1
Season ( $Feb_t$ )	0.17	0.37	0	1
Season ( $April_t$ )	0.17	0.37	0	1
Season ( $June_t$ )	0.17	0.37	0	1
Season ( $Aug_t$ )	0.17	0.37	0	1
Season ( $Oct_t$ )	0.17	0.37	0	1
Processing ban ( $ban_t$ )	0.23	0.42	0	1
Trend ( $trend_t$ )	42.5	24.39	1	84

Note: All prices are adjusted to 2012 dollars (U.S. Department of Labor, Bureau of Labor Statistics).

**Table 3. Results of Yearling Supply Model Using Alternative Estimation Methods**

Equation	Variable	Ordinary Least		Simultaneous
		Squares	Autoregressive	Estimation <sup>a</sup>
Supply ( $lnq_t$ )	<i>Intercept</i>	7.94*** (2.78) <sup>b</sup>	7.29** (2.75)	7.22 (4.38)
	Lag yearling quantity ( $lnq_{t-12}$ )	0.15 (0.13)	0.20 (0.13)	0.23 (0.17)
	Lag yearling price ( $lnp_{t-12}$ )	0.25** (0.09)	0.32*** (0.09)	0.27*** (0.10)
	Lag mare price ( $lnmp_{t-12}$ )	0.13 (0.15)	0.10 (0.14)	0.16 (0.20)
	Lag interest rate ( $lnir_{t-12}$ )	-0.19** (0.07)	-0.23*** (0.06)	-0.21*** (0.07)
	Lag cattle price ( $lncp_{t-12}$ )	-0.09 (0.21)	-0.11 (0.21)	-0.20 (0.25)
	Lag alfalfa hay price ( $lnap_{t-12}$ )	-0.49*** (0.17)	-0.49*** (0.16)	-0.46* (0.27)
	January sale ( $Jan_t$ )	0.42*** (0.13)	0.41*** (0.12)	0.37* (0.21)
	February sale ( $Feb_t$ )	0.53*** (0.11)	0.51*** (0.11)	0.48** (0.16)
	April sale ( $April_t$ )	0.54*** (0.09)	0.55*** (0.09)	0.52*** (0.15)
	June sale ( $June_t$ )	0.26*** (0.07)	0.29*** (0.07)	0.28** (0.11)
	August sale ( $Aug_t$ )	0.01 (0.07)	0.03 (0.06)	0.04 (0.10)
	Autoregressive (8)			0.40*** (0.14)
	Adjusted R <sup>2</sup>		0.80	0.85
				-0.38** (0.17)

\* Significance levels where  $\alpha=0.1$ .

\*\* Significance levels where  $\alpha=0.05$ .

\*\*\* Significance levels where  $\alpha=0.01$ .

<sup>a</sup> Results from simultaneous estimation of the supply and demand equations using full information maximum likelihood.

<sup>b</sup> Numbers in parentheses are standard errors.

**Table 4. Results of Yearling Demand Model Using Alternative Estimation Methods**

Equation	Variable	Ordinary Least Squares	Autoregressive	Simultaneous Estimation <sup>a</sup>
Inverse Demand				
	<i>Intercept</i>	7.77*** (2.02) <sup>b</sup>	8.72*** (1.73)	10.62*** (2.18)
	Log yearling quantity ( <i>lnq<sub>t</sub></i> )	-0.08 (0.12)	-0.19* (0.11)	-0.71** (0.31)
	Log sale quantity ( <i>lnsq<sub>t</sub></i> )	-0.01 (0.06)	-0.02 (0.05)	0.07 (0.09)
	Two-year-old log price ( <i>lntwop<sub>t</sub></i> )	0.08 (0.12)	0.08 (0.11)	0.13 (0.16)
	Log interest rate ( <i>lnir<sub>t</sub></i> )	0.01 (0.08)	-0.01 (0.06)	-0.06 (0.07)
	Cattle log price ( <i>lncp<sub>t</sub></i> )	0.17 (0.27)	0.14 (0.23)	0.47 (0.30)
	Alfalfa hay log price ( <i>lnap<sub>t</sub></i> )	-0.05 (0.16)	0.00 (0.14)	0.10 (0.25)
	January sale ( <i>Jan<sub>t</sub></i> )	-0.12 (0.15)	-0.05 (0.14)	0.34 (0.29)
	February sale ( <i>Feb<sub>t</sub></i> )	-0.29** (0.13)	-0.22** (0.11)	0.16 (0.22)
	April sale ( <i>April<sub>t</sub></i> )	-0.43*** (0.11)	-0.39*** (0.10)	-0.09 (0.23)
	June sale ( <i>June<sub>t</sub></i> )	-0.34*** (0.08)	-0.34*** (0.08)	-0.18 (0.16)
	August sale ( <i>Aug<sub>t</sub></i> )	-0.22*** (0.07)	-0.22*** (0.08)	-0.22 (0.20)
	Processing ban ( <i>ban<sub>t</sub></i> )	-0.11 (0.10)	-0.20** (0.09)	-0.25* (0.14)
	Sale Time Trend ( <i>time<sub>t</sub></i> )	-0.01*** (0.00)	-0.01*** (0.00)	-0.01*** (0.00)
	Autoregressive (1)			-0.28** (0.14)
	Autoregressive (5)		0.38*** (0.12)	-0.35* (0.17)
	Adjusted R <sup>2</sup>	0.77	0.83	0.74

\*Significance levels where  $\alpha=0.1$ .

\*\*Significance levels where  $\alpha=0.05$ .

\*\*\*Significance levels where  $\alpha=0.01$ .

<sup>a</sup> Results from simultaneous estimation of the supply and demand equations using full information maximum likelihood.

<sup>b</sup> Numbers in parentheses are standard errors.

**Table 5. Estimates of Supply Elasticity and Demand Price Flexibility for Alternative Estimation Methods**

	Variable	Ordinary Least Squares	Autoregressive	Simultaneous Estimation
Supply	Short-run elasticity	0.25	0.32	0.27
$(\ln q_t)$	Long-run elasticity	0.29	0.40	0.35
Demand	Price flexibility	-0.08	-0.19	-0.71
$(\ln p_t)$				

**APPENDIX A – TABLES REPORTING ALTERNATIVE  
ESTIMATION METHODS OF QUARTER HORSE  
SUPPLY AND DEMAND MODELS**

**Table A-1. Alternative Specification Results of Yearling Supply Model Using Alternative Estimation Methods**

Equation	Variable	Ordinary Least Squares	Autoregressive	Simultaneous Estimation <sup>a</sup>
Supply ( $lnq_t$ )	<i>Intercept</i>	9.25*** (2.36) <sup>b</sup>	8.43*** (2.23)	8.77** (3.33)
	Lag yearling quantity ( $lnq_{t-12}$ )	0.12 (0.13)	0.19 (0.12)	0.22 (0.17)
	Lag yearling price ( $lnp_{t-12}$ )	0.29*** (0.08)	0.35*** (0.07)	0.33*** (0.09)
	Lag interest rate ( $lnir_{t-12}$ )	-0.19** (0.07)	-0.23*** (0.06)	-0.22*** (0.08)
	Lag cattle price ( $lncp_{t-12}$ )	-0.12 (0.21)	-0.16 (0.19)	-0.26 (0.28)
	Lag alfalfa hay price ( $lnap_{t-12}$ )	-0.55*** (0.16)	-0.54*** (0.15)	-0.52** (0.25)
	January sale ( $Jan_t$ )	0.50*** (0.10)	0.46*** (0.10)	0.44*** (0.15)
	February sale ( $Feb_t$ )	0.58*** (0.10)	0.54*** (0.10)	0.52*** (0.15)
	April sale ( $April_t$ )	0.57*** (0.09)	0.57*** (0.08)	0.55*** (0.12)
	June sale ( $June_t$ )	0.27*** (0.07)	0.29*** (0.07)	0.28*** (0.10)
	August sale ( $Aug_t$ )	0.00 (0.07)	0.03 (0.06)	0.04 (0.10)
	Autoregressive (8)		0.41*** (0.14)	-0.38** (0.17)
	Adjusted R <sup>2</sup>	0.80	0.85	0.81

\* Significance levels where  $\alpha=0.1$ .

\*\* Significance levels where  $\alpha=0.05$ .

\*\*\* Significance levels where  $\alpha=0.01$ .

<sup>a</sup> Results from simultaneous estimation of the supply and demand models using full information maximum likelihood.

<sup>b</sup> Numbers in parentheses are standard errors.

**Table A-2. Alternative Specification Results of Yearling Demand Model Using Alternative Estimation Methods**

Equation	Variable	Ordinary Least Squares	Autoregressive	Simultaneous Estimation <sup>a</sup>
Inverse Demand				
( $lnp_t$ )	<i>Intercept</i>	8.41*** (1.77) <sup>b</sup>	9.22*** (1.55)	10.85*** (1.86)
	Log yearling quantity ( $lnq_t$ )	-0.08 (0.12)	-0.19* (0.11)	-0.61** (0.27)
	Log sale quantity ( $lnsq_t$ )	-0.01 (0.06)	-0.01 (0.05)	0.06 (0.09)
	Log interest rate ( $lnir_t$ )	0.00 (0.08)	-0.01 (0.06)	-0.05 (0.07)
	Cattle log price ( $lncp_t$ )	0.18 (0.27)	0.16 (0.23)	0.48 (0.32)
	Alfalfa hay log price ( $lnap_t$ )	-0.06 (0.16)	-0.00 (0.14)	0.08 (0.23)
	January sale ( $Jan_t$ )	-0.08 (0.14)	-0.02 (0.13)	0.33 (0.28)
	February sale ( $Feb_t$ )	-0.27** (0.12)	-0.22* (0.11)	0.11 (0.20)
	April sale ( $April_t$ )	-0.42*** (0.11)	-0.39*** (0.10)	-0.14 (0.25)
	June sale ( $June_t$ )	-0.34*** (0.08)	-0.34*** (0.08)	-0.20 (0.18)
	August sale ( $Aug_t$ )	-0.21*** (0.07)	-0.22*** (0.08)	-0.21 (0.20)
	Processing ban ( $ban_t$ )	-0.12 (0.10)	-0.21** (0.09)	-0.23* (0.12)
	Sale time trend ( $time_t$ )	-0.01*** (0.00)	-0.01*** (0.00)	-0.01*** (0.00)
	Autoregressive (1)			-0.26* (0.14)
	Autoregressive (5)		0.38*** (0.11)	-0.39** (0.17)
	Adjusted R <sup>2</sup>	0.77	0.82	0.76

\*Significance levels where  $\alpha=0.1$ .

\*\*Significance levels where  $\alpha=0.05$ .

\*\*\*Significance levels where  $\alpha=0.01$ .

<sup>a</sup> Results from simultaneous estimation of the supply and demand models using full information maximum likelihood.

<sup>b</sup> Numbers in parentheses are standard errors.

**Table A-3. Alternative Model Specification Estimates of Supply Elasticity and Demand Price Flexibility for Alternative Estimation Methods**

		Ordinary Least		
Variable		Squares	Autoregressive	Simultaneous Estimation
Supply	Short run elasticity	0.29	0.35	0.32
$(lnq_t)$	Long run elasticity	0.33	0.43	0.41
Demand	Price flexibility	-0.08	-0.18	-0.65
$(lnp_t)$				