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The Impacts of U.S. Horse Slaughter Plant Closures on a Western Regional Horse Market

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This study quantifies the price impacts from the closure of all U.S. horse slaughter plants in 2007 on live horses at a Montana auction. The hedonic pricing model includes supply and demand factors such as horse-specific characteristics, spatial and time effects, the U.S. economic downturn beginning in 2008, and slaughter plant closures. The hedonic model was estimated using a quantile regression, which revealed price declines of 12% to 16% for horses priced at or below $1,500 per head attributable to the end of U.S. horse slaughter.

Key words: horses, slaughter, quantile regression

Introduction

In the United States, horses have long served people as work animals, recreation companions, and even as family pets. Horses can live to be thirty years old and, therefore, may experience several of these roles over their lifetimes. Ownership of a horse is also likely to change because activities evolve with a horse's age. At many horse auctions, sellers provide information on the breeding, training, accomplishments, and potential uses of a horse to signal value that may not be obvious from just observing the animal's physical traits.

Within the population of buyers looking to purchase a horse for these activities, another subset of buyers has an entirely different use in mind for the horses they purchase. These buyers purchase horses to be slaughtered for meat, usually for human consumption.[1] It is unusual in livestock markets to have such a combination of buyers at one auction, but horses are not raised for meat, so there are no markets for horses similar to those found for cattle or hogs destined for slaughter. The proportion of recreational and slaughter buyers at an auction is unobservable to other market participants. It is not known what any buyer intends to do with a horse they purchase, so discernible market transactions for horses intended for slaughter are not publically available.

Horse slaughter has existed in the United States for decades and served as an outlet for horses without sufficient value in the recreation market. During the 1980s, sixteen U.S. horse slaughter plants were in operation (Government Accountability Office, 2011). That number declined to seven in 1994, and only two plants were running in 2002. By 2006, three slaughter plants were operating in the United States, processing a total of 104,899 head annually. The horse-slaughter industry in the United States has been under fire recently from various activist groups concerned with animal welfare. Politically, horse slaughter tends to be unpopular because horsemeat consumption is not a culturally accepted practice in the United States; meat from domestically slaughtered horses is shipped to foreign customers.

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[1] Some horsemeat is also used by zoos for animal feed. Horsemeat has not been used in pet food since the 1970s, when it was outlawed in the United States.

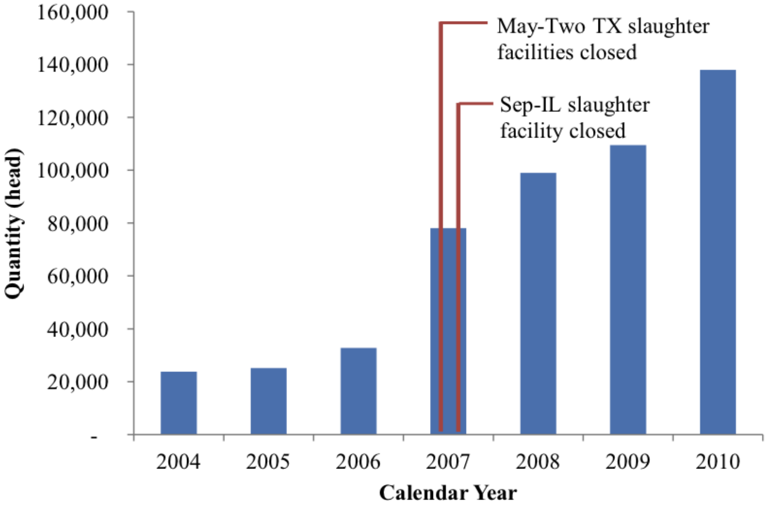

Figure 1. Number of U.S. Horses Exported for Slaughter to Canada and Mexico (Government Accountability Office, 2011, pg. 12)

A series of attempts to ban domestic horse slaughter at the federal level have been made since the 1990s. A 2005 amendment to the Federal Meat Inspection Act (FMIA) of 1906 attempted to ban the use of government funds for plant inspectors. An appeal to the USDA by the three slaughter plants was subsequently approved, allowing voluntary inspection paid for by the plant owners (Cowan, 2012). Although unsuccessful at the federal level, progress toward ending horse slaughter was being made through state legislative channels. Of the three horse-slaughter facilities operating in the United States, two were in Texas and one was in Illinois. Slaughter in Texas was ended in January 2007, when the U.S. Court of Appeals for the Fifth Circuit upheld a 1949 Texas law banning the sale of horsemeat. In May of the same year, the Illinois state legislature passed a law banning horse slaughter in the state, thus closing the last U.S. slaughter facility (Cowan, 2012).

The forced closure of U.S. horse slaughter plants did not eliminate the purchase of U.S. horses for slaughter. Exports of horses to slaughter facilities in Canada and Mexico have grown to more than four times their pre-ban volume, as shown in figure 1. By 2010, the number of horses exported to Canada and Mexico for slaughter was equal to the total number of horses slaughtered domestically (104,899) and those exported for slaughter (32,789) in 2006, the last full year of U.S. slaughter.

Shortly after the slaughter ban was imposed, participants in the horse markets began to see a decline in horse prices (Government Accountability Office, 2011). Proponents of the ban attributed the softening of the horse market to the economic downturn that began in 2008 and the high cost of feed, not the slaughter plant closures (Sulzberger, 2011). The dispute over whether the slaughter ban has affected horse prices since 2007, and to what extent, is challenging to resolve due to a lack of publicly available horse-auction data and the nature of a market for animals not raised specifically for slaughter. However, determination of the economic impacts of the slaughter ban is essential for informing future political decisions regarding domestic slaughter and live horse exports.

This article examines a proprietary dataset of market transactions from a biannual horse auction in Billings, Montana. The sale attracts buyers and sellers from over thirty states and four Canadian provinces and provides a representative sample of other western regional U.S. horse markets with both domestic and foreign buyers. Ordinary least squares (OLS) and quantile regression (QR) methods are employed to estimate a hedonic price function of horse characteristics, seller marketing tactics, feed costs, and time-dependent effects including the national recession and the domestic slaughter ban.

Results indicate that the choice of regression method dramatically affects the conclusions with regard to the slaughter ban policy. The OLS model indicates that the slaughter ban did not affect horse prices at the Montana auction, holding all other horse-, seller-, and time-specific factors constant. Using QR however, the slaughter-ban parameter is significantly different from zero and decreases prices by 12% to 16% for horses priced at or below $1,500 per head. Horses priced above this range of sale prices were not affected by the slaughter ban. These results suggest that, although we cannot directly observe who purchases horses at this auction or what they intend to do with the horses they buy, certain price ranges of horses have been adversely affected by the ban.

Literature Review

Several studies of horse auctions have been conducted, most using a hedonic model to measure the value of implicit characteristics on sale prices (Chezum and Wimmer, 1997; Lansford et al., 1998; Vickner and Koch, 2001; Robbins and Kennedy, 2001; Taylor et al., 2006). Other factors, such as macroeconomic conditions, have also been shown to affect prices at auction (Buzby and Jessup, 1994; Neibergs and Thalheimer, 1997). While OLS is the typical regression method employed, QR has also been used in analysis of horse auction data to examine effects of explanatory variables across the distribution of prices (Parsons and Smith, 2008).

Studies on horse auctions in the existing literature have several commonalities. First, sale prices of horses tend to be highly skewed. While the majority of horses sell within a small range, there are typically a few horses that sell for very high prices. This may be due to pedigree, training, or performance record. The skewed distribution typical of horse-auction data has led researchers to employ semi-log functional forms for estimation of hedonic models. Another commonality is that certain characteristics of horses are consistently found to be statistically significant determinants of price. These characteristics are horse-specific and include age, sex, and pedigree. Lastly, the data used in horse-auction studies tend to originate from sales that have a particular theme or requirement for participation. Sales typically are organized around discipline (showing, racing), sex (broodmares), or age (yearlings). This provides an element of uniformity in the data available on horses sold at auction.

The data used in this article contrast sharply with themed sales analyzed in previous studies. The Montana sale is referred to as a catalog sale because a bulletin is published with information on each horse entered in the sale. This publication is available to potential buyers prior to the sale. Besides asking sellers to provide information for the sale catalog, no specific requirements are made of the horses being brought to auction. This is the only auction studied in the literature that does not place stipulations—such as requiring breed registration, providing proof of a negative Coggins test, having discipline-specific training, or the horses being of a certain age or sex—on the horses sold.[2]

A general sale of this type creates a great deal of heterogeneity in the data, which can be beneficial for statistical analysis. However, the lack of uniformity in the information supplied by the sale catalog may constrain certain categories of independent variables. For example, performance record (showing or racing) has been shown to be a statistically significant predictor of sale price (Vickner and Koch, 2001; Taylor et al., 2006). But this information will not be present for green-broke horses because they have never performed in a manner that can be objectively measured. Therefore, model specification and the inclusion of certain horse-specific characteristics are drawn from previous literature to the extent possible.

Previous studies on the economic implications of a U.S. slaughter ban are limited. In an *ex ante* study of the slaughter ban, North, Bailey, and Ward (2005) argued that the existence of a slaughter market gives a salvage value for horses not demanded by other market buyers. Removal of the slaughter market drives this salvage value to zero and the negative impact on the economy

[2] Proof of a negative Coggins test is required for a horse to be transported across state lines. It is also required at some organized horse activities, but this varies widely with the activity.

was estimated to be $20–$29 million from increased disposal costs of cull horses. The loss of the slaughter market would also cause the U.S. export market for horsemeat to disappear, resulting in an additional economic cost of $26 million. The authors point out that use of the net present value method for determining the cost of disposing cull horses does not include potential impacts on prices of horses that are not slaughtered and, at the time of the study, data to measure this impact were not available.

In 2011, the Government Accountability Office (GAO) released an analysis of the horse-slaughter ban addressing both the economic and animal-welfare impacts of the ban. The econometric model of horse prices was based on data collected from three horse auctions in Montana, Oklahoma, and Virginia. The data were collected to represent price, geographic, and quality variability of horses. The hedonic pricing model was specified to include horse characteristics such as age, gender, and breed as well as auction characteristics including location, frequency of sale, and percentage of horses entering the ring that did not ultimately sell. The results of the analysis show a negative impact on horse prices from the slaughter ban ranging from -24% to -8% for horses in the price range of $600 to $1,400 per head.

This article shares a similar econometric methodology with the GAO analysis. However, two features distinguish the current study from the existing literature. First, the use of a single auction facilitates a more detailed specification of the hedonic model in terms of horse- and seller-specific parameters. The GAO model was constrained by a lack of similar data on horse characteristics across the auctions they considered. Second, information gathered from the operator of the Montana auction confirms that both U.S. and Canadian buyers, some of whom buy for the slaughter market, regularly attend this auction. There is no information on the presence of either U.S or foreign slaughter buyers at the sales in Oklahoma or Virginia.

Model of the U.S. Horse Slaughter Market

While consumption of horsemeat has never been a culturally accepted practice in the United States, there are several other countries where horsemeat is consumed and often considered a delicacy. The United States, with an estimated supply of 9.8 million head of horses in 2010 (Food and Agriculture Organization of the United Nations) and no domestic demand for horsemeat, has historically been a net exporter. In 2006, the United States exported horsemeat to the following countries (listed in order by highest value importer): Belgium-Luxembourg, Switzerland, France, Russia, Japan, Mexico, Germany, Italy, Netherlands, Taiwan, and the Bahamas (Foreign Agriculture Service, Global Agricultural Trade Service Online). Live horses have also historically been exported from the United States to slaughter facilities in Canada and Mexico (see figure 1).

The market for U.S. horses intended for slaughter is depicted in figures 2a and 2b. Figure 2a, representing the market prior to the 2007 slaughter ban, shows that the cumulative demand for slaughter horses is the sum of domestic slaughter buyers and foreign slaughter buyers. The total number of horses purchased for slaughter in domestic and foreign plants is Q_1 and the market-clearing price is P_1. The relative number of horses purchased for slaughter by domestic buyers is higher than foreign buyers, reflecting domestic horse slaughter of 104,899 (Q_{US1}) head and exports of 32,789 (Q_{EX1}) head in 2006, the last full year of domestic slaughter (Government Accountability Office, 2011).

Panel 2b depicts the impact of a ban on horse slaughter in the United States. Under the ban, U.S. slaughter buyers no longer have an outlet for their horses, forcing demand to zero. The result is an inward shift in the total demand for U.S. horses (D to D') with a new equilibrium quantity (Q_2) and price (P_2). At P_2, foreign buyers will purchase more U.S. horses for export. Evidence of such an increase in horses purchased by foreign buyers can be seen in the 2008 to 2010 trade data presented in figure 1. The corresponding decrease in price to P_2 is less easily seen due to the lack of public price data on slaughter horses.

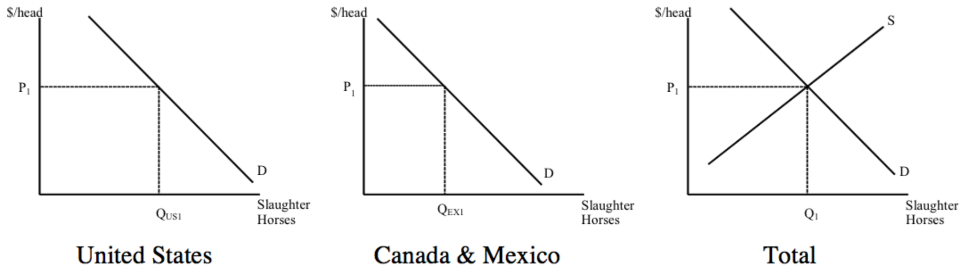

Figure 2a. Market for U.S. Slaughter Horses prior to Domestic Ban of Horse Slaughter

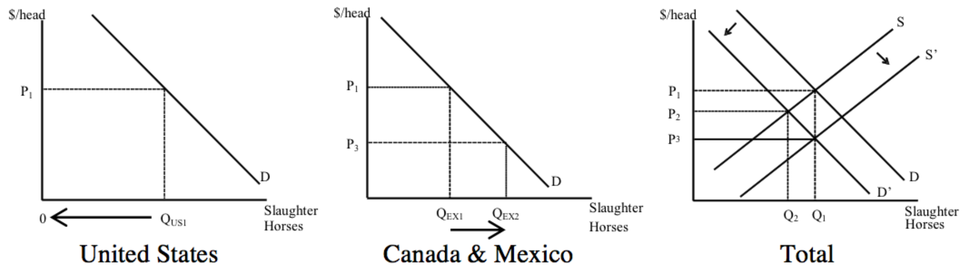

Figure 2b. Market for U.S. Slaughter Horses after U.S. Slaughter Ban Enacted

The horse export data, however, indicate an additional change in the U.S. slaughter horse market. Exports of U.S. horses not only increased, but by 2010 the number of horses exported for slaughter was equal to the total number of horses slaughtered domestically and exported for slaughter in 2006. This suggests that the total quantity of U.S. horses purchased in 2010 returned to Q_1. A sufficiently large outward shift in the supply of slaughter horses in the U.S. market (S to S') could decrease price to P_3, a price low enough to entice foreign buyers to purchase Q_{EX2}.

What would cause such a shift in the supply of horses suitable for slaughter? One plausible explanation (and the primary reason given by animal rights groups for the decline in horse prices) is the recession. Horse activities, as with many expenditures of discretionary income, are likely to decrease as household income levels become stagnant or decline. Evidence gathered by the GAO and outlined in their report documents increases in the number of horses going to large-animal shelters or being abandoned on public land (Government Accountability Office, 2011). It does not seem likely that horses worth several thousand dollars at auction would be abandoned or given up for adoption; rather, it is probably the lower valued horses that are being liquidated.

Empirical Model of Horse Prices

The economic model estimated in this article is specified to reflect the information gathered from analysis of supply and demand conditions proposed in figures 2a and 2b, domestic and foreign slaughter, and the Montana horse auction. The combination of these sources suggests that prices for slaughter horses have declined, but not due solely to the slaughter ban. The hedonic model will allow us to test for a slaughter-ban price decline as well as impacts of other factors.

Following Rosen's (1974) model of implicit prices, horses are assumed to be a heterogeneous good, and the price paid for them at auction is influenced by the horses' characteristics. We specify the price of a given horse at auction as:

Table 1. Summary Statistics of Regression Dataset

Variable	Description	Mean	Std Dev	Min	Max
Sale_Price	Sale price ($/head)	1,615.420	1,764.994	50	43,000
ln(Sale_Price)	Natural log of sale price	7.029	.870	4	11
Age	Age of horse (years)	7.070	3.954	2	26
Age^2	Age of horse, squared	65.616	79.186	4	676
Gelding	Binary variable equal to 1 if horse is a gelding, 0 otherwise	.662	.473	0	1
Stallion	Binary variable equal to 1 if horse is a stallion, 0 otherwise	.024	.153	0	1
*Mare**	Binary variable equal to 1 if horse is a mare, 0 otherwise	.313	.464	0	1
$G \times Age$	Interaction variable between Gelding and Age	4.673	4.374	0	26
$G \times Age^2$	Interaction variable between Gelding and Age^2	40.965	60.501	0	676
$S \times Age$	Interaction variable between Stallion and Age	.149	1.201	0	22
$S \times Age^2$	Interaction variable between Stallion and Age^2	1.464	17.253	0	484
$M \times Age$	Interaction variable between Mare and Age	2.235	4.248	0	26
$M \times Age^2$	Interaction variable between Mare and Age^2	23.036	66.153	0	676
QH	Breed listed as Quarter Horse	.536	.499	0	1
AP	Breed listed as Appaloosa or Paint	.096	.295	0	1
Other	Breed listed other than QH or AP	.023	.150	0	1
*Grade**	No breed listed	.345	.475	0	1
Broke	Horse is broke, but not otherwise trained	.248	.432	0	1
Mountain	Horse is trained for mountain, pack work	.064	.244	0	1
Ranch	Horse is trained for ranch work	.412	.492	0	1
Showing	Horse is trained for showing or performance disciplines	.112	.316	0	1
Breeding	Horse listed as breeding stock	.095	.294	0	1
*Not_Started**	Horse training has not started	.043	.203	0	1
Bred	Mare being sold is currently in foal	.080	.271	0	1
Hip	Approximate sale order of horse in the auction	298.564	185.428	1	755
Hip^2	Approximate sale order of horse in the auction, squared	123,515.800	122,122.800	1	570,025
Picture	Picture of horse appears in sale catalog	.276	.447	0	1
Contact	Contact information of seller given in sale catalog	.146	.353	0	1
Coggins	Coggins paperwork available	.770	.421	0	1
Pedigree	Sire information of horse listed in sale catalog	.653	.476	0	1
Earnings	Earnings of horse over lifetime listed in sale catalog	.009	.097	0	1
Distance	Miles from auction horse was transported	385.820	312.788	8	1,731
Distance^2	Miles from auction horse was transported, squared	246,670.000	358,494.100	71	2,996,915
Fall_Sale	Binary variable equal to 1 if horse sold in fall catalog sale, 0 otherwise	.495	.500	0	1
*Spring_Sale**	Binary variable equal to 1 if horse sold in spring catalog sale, 0 otherwise	.505	.500	0	1
Year_2004	Binary variable equal to 1 if horse sold in 2004, 0 otherwise	.063	.242	0	1
*Year_2005**	Binary variable equal to 1 if horse sold in 2005, 0 otherwise	.187	.390	0	1

(continued on next page. . .)

Table 1. – continued from previous page

Variable	Description	Mean	Std Dev	Min	Max
Year_2006	Binary variable equal to 1 if horse sold in 2006, 0 otherwise	.162	.368	0	1
Year_2007	Binary variable equal to 1 if horse sold in 2007, 0 otherwise	.193	.395	0	1
Year_2008	Binary variable equal to 1 if horse sold in 2008, 0 otherwise	.186	.389	0	1
Year_2009	Binary variable equal to 1 if horse sold in 2009, 0 otherwise	.146	.354	0	1
Year_2010	Binary variable equal to 1 if horse sold in 2010, 0 otherwise	.063	.243	0	1
Drought_Index	Palmer drought severity index, 6 month lag	-.927	1.516	-4	1
Unemp_Index	BLS unemployment index, 6 month lag	5.148	1.849	4	10
Slaughter_Ban	Binary variable equal to 1 if horse sold after slaughter ban enacted in summer 2007, 0 otherwise	.494	.500	0	1

Notes: The dataset contains 4,111 observations. A single asterisk (*) denotes variables omitted from hedonic regression for model identification.

$$P(\boldsymbol{x},\boldsymbol{z}) = f(x_1,\ldots,\; x_n, z_1,\ldots,\; z_n), \tag{1}$$

where $\boldsymbol{x}$ is a vector of horse-specific characteristics and $\boldsymbol{z}$ is a vector of time-specific characteristics. The price function is continuously differentiable up to the second order. The price function is simultaneously determined by bid and offer functions of buyers and sellers. The regression variables are listed in table 1, along with descriptions.

The vector of horse-specific characteristics used in the hedonic pricing model includes physical attributes, training or experience level of the horse, and strategies used by the seller to market the horse's best qualities. Physical attributes of the horses, including their gender, age, breed, and whether or not they are in foal (mares only) are included in the model.

Gender is categorized into one of three parameters: *Mare* equals 1 for female horses and 0 otherwise; *Stallion* equals 1 for male horses and 0 otherwise; and *Gelding* equals 1 for neutered male horses and 0 otherwise. We do not have any expectations of price impact of the gender variables *a priori*. The age of a horse enters the model in linear and quadratic form to account for the potential nonlinear impact of years of experience and training. The variables for age are interacted with the gender variables (G_Age, S_Age, M_Age, G_Age^2, S_Age^2, M_Age^2) to account for likely differences in the effect that age has on price as a result of breeding potential and temperament (Taylor et al., 2006).

Horses can be characterized as either purebreds (Quarter Horse, Appaloosa/Paint, Thoroughbred) or a mixed/unknown breed (grade); this information is given to buyers at auction. The parameters describing information on breed are categorized into four distinct groups: *QH* are horses whose breed is listed as Quarter Horse, *AP* are Appaloosa or Paint breeds, *Other* are a mixture of other specified breeds, and *Grade* are horses whose breed is not listed in the sale catalog. The effects of these factors on sale price is not clear and, therefore, left to be determined empirically.

The training and experience of a horse is expected to affect the number of potential buyers and the overall sale price. Horses with training for specific tasks or performance records that indicate high skill levels are likely to fetch a higher price in the market. To capture these potential effects, the training of each horse was categorized into six distinct groups of binary indicator variables.[3] The first variable is *Broke*, indicating a horse has been broke to ride, but does not have any other training.

[3] The information regarding training was taken from the sale catalogs and is provided by the seller. There is no third-party confirmation of the extent or quality of the training. Therefore, while this information provides a signal to potential buyers, it is not a totally objective measure.

The next training variable is *Mountain* and indicates a horse has experience being ridden or used as a pack animal in the backcountry. The third category of training is measured by the variable *Ranch* and indicates a horse has experience doing a variety of tasks commonly needed for ranch work. The fourth training variable, *Showing*, indicates a horse that has experience in the show ring and is likely to be trained for any one of a variety of disciplines (i.e., cutting, reining, Western pleasure, etc.). The fifth variable is *Breeding*, which indicates that a horse is most suitable for breeding purposes. The final training variable is *Not_Started*, which indicates that the horse has not been broke to ride or received any specific training. The effect of these training parameters on sale price is difficult to determine *a priori* and is left as a quantitative effort.

The last physical characteristic in the model is the binary variable *Bred*, which denotes if a mare is currently in foal if equal to 1 and not bred if 0. A mare that is already bred may bring a higher value, *ceteris paribus*, because of the added value of the foal. This positive price effect will be diminished if the choice of sire is not valued by potential buyers.

Other horse-specific factors that may affect the selling price of a horse at auction are not considered physical but rather reflect marketing strategies employed by sellers or auction management. For example, the order in which the horses are sold, the extent of information provided by a seller to potential buyers, and the distance travelled by the horse to the sale are all specific to each horse sold but are not characteristics of the horses themselves. Sale order (commonly referred to as the hip number) is a continuous variable that enters the model as both a linear term (*Hip*) and a quadratic term (Hip^2) to capture any nonlinear effects that sale order may have on the final bids of buyers.

The effort that sellers make to market their horses may also affect the sale price. The catalog of all the horses entered in the sale provides useful information to potential buyers. The exact description listed for each horse varies widely, from two or three lines of basic information to an extensive description of the horse: its pedigree, training, and competition earnings; a picture of the horse; and the seller's contact information. The amount of information provided in the sale catalog may signal quality of the horse to potential buyers. Therefore, variables are included in the model to account for this signaling effect. The first parameter (*Picture*) is a binary variable equal to 1 if a picture of the horse is included in the catalog and equal to 0 otherwise. The second variable (*Contact*) is also binary and equals 1 if the seller's contact information is listed in the catalog. It is equal to 0 if no contact information is provided. Also included in the model is a binary variable indicating if a horse has documentation of a negative Coggins test (*Coggins*). While not every listing provides pedigree information (names of sire and dam's sire), horses with recognizably good breeding may bring a higher price if the information is available to potential buyers. The binary variable *Pedigree* is equal to 1 if lineage information is provided and 0 otherwise. Another piece of information that conveys the value of a horse is its lifetime earnings from competition. For those horses that have won cash prizes, the binary variable *Earnings* equals 1 and is 0 otherwise.[4] We expect all the marketing variables to positively affect sale price.

The remaining horse-specific variable included is the distance traveled to the sale. The catalog description for each horse contains a reference to the hometown and state of the horse. This information was used to calculate the approximate number of miles traveled to get the horse to auction. The number of miles traveled enters the model as a linear variable, *Distance*, and a quadratic variable, $Distance^2$. This allows for a nonlinear effect of miles traveled on sale price. It is not clear how distance traveled may affect sale price.

For a given auction, the observations of horses sold constitute a cross-section of data. The data presented in this article are observations on horses sold at the same auction over a period of seven years. However, the number of horses that are sold more than once at this sale during the time period analyzed is unknown. Therefore, we consider these data to be a repeated cross-section of observed

[4] It would be preferable to use the earnings values, rather than assign the existence of the information to a binary variable. However, what would be considered a sizeable earning record in one discipline may be low for another. We have no way to normalize these data, so a binary specification was chosen.

sale prices rather than a panel dataset. Given the potential for both seasonal and annual changes in the economic conditions that may affect buyers' willingness to pay for horses, we add fixed effects to the model that are time specific. The parameter *Fall* is included in the model as a binary variable equal to 1 if an observation is from a fall sale and 0 if it is from a spring sale. Annual fixed effects are included in the model to account for any factors that may be pertinent to the horse industry for the years of data in the sample (*Year_2004* to *Year_2010*). The signs of the year and seasonal fixed effects are unknown *a priori*.

The cost of feeding horses is expected to have an impact on the price buyers are willing to pay. Depending on the way a horse is boarded, feed cost can be comprised of pasture-grazing fees, hay and grain prices, and feed-supplement prices. Drought or wet conditions can impact not only the quality and carrying capacity of pasture, but also the availability of hay. For both feed sources, drought conditions can greatly increase the cost of feeding horses. As a proxy for the cost of feeding a horse, we include a six-month historical drought-index variable, *Drought_Index*. It is expected that as the price of feed increases (drought conditions worsen and the index number falls) the price people are willing to pay for horses will decline.

As previously discussed, it is likely that a shift in the supply of slaughter horses occurred shortly after the U.S. slaughter-plant closures and the driving force for this shift was the recession. It is not feasible to obtain a direct measure of the impact of the economic downturn on horse owners. Therefore, a proxy for the overall impact on U.S. households was chosen. The 2008 recession is proxied by a six-month moving average of the Bureau of Labor Statistics unemployment index. The unemployment-index variable, *Unemp_Index*, represents the changes in household disposable income that are likely to be used for purchases like horses. An increase in the unemployment index is expected to correspond with an outward shift in the supply of horses to the market, causing a decline in auction prices.

The thesis question is whether or not closure of all U.S. horse-slaughter plants in 2007 affected the Montana horse market. A fixed effect variable is used to measure impacts of the last three domestic plants ending operations in the summer of 2007 on prices received for horses at the Montana auction. The variable *Slaughter_Ban* is equal to 1 if an observation comes from a sale that occurred after the plant closures and 0 if the observation is from a sale held prior to the closures. Based on the economic reasoning discussed in the previous section, the expected sign of the *Slaughter_Ban* variable is negative.

Data

The data used for this analysis include 4,111 auction transactions. The horses sold in the sale came from thirty-two states and four Canadian provinces, with a majority from Montana (29%) and Wyoming (16%). This auction averages over 390 horses sold per sale, with an average sale price of $1,615 per head and a median sale price of $1,200 per head. The average and median per head sale prices for each sale in the time period analyzed are given in table 2. For each sale, the average and median prices are not close in magnitude, suggesting skewness of the data. Graphical analysis of the price data supports this observation, and a natural log transformation of the dependent price variable, ln*(Sale_Price)*, is used to prevent bias in the OLS estimates. Summary statistics of the variables used in the hedonic regression are given in table 1.

The data used to estimate the model were collected from several sources. The sale price data and corresponding sale-catalog information on each horse in the dataset were gathered from sales held at the Billings Livestock Commission Company in Billings, Montana. The variables included in the hedonic model were based on information that was available for all the horses in the sale catalogs.

Additional data were collected for the variables used to proxy feed costs (*Drought_Index*) and the economic downturn (*Unemp_Index*). The variable *Drought_Index* was created using a six-month historical average of the Palmer Drought Severity Index (PDSI) for the state of Montana (National

Table 2. Summary Statistics of Auction Prices from Billings, Montana

	Spring Sale			Fall Sale		
Sale Year	**# of Horses Sold**	**Avg Sale Price ($/hd)**	**Median Sale Price ($/hd)**	**# of Horses Sold**	**Avg Sale Price ($/hd)**	**Median Sale Price ($/hd)**
2004	–	–	–	257	1,322.12	900.00
2005	356	1,641.15	1,400.00	413	1,954.30	1,400.00
2006	336	1,835.00	1,600.00	330	1,514.46	1,100.00
2007	388	1,769.09	1,600.00	407	1,667.20	1,000.00
2008	405	1,630.67	1,300.00	359	1,603.87	1,000.00
2009	335	1,495.82	1,000.00	267	1,100.36	650.00
2010	258	1,540.47	1,450.00	–	–	–

Oceanic and Atmospheric Administration, 2011). For each fall and spring sale in the dataset, the average value of the PDSI in the previous six months was calculated. The variable *Unemp_Index* was calculated using a seasonally adjusted unemployment index for the Mountain region, published by the Bureau of Labor Statistics (2011).[5] This index enters the model as an average of the index value for the six months preceding each sale in the dataset.

Econometric Model Results

The hedonic model specified in equation (1) was first estimated using Ordinary Least Squares (OLS) regression. The results of the OLS regression are presented in table 3. The semi-logarithmic form of the regression requires the coefficients of binary variables be transformed prior to interpretation. Following Kennedy (1981):

$$g^* = exp(\hat{c} - 0.5\hat{V}(\hat{c})) - 1, \quad (2)$$

where $\hat{c}$ is the estimated coefficient of the binary variable and $\hat{V}(\hat{c})$ is an estimate of the variance of $\hat{c}$. For each binary variable, the transformed coefficients are given in table 3. The estimated coefficients indicate that both horse-specific and time-specific factors impact sale prices.

Physical Characteristics of Horses

As expected, both a horse's gender and age affect its value at auction. Geldings are estimated to sell at a premium of 26.1% over mares with the same characteristics, while stallions are projected to sell at a premium of 155.9% over otherwise identical mares. Age is also a large driver of prices received for horses. Geldings increase in value by 14.2% for each year beyond age one, but do so at a declining rate. The peak of this age effect on price occurs between ages eight and nine, holding all other parameters in the model constant. Mares have a similar price effect from age, with a peak effect occurring between ages nine and ten. Stallions, however, show a different pattern due to age. They tend to decrease in price as they mature beyond age one and do so at an increasing rate.

Horses registered as Quarter Horses, Appaloosas, Paints, or other recognized breeds do not sell at a statistically different price relative to horses listed in the sale catalog as grade. We expect a registered horse to sell for more than an unregistered horse, but the distinction doesn't appear to matter enough for buyers at this sale to bid more for a registered horse.

Training increases the value of horses, as compared to horses that have not been started. The largest premiums go to horses trained for showing (144.5%), ranch work (83.6%), and mountain work (57.3%). Horses listed in the sale catalog as broke or green broke receive a premium of 40.9%,

[5] The BLS Mountain division includes Arizona, Colorado, Idaho, Montana, Nevada, New Mexico, Utah, and Wyoming.

Table 3. Regression Results of the Hedonic Pricing Model by Estimation Method

	Ordinary Least Squares Regression			Median Quantile Regression		
Variable	**Coeff**	**Std Err**	**P-Value**	**Coeff**	**Std Err**	**P-Value**
Gelding	0.261	0.077	0.002	0.391	0.087	0.000
Stallion	1.559	0.197	0.000	1.149	0.223	0.000
$G \times Age$	0.142	0.014	0.000	0.141	0.015	0.000
$G \times Age^2$	−0.008	0.001	0.000	−0.008	0.001	0.000
$S \times Age$	−0.037	0.052	0.485	−0.082	0.059	0.166
$S \times Age^2$	0.002	0.003	0.484	0.005	0.003	0.115
$M \times Age$	0.070	0.014	0.000	0.073	0.016	0.000
$M \times Age^2$	−0.004	0.001	0.000	−0.003	0.001	0.000
QH	0.096	0.135	0.454	0.230	0.153	0.132
AP	−0.155	0.138	0.251	0.002	0.156	0.988
Other	−0.181	0.138	0.170	−0.021	0.156	0.893
Broke	0.409	0.047	0.000	0.374	0.053	0.000
Mountain	0.573	0.062	0.000	0.443	0.071	0.000
Ranch	0.836	0.048	0.000	0.607	0.054	0.000
Showing	1.445	0.055	0.000	0.862	0.062	0.000
Breeding	0.130	0.069	0.072	0.118	0.078	0.130
Bred	−0.101	0.058	0.072	−0.158	0.066	0.016
Hip	0.001	$2.12E-04$	0.000	0.001	$2.39E-04$	0.000
Hip^2	$-2.71E-06$	$3.25E-07$	0.000	0.000	$3.68E-07$	0.000
Picture	0.204	0.025	0.000	0.198	0.028	0.000
Contact	0.332	0.034	0.000	0.273	0.038	0.000
Coggins	0.126	0.026	0.000	0.100	0.030	0.001
Pedigree	0.206	0.134	0.143	0.038	0.151	0.799
Earnings	1.197	0.117	0.000	0.978	0.132	0.000
Distance	$-1.91E-04$	$1.06E-04$	0.071	0.000	$1.20E-04$	0.283
$Distance^2$	$1.69E-07$	$9.22E-08$	0.066	0.000	$1.04E-07$	0.219
Fall_Sale	−0.185	0.035	0.000	−0.173	0.040	0.000
Year_2004	−0.045	0.063	0.483	−0.058	0.071	0.420
Year_2006	−0.283	0.053	0.000	−0.379	0.060	0.000
Year_2007	−0.395	0.064	0.000	−0.539	0.073	0.000
Year_2008	−0.353	0.083	0.000	−0.364	0.093	0.000
Year_2009	−0.328	0.142	0.007	−0.256	0.161	0.112
Year_2010	−0.158	0.188	0.412	0.116	0.212	0.585
Drought_Index	0.065	0.015	0.000	0.072	0.017	0.000
Unemp_Index	−0.128	0.026	0.000	−0.164	0.030	0.000
Slaughter_Ban	−0.038	0.062	0.547	−0.141	0.070	0.043
Constant	6.804	0.144	0.000	6.908	0.162	0.000
Adjusted R^2	0.400			Pseudo R^2	0.265	

Notes: The binary variable coefficients of the OLS regression are transformed due to the semilogarithmic form of the regression.

while horses listed as best suitable only for breeding receive the smallest premium—13.0%—over horses that have not been not started.

A bred mare sells at a statistically significant discount of 10.0% versus an identical mare that is not bred. A bred mare may be considered by some bidders to be more valuable because stud fees have already been paid. However, the negative coefficient indicates buyers value the ability to make their own breeding choices rather than purchasing a mare whose foal's pedigree is predetermined.

Marketing Strategies

The marketing and sale-related parameters indicate several of the strategies used by sellers positively impact price. As the sale progresses, prices tend to increase but do so at a decreasing rate. The highest point in the quadratic curve of the sale-order estimate is hip number 208, which is located about two-thirds of the way through a typical sale.

Sellers who provide a picture of their horse, their personal contact information, proof of a negative Coggins test, and list their horse's earnings record can expect premiums over comparable horses lacking this information in the sale catalog. The only piece of information that does not appear to change the price buyers are willing to pay for a horse is pedigree information on the horse's sire and dam's sire. Pedigree is typically found to be a statistically significant determinant of price in the literature, so the results from this sale indicate that horses of good breeding may find higher premiums at more specialized sales.

The distance a horse is transported to participate in the sale also affects price. Longer distances are estimated to decrease sale price at an increasing rate. This may indicate that as the cost of transportation for a return trip increases, sellers will decrease the reservation price they are willing to accept.

Other time-specific variables also impact the price of horses, including whether or not the sale is held in the spring or fall. Horses sold in the fall sell for approximately 18.5% less than identical horses sold at the spring sale. The annual fixed effects indicate that while 2004 and 2010 are not statistically different from the omitted year of 2005, the years from 2006 to 2009 have negative and statistically significant coefficients. These annual fixed effects are included in the model to account for factors (not otherwise specified in the model) affecting either supply or demand for horses at the regional level.

Based on the results, current drought conditions in the western states do affect horse sale prices. The variable for the Palmer Drought Index, which decreases as drought conditions worsen, has a positive estimated coefficient. The value of the coefficient indicates that an improvement in pasture carrying capacity resulting from a lessening of drought conditions will increase sale price by 6.5% for each one-unit change in the index.

Slaughter Ban and Supply Shifts

An index measuring the unemployment rate for the western United States was used as a proxy for recessionary effects causing an outward shift in the supply of horses brought to market that are within the price range of slaughter buyers. The coefficient can be interpreted as having a statistically significant -12.8% impact on slaughter-horse prices as the unemployment index rate rises by one unit.

The other variable related to the question of interest is the binary variable for the closing of U.S. slaughter plants. The coefficient for the slaughter ban is not statistically different from zero in the OLS model, suggesting that the closure of the slaughter plants did not affect horse prices at the Montana sale.

This result was surprising, given the information available on slaughter horse exports, summary statistics from the auction data, and the expected shift in demand described in figure 2. Further analysis to verify this result seems warranted. Therefore, a Quantile Regression (QR) method was employed and the model was re-estimated. The *a priori* justification for turning to a QR analysis stems from two issues with the data: a skewed distribution of sale prices and the lack of price data specific to slaughter buyers.

Two statistical properties of QR make it attractive for an application to highly skewed data. First, QR does not require a normally distributed data population to obtain unbiased parameter estimates, as with OLS. We applied a natural log transformation to the sale-price data to reduce the skewness,

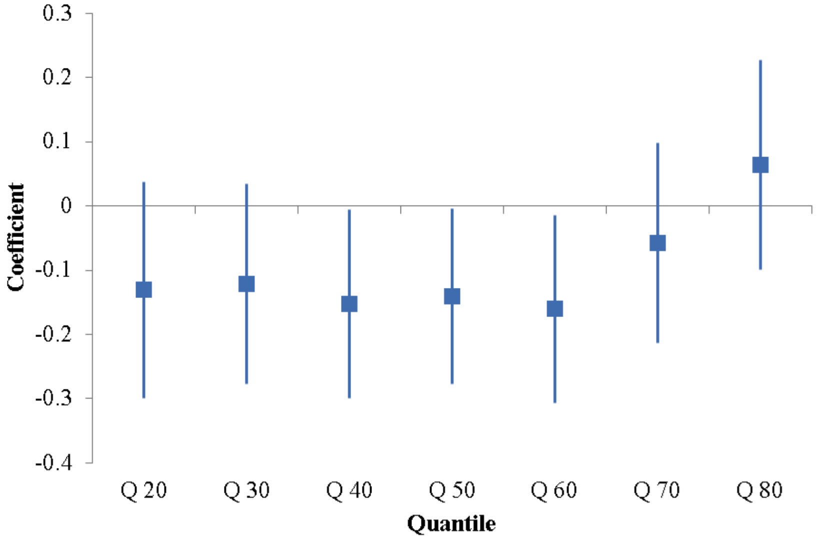

Figure 3. Coefficient Estimates of *Slaughter_Ban* Parameter and 95% Confidence Intervals across Quantile Regressions

but subsequent tests for skewness of the transformed data rejected the null hypothesis of normality. Therefore, the OLS estimates remain susceptible to bias, and an alternative estimation method is preferable. The second desirable statistical property of QR is that application of the natural log to price data does not complicate the QR regression, as it is invariant to monotone transformations such as the natural log (Koenker, 2005).

The absence of sale data specific to horses going to slaughter is another complication in our analysis of the slaughter ban. Because a buyer's intentions for the horses they purchase are not made public, we cannot know exactly which horses at the Montana auction are part of the slaughter market and which are sold in the recreational market. We do know that the price that slaughter buyers are willing to pay is constrained by the per pound prices they receive from the slaughter plants, so it is possible that the slaughter ban will affect horses selling within a certain price range and not those outside that range. The QR method allows us the flexibility to estimate the model across different quantiles of the logged sale price and see if the effect of the slaughter ban changes as the price per head increases or decreases.

The results of the QR estimated at the median sale price of $1,200 per head are listed in table 3 beside the OLS results. Two observations are readily made from a comparison of the OLS and QR results. The first is that statistical significance and signs of coefficient estimates are largely unchanged from the OLS results. The second observation is that the coefficient estimate of the binary variable for slaughter ban is now statistically significant, with a p-value of 0.043. The coefficient estimate of -14.1% indicates that prices declined in the period following the closure of U.S. slaughter plants for horses selling close to the median price of $1,200 per head.

Although only the median QR results are reported, the model was estimated for several other quantiles to determine if the slaughter ban coefficient varied across the price distribution. The estimated *Slaughter_Ban* coefficients and corresponding 95% confidence intervals are shown graphically in figure 3 for each quantile estimated. The confidence interval includes zero for the slaughter ban coefficient estimated at the twentieth, thirtieth, seventieth, and eightieth quantiles. However, the p-values of the slaughter ban coefficients for the twentieth and thirtieth quantiles are between 0.125 and 0.128, suggesting that there was also a negative price impact for these price quantiles at reasonably high levels of statistical significance. The *Slaughter_Ban* coefficient is -13.0% for the twentieth quantile and -12.2% for the thirtieth quantile.

The *Slaughter_Ban* coefficient estimates of -15.2%, -14.1%, and -16.1% for the fortieth ($950/head), median ($1,200/head), and sixtieth quantiles ($1,500/head), respectively, are statistically different from zero at p-values of 0.04 or less. The results of the coefficient estimates at all quantiles indicate that while the slaughter ban has not decreased prices for horses above $1,500 per head, those selling at or below $1,500 per head have experienced a decline in prices between 12% and 16% since the ban took effect.

Discussion

This study provides evidence that closure of all remaining U.S. horse-slaughter facilities in September 2007 negatively impacted horse prices at the Montana auction. However, the estimated 12% to 16% decline in price from the end of U.S. slaughter was not a universal impact, and additional negative price effects may be accredited to the recession, which began shortly after the slaughter ban took effect. These results are similar to those reported in the 2011 GAO analysis, where the negative effects ranged from -23.5% to -8.2% over a price range of $600 to $1,400 per head, respectively. The difference in results between the two studies may be attributed to a hedonic model specification with more horse-specific characteristics and the use of data from a single regional horse market.

Determining the exact price impact of elimination of the domestic horse-slaughter industry on a regional horse market is complicated by the nature of available data on horse prices, the relative proximity of Canadian slaughter plants to Montana, and the close timing of the slaughter ban relative to the national recession. A lack of public data on prices paid for horses taken to slaughter required a proprietary dataset for a large, regional horse market and a creative approach to regression modeling that allowed flexibility in parameter estimation. The QR method revealed a negative price impact on horses selling within a certain price range, a result that was masked by the OLS regression.

The price range that slaughter buyers pay for horses at this market could not be determined *a priori*, and the QR analysis suggests that slaughter-ban impacts differed across various price ranges. It is possible that horses in the $950 to $1,500 per head price range were bid on by slaughter buyers directly, which caused the decline in price upon implementation of the ban. It is also possible these horses are just outside the price range of slaughter buyers, but the existence of a residual demand from slaughter buyers comprises a portion of the market value of these horses. The adverse impact on residual demand by slaughter buyers appears to have “trickled up” to the next price level of horses. This result is consistent with arguments made by North, Bailey, and Ward (2005), in which the removal of a salvage value for horses could impact the price of horses not sold directly for slaughter.

The proximity of the Montana auction to Canada has consistently drawn buyers and sellers from several provinces over the time period examined in this study. The presence of Canadian slaughter buyers suggests that the estimated negative impact on horses purchased for slaughter is understated, as compared to a regional auction located farther away from either Canadian or Mexican slaughter plants. A larger negative price impact would be expected in the Midwest, for example. This hypothesis is supported by current plans to open a slaughter plant in Missouri, following a reversal of the 2005 FMIA amendment in late 2011 (Cummings, 2012).

The accuracy of the point estimate for the price impacts of the slaughter ban is also limited by the extent to which the proxy used in the analysis represents the recession’s impact on household decisions regarding horse activities. A more disaggregated measure of household purchases and liquidations of horses would be preferred but is not feasible to obtain. However, the negative sign on the unemployment index corresponds to the expected impact based on the information presented on the increased number of horses priced below the median at the Montana auction and increases in Canadian exports after the slaughter ban.

The evidence presented in this study points to a nearly simultaneous inward demand shift from the slaughter ban and an outward supply shift due to the recession within the slaughter horse market.

Both factors occurring with such closing timing have created a perfect storm of negative price impacts for the Montana horse market. The result of the past five years of policy and macroeconomic changes has been a decline in revenues for horse owners looking to liquidate their horse herds and an elimination of markets for U.S. slaughter horse buyers and plant owners. The situation, however, has been beneficial for Canadian horse buyers and slaughter plant owners as they continue to enjoy depressed prices for the horses they purchase to meet foreign customers' demand.

The reversal of the 2005 FMIA amendment in November 2011 makes U.S. horse slaughter possible, assuming funding for USDA inspectors is subsequently made available. If this occurs, the first slaughter plants to open in the United States will enjoy a short-run benefit from low horse prices due to poor economic conditions. The 12% to 16% price decline from the slaughter ban, however, will be bid away as more plant capacity is brought online in coming years. Reversing the policy will also benefit horse owners who suffered a loss in asset value due to the ban on horse slaughter. Lastly, allowing horse slaughter to resume will increase economically attractive options for horse owners wanting to sell horses they can no longer afford to care for. This may reduce the number of horse abandonments and improve welfare for some horses in the United States.

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