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Reducing Self-Selection Bias in Feeder Cattle Premium Estimates Using Matched Sampling

Brian R. Williams, Eric A. DeVuyst, Derrell S. Peel, and Kellie Curry Raper

Past value-added research employs hedonic pricing models to estimate premiums associated with value-added feeder cattle characteristics. However, hedonic pricing models require restrictive assumptions and impose a functional form. Producers also self-select into a treatment group, potentially biasing estimates. Using propensity score matching, we reduce potential bias from producer self-selection and from imposing a functional form. Results suggest that hedonic pricing models may be negatively biased in estimates of premiums received by value-added calf producers. Current adopters receive a premium of \$5.38/cwt from participation in a certified preconditioning program, while nonadopters would realize \$5.17/cwt by adopting certification. Hedonic model values range from \$0.52/cwt to \$4.32/cwt, for similar or identical preconditioning programs.

Key words: feeder cattle, propensity score matching, selection bias, value-added marketing

Introduction

Each year, thousands of Southern Plains cow-calf producers sell feeder cattle at local auction barns. As the calves pass through the sale ring, buyers quickly assess the relative value of each lot. Some information can be quickly observed visually, such as hide color, horns, weight, head, gender, and general health. Additional information can occasionally be obtained from the auctioneer, including vaccinations, weaning status, preconditioned status, and the seller's name. Lalman and Smith (2001); Avent, Ward, and Lalman (2004); Dhuyvetter, Bryant, and Blasi (2005); Bulut and Lawrence (2007); and Williams et al. (2012) show that weaned, vaccinated, and preconditioned calves sell for a premium over calves straight from their dams' sides ("bawlers" in the jargon of the sale barn). These premiums provide incentives for producers to represent their calves as having value-added traits, even if they do not. In economics jargon, producers providing false information are said to be "masquerading."

Given the potential for masquerading producers, third-party verification of value-added practices may improve the credibility of seller claims regarding credence attributes, improving sale prices for their calves. Oklahoma Quality Beef Network (OQBN) is one such third-party verification program (Oklahoma Cooperative Extension Service, 2013). The third party, Oklahoma Cooperative Extension Service, has no vested interest in cattle sold in this program and so lends credence to value-added producers' claims of completed management practices. Schumacher, Schroeder, and Tonsor (2012) find that feedlots are willing to pay an additional \$0.85/cwt for third-party certification and an additional \$2.37/cwt for USDA certification that calves have been weaned and vaccinated. However, it is possible that producers who wean and/or vaccinate their calves annually may already

Brian R. Williams is an assistant extension professor in the Department of Agricultural Economics at Mississippi State University. Eric A. DeVuyst is a professor, Derrell S. Peel is a professor and Breedlove Chair, and Kellie C. Raper is an associate professor in the Department of Agricultural Economics at Oklahoma State University.
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have a reputation, may be more likely to have adopted many of the value-added management practices, and may receive a premium without third-party certification.

Previous research concerned with the marginal value of various characteristics in calves generally employs hedonic pricing models. Schroeder et al. (1988) is one of the first to utilize a hedonic model to investigate the impact of animal health, body condition, fill, and muscling on feeder cattle prices. Coatney, Menkhaus, and Schmitz (1996) implement a system of hedonic equations to estimate the values of cattle characteristics. Other research uses hedonic pricing models to examine the contribution of value-added practices such as preconditioning, weaning, and vaccinating. Lalman and Smith (2001) and Dhuyvetter, Bryant, and Blasi (2005) examine the premium received for preconditioning calves and compare the added revenue to the cost of preconditioning.

Several researchers use data from video auctions. For example, Bailey, Peterson, and Brorsen (1991) compare video auction prices to market prices. King et al. (2006) and Zimmerman et al. (2012) use hedonic modeling to estimate premiums at Superior Livestock auctions for a variety of factors including vaccinations, horns, and breed. Blank, Forero, and Nader (2009) estimate a hedonic pricing model to examine premiums for various management practices using data from Western Video Market. Blank, Forero, and Nader (2009) include premiums for preconditioning, but not for third-party certification. Similarly, Turner, Dykes, and McKissick (1991) estimate premiums for cattle characteristics in teleauctions.

Others estimate hedonic pricing models using data from conventional auctions. Lawrence and Yeboah (2002) estimate the value of age and source verification. Bulut and Lawrence (2007) and Avent, Ward, and Lalman (2004) estimate the value of calves that are certified, weaned, and vaccinated, but do not report the value of certification. Similarly, Williams et al. (2012) employ hedonic pricing models to determine the marginal value of vaccinations, weaning, certification, and other value-added characteristics at OQBN and non-OQBN sales in Oklahoma.

Cow-calf producers are a diverse group with varying management abilities. A significant proportion of cow-calf producers are small in size: 14.5% of Oklahoma producers maintain a herd size of twenty-five or fewer and nearly 44% of Oklahoma producers have fewer than fifty head (Williams et al., 2013). Producers with smaller herds likely have additional income sources and therefore have less time to dedicate to herd management. Conversely, producers with 250 or more head account for about 5% of all Oklahoma producers. Oklahoma's largest cattle producers adopt more value-added management practices than smaller producers (Williams et al., 2013), likely because they typically do not have other sources of income, but rather choose to direct more of their time and resources toward herd management. A producer whose survivability depends on the profitability of their cattle operation is more likely to carefully manage herd genetics, have a shorter calving window to increase size uniformity, and pay attention to more of the small management details such as calf fill and fleshiness. Some producers may lack the facilities (e.g., working facilities) necessary to conveniently complete value-added practices. Yet other producers may have high opportunity costs associated with value-added management.

Even though calves from two producers may be nearly identical in all observable characteristics except value-added management, the underlying decision to engage in value-added practices involves unobservable producer characteristics. Hence, it is rational for some producers to seek third-party certification of their management practices while other producers may find the opportunity cost of the additional time and resources needed for certification to be too great. Given these differences, it is likely that producers are self-selecting into the OQBN program based upon differences in incentives and opportunity costs that are not easily quantified by data collectors. This self-selection into a treatment group potentially creates bias in hedonic parameter estimates (Tauer, 2009).

To reduce the potential for self-selection bias, a propensity score matched sampling methodology without the restrictions and assumptions necessary in regression models is employed using data collected at Oklahoma feeder calf auctions in fall 2010. Matching value-added lots with similar non-value-added lots imitates the random placement of lots of feeder cattle into treatment and control groups and so resembles a controlled experiment (Tauer, 2009; Gillespie and Nehring, 2012). If placement into the treatment group is random, the treatment is considered independent of covariates (Sekhon, 2011) and selection bias is reduced. Using the matching samples method, we compute 1) the premiums received by adopters of value-added practices, 2) the premiums foregone by nonadopters, and 3) the average premium available to or received by all producers. Using matched methods, lots of calves that are similar except for one characteristic (or a bundle of characteristics) are matched. Treatment lots, possessing some trait, are then directly compared to matching control lots lacking the trait under consideration. This direct comparison allows for the estimation of treatment effects as if a controlled experiment had been conducted, whereas a hedonic pricing model groups all observations together and parameter estimates are estimated by minimizing error across the entire dataset. While propensity score matching does not completely eliminate selection bias, it has been shown to reduce the potential for bias relative to a hedonic model (Heckman et al., 1998). Producers who would receive the positive net economic returns for adopting a value-added management practice are expected to select into the treatment group.

Unlike hedonic models, propensity score matching also provides a means to estimate the premiums for adopters and nonadopters separately. Given that many producers do not adopt value-added management practices and with such diversity among Oklahoma's cattle producers, there are many potential explanations as to why a producer may choose not to adopt a management practice. Among those reasons is the idea that nonadopters may not receive as high of a premium as adopters. In addition to reducing selection bias relative to a hedonic model, propensity score matching also allows us to compare the premiums for adopters and nonadopters and determine if there is a difference in premium between the two groups.

Methods

The focus of this paper is to find the premiums associated with the management practices required for cattle to be OQBN certified while accounting for potential presence bias resulting from self-selection and misspecification found in hedonic pricing models. To qualify for OQBN certification, calves must be dehorned, weaned a minimum of forty-five days, vaccinated, and dewormed; bull calves must also be castrated (Oklahoma Quality Beef Network, 2012). Using the matched samples approach, calves with a trait are assigned to the treatment group ($T_i = 1$) and calves without the trait are assigned to the control ($T_i = 0$). Then, the basis for lot i is defined as $Y_i T_i$, where

$$(1) \qquad Y_i(T_i) = \begin{cases} Y_i(0) \text{ if } T_i = 0; \\ Y_i(1) \text{ if } T_i = 1. \end{cases}$$

The basis for each lot is calculated as the difference between the sale price of the lot of calves and the weekly Oklahoma City average price for a 750-pound steer (U.S. Department of Agriculture, Agricultural Marketing Service, 2010).

While methods such as the Heckman correction model (Heckman, 1979) are available to correct for selection bias, these methods are feasible only when producer characteristics are known. Heckman's 1979 two-step correction model first uses a probit model to estimate a Mill's Ratio with adoption as the dependent variable and an individual's characteristics as the independent variable. The Mill's Ratio is then used as an independent variable in the hedonic model. Because producer characteristics are not observed, we use another method known as matched sampling.

Several matching methods have been proposed in past literature. Exact matching occurs when treatments and controls are matched exactly on $\boldsymbol{X}$, where $\boldsymbol{X}$ is a vector of traits shared by both control and treatment observations. However, two types of exact matching can occur: complete and incomplete matching on $\boldsymbol{X}$ (Rosenbaum and Rubin, 1985). Complete matching occurs when all treated lots are matched with a control lot containing exactly the same values for $\boldsymbol{X}$, while incomplete matching occurs when a subset of the treatments are matched with controls and the remainder of the observations are discarded (Rosenbaum and Rubin, 1985). Rosenbaum and Rubin (1985) show that omitting observations in incomplete exact matching introduces bias in estimating treatment effects. Unfortunately, exact matches do not exist for all treatment lots, eliminating the possibility of using an exact matching method. To correct for these problems, Rosenbaum and Rubin (1983), propose a propensity score that increases the balance (the similarity between the distribution of $\boldsymbol{X}$ in the control and treatment groups) by estimating a propensity score for each observation and then matching on that propensity score. The propensity score measures the likelihood that a lot of cattle will be sold as value-added. Most propensity scores are found using a logistic regression, as in equation (2), in which T_i is the dependent variable and $\boldsymbol{X}$ are independent variables. The propensity score for lot i is calculated as

$$P(T_i = 1|\boldsymbol{X_i}) = \frac{e^{F(\boldsymbol{X_i})}}{1 - e^{F(\boldsymbol{X_i})}}, \tag{2}$$

where the propensity score $P(T_i = 1|\boldsymbol{X_i})$ is the probability that T_i equals 1 given X_i and $F(X_i)$ is a function of the explanatory variables such as the observable traits of feeder cattle. Ideally, we would include producer characteristics in our propensity score estimation to reflect management ability, but those characteristics are not easily observed. Rather, characteristics of the lot of cattle are used as a proxy for producer characteristics. Cattle with similar characteristics or groups of characteristics are assumed to reflect similar producer management preferences, abilities, and facilities. In our model, which is derived from Williams et al. (2012),

$$\begin{aligned} F(X_i) \quad = \quad & \beta_0 + \beta_1 head_i + \beta_2 head_i^2 + \beta_3 avgwt_i + \beta_4 avgwt_i^2 + \\ & \beta_5 wean_i + \beta_6 vac_i + \sum_{j=1}^{7} \beta_{6+j} color_{ij} + \beta_{13} Brahman_i + \sum_{k=1}^{2} \beta_{13+k} flesh_{ik} + \\ & \sum_{l=1}^{2} \beta_{15+l} gender_{il} + \beta_{18} horns_i + \sum_{m=1}^{2} \beta_{18+m} fill_{im} + \beta_{21} Health_i. \end{aligned} \tag{3}$$

Williams et al. (2012) use the equation on the right-hand-side of equation (3) to directly estimate feeder cattle basis, whereas in our equation $F(X_i)$ is a logit model of the probability a given lot is in the treatment group (i.e., value-added). This equation does not model the marginal economic value of value-added practices but rather the impact of a variable on the likelihood that a lot is value added in the characteristic(s) of interest. In equation (3), $head_i$ is the number of head in the lot (the observational unit), $avgwt_i$ is the average weight of calves in the lot, $wean_i$ is a binary variable equal to 1 if calves are weaned and 0 otherwise, vac_i is a binary variable equal to 1 if calves are vaccinated and 0 otherwise, $color_{ij}$ is a series of binary variables indicating calf color (colors included are black, mixed, red, red mixed, hereford, dairy, white, and other), $Brahman_i$ is a binary variable equal to 1 if calves have Brahman influence and 0 otherwise, $flesh_{ik}$ are binary variables indicating calves' average condition score, $gender_{il}$ are binary variables indicating calves' gender where steer is the base variable omitted, $horns_i$ is a binary variable equal to 1 if horns are present and 0 otherwise, $fill_{im}$ are binary variables indicating average gut fill, and $health_i$ is a binary variable equal to 1 if healthy and 0 otherwise. To ensure that the matches are balanced—meaning that the distribution of the independent variables X_i in the control group has the same mean and variance as the distribution of independent variable X_i in the treatment group—a method developed by Becker and Ichino (2002) is incorporated. This method selects $F(X_i)$ so that control and treatment groups are balanced, leaving out certain variables in some practices or bundles of practices (Mahasuweerachai, Whitacre, and Shideler, 2010).

The strengths and weaknesses of other matching methods were considered, including exact matching, kernel matching, Mahalanobis, and more.footnoteSeveral matching methods were used and the differences between models were not significant. Certification ATE premiums using Mahalanobis matching and Kernel matching fall well within the 95% confidence interval using nearest-neighbor matching. Nearest-neighbor matching is one of the more common methods of matching and seems to work well when considering a large number of covariates and statistical packages to ensure that a balanced sample between treated and control lots is readily available (Stuart, 2010). The nearest-neighbor method minimizes

$$C_i = \min_j ||P(T_i) - P(T_j)||, \tag{4}$$

where C_i is the set of controls matched to treated lot i, $P(T_i)$is the propensity score for treated lot i, and $P(T_j)$ is the propensity score for control lot j (Becker and Ichino, 2002). The matches are found using the statistical program Stata (StataCorp, 2011). As many as five untreated lots can be matched with each treated lot.

To estimate the treatment effects, assignment to the treatment group is assumed to be unconfounded. That is,

$$\{Y(0), Y(1) \perp T\}|X. \tag{5}$$

In other words, selection into the treatment and control group is random given observable covariates X. Because the treatment of each lot is independent of $\boldsymbol{X}$, the estimated treatment effects are unbiased.

The matched pairs are used to find the treatment effect of the management practice. Following Sekhon (2011), the average treatment effect (ATE) is

$$\text{ATE} = E(Y_i(1)|T_i = 1) - E(Y_i(0)|T_i = 0), \tag{6}$$

where $E(Y_i(1)|T_i = 1)$ is the expected premium for observation i given that the feeder calves in that lot have the characteristic of interest and $E(Y_i(0)|T_i = 0$ is the expected premium for observation i given that the feeder calves in the lot lack the characteristic of interest.

Equivalent to the marginal effect in a hedonic model, the ATE is the treatment effect for all observations. However, because of the possibility of self-selection by producers into a certification program or other treatment, the outcome may differ for those in treatment versus those in control groups (Sekhon, 2011). The average treatment effect for the treated (ATT) yields the premium received by producers who adopt a management practice. The average treatment effect for the control (ATC) is the premium that nonadopters would have received had they adopted a management practice. To find the treatment effect for each group, ATT is calculated as

$$\text{ATT} = E(Y_i(1)|T_i = 1) - E(Y_i(0)|T_i = 1) \tag{7}$$

and ATC is

$$\text{ATC} = E(Y_i(1)|T_i = 0) - E(Y_i(0)|T_i = 0), \tag{8}$$

where $E(Y_i(0)|T_i = 1)$ is the expected premium for those in the control group given that the feeder calves in that lot lack the characteristic of interest and $E(Y_i(1)|T_i = 0)$ is the expected premium for those in the treatment group given that the feeder calves in that lot have the characteristic of interest. However, $E(Y_i(0)|T_i = 1)$ and $E(Y_i(1)|T_i = 0)$ are not observed in the data, and equations (7) and (8) cannot be directly estimated (Sekhon, 2011).

Heckman et al. (1998) describe an alternative way of calculating ATT that is conditional on characteristics $\boldsymbol{X}$. Assuming that equation (5) holds, Heckman et al. (1998) rewrite equation (7) as

$$\text{ATT} = E(Y_i(1)|\boldsymbol{X}, T_i = 1) - E(Y_i(0)|\boldsymbol{X}, T_i = 1), \tag{9}$$

where $E(Y_i(1)|\boldsymbol{X}, T_i = 1)$ is the expected premium for those in the treatment group given a set of characteristics $\boldsymbol{X}$ and treatment $T = 1$ and $E(Y_i(0)|\boldsymbol{X}, T_i = 1)$ is the expected premium for those in the control group given a set of characteristics $\boldsymbol{X}$ and treatment $T = 1$.

Following Heckman et al. (1998), ATC can be rewritten as

$$\text{ATC} = E(Y_i(1)|\boldsymbol{X}, T_i = 0) - E(Y_i(0)|\boldsymbol{X}, T_i = 0), \tag{10}$$

where $E(Y_i(1)|\boldsymbol{X}, T_i = 0)$ is the expected premium for those in the treatment group given a set of characteristics $\boldsymbol{X}$ and treatment $T = 0$ and $E(Y_i(0)|\boldsymbol{X}, T_i = 0)$ is the expected premium for those in the control group given a set of characteristics $\boldsymbol{X}$ and treatment $T = 0$.

Imperfect matches can result in a biased estimated treatment effect. For example, research has shown that, *ceteris paribus*, buyers will pay a premium for larger lots. If a lot of two calves is matched with a lot of twenty calves, the resulting treatment effect will be biased. Bias is removed using a regression adjustment as proposed by Rubin (1979). Following Tauer (2009), we define the regression function for bias adjustment as

$$\hat{\mu}_T(\boldsymbol{X}) = \hat{\alpha}_{T0} + \hat{\alpha}_{T1}\boldsymbol{X}, \tag{11}$$

where $\hat{\mu}_T(\boldsymbol{X})$ is the estimated basis for treatment T given characteristics $\boldsymbol{X}$ and $\hat{\alpha}_{T0}$ and $\hat{\alpha}_{T1}$ are the parameters estimated from the least squares regression. Equation (11) is then used to predict the estimated outcome as

$$\tilde{Y}_i(0) = \begin{cases} Y_i & \text{if } T_i = 0; \\ \frac{1}{N}\sum_{j \in N} Y_j + \hat{\mu}_0(\boldsymbol{X_i}) - \hat{\mu}_0(\boldsymbol{X_j}) & \text{if } T_i = 1; \end{cases} \tag{12}$$

and

$$\tilde{Y}_i(1) = \begin{cases} \frac{1}{N}\sum_{j \in N} Y_j + \hat{\mu}_1(\boldsymbol{X_i}) - \hat{\mu}_1(\boldsymbol{X_j}) & \text{if } T_i = 0; \\ Y_i & \text{if } T_i = 1; \end{cases} \tag{13}$$

where $\tilde{Y}_i(0)$ is the estimated basis for lots in the control group, $\tilde{Y}_i(1)$ is the estimated basis for lots in the treatment group, $\hat{\mu}_1(\boldsymbol{X})$ is the estimated premium for the treatment group given characteristics $\boldsymbol{X}$, $\hat{\mu}_0(\boldsymbol{X})$ is the estimated basis for the control group given characteristics $\boldsymbol{X}$, N is the total number of matches, Y_j is the reported basis for observation j, and observation j is a subset of observations only in the control group in equation (13) and only in the treatment group in equation (12).

The estimated outcomes from equations (12) and (13) are used to rewrite the estimator for ATE as

$$\text{ATE} = E(\tilde{Y}_i(1)|T_i = 1) - E(\tilde{Y}_i(0)|T_i = 0). \tag{14}$$

The regression adjusted estimator for ATT is

$$\text{ATT} = E(\tilde{Y}_i(1)|\boldsymbol{X}, T_i = 1) - E(\tilde{Y}_i(0)|\boldsymbol{X}, T_i = 1) \tag{15}$$

and the regression adjusted estimator for ATC is

$$\text{ATC} = E(\tilde{Y}_i(1)|\boldsymbol{X}, T_i = 0) - E(\tilde{Y}_i(0)|\boldsymbol{X}, T_i = 0). \tag{16}$$

After calculating the ATE, ATT, and ATC, a bootstrap is used to estimate the standard errors and p-values.

Nearest-neighbor matching does not use all observations to calculate the ATE, ATT, and ATC. Rather, all treated lots are matched with at least one control lot, but not every control lot is matched to a treatment lot. This prevents potential bias when a close match does not exist for a control lot. For example, we do not want to match a longhorn control with a black-hided treatment lot with a similar propensity score. We test the sensitivity of the hedonic model estimated by Williams et al. (2012) by re-estimating their hedonic model and omitting the same control observations omitted in the matching sample method.

Data

Data were collected at sixteen feeder cattle auctions from October through December 2010. Data include 2,973 lots consisting of 22,363 head of cattle (Williams et al., 2012). Eight auctions included OQBN cattle, with two comprised entirely of OQBN cattle (Williams et al., 2012). The OQBN certification program certifies that calves have participated in a preconditioning program in which calves are vaccinated, dehorned, and castrated, in addition to being weaned for a minimum of forty-five days. Information on price, lot size, management practices, and phenotype was collected for each lot of cattle. Phenotypic (physically observable) characteristics include per animal weight, hide color, fleshiness, gender, frame score, uniformity, health, horns, muscling, and fill (Williams et al., 2012). Management practices such as vaccinations, weaning, certification from a preconditioning program, and age and source verification were also collected. Additional data collected include sale location and time and whether seller identification was announced. To maintain consistency, all data were collected by five individuals trained by United States Department of Agriculture (USDA) Agriculture Marketing Service (AMS) professionals (Williams et al., 2012). To account for cattle price variation over time, a basis is calculated as the difference between the sale price of each lot and the weekly average Oklahoma City price for a 750-pound steer as reported by in the "Weekly Cattle Summary" for Oklahoma City (U.S. Department of Agriculture, Agricultural Marketing Service, 2010).

Observations with a mean lot weight of less than 300 pounds or greater than 800 pounds are removed. Observations with missing data or recording errors are also removed from the dataset. The final dataset consists of 2,762 observations, including 816 OQBN certified lots and 1,946 uncertified lots.

The summary statistics for all lots, OQBN certified lots only, and noncertified lots only are shown in table 1. There are only a few minor differences in characteristics among groups. The mean lot size is slightly larger for OQBN certified lots, with nearly nine head compared to 7.48 in uncertified lots. All calves in certified lots are weaned, vaccinated, and dehorned, while 51% are weaned and 20% are vaccinated in uncertified lots.

Lots containing calves with at least 50% black-hided calves make up 77% of the certified lots, while 69% of uncertified lots have at least 50% black-hided calves in them. The distribution of other hide colors is similar among groups. Calves in the certified group tend to have higher body condition scores than those in the uncertified group. This is not surprising, given that these calves are preconditioned for at least forty-five days. In the certified group, 1% of calves are classified as thin compared to 3% of calves in the uncertified group, and 36% of calves in the certified group are classified as fleshy compared to 27% in the uncertified group.

Data from one of the sale barns creates a modeling challenge. In one sale barn, OQBN calves are comingled. That is, OQBN calves from two or more producers are sorted into relatively homogeneous (in terms of size and breed) lots of cattle. This is the only sale barn with comingled sales. We have reason to believe that there is a tradeoff between lot size and comingling. Comingling, while increasing lot size to a more desirable level, also increases the possibility of introducing new pathogens or diseases from one group of cattle to another group of cattle and can potentially reduce feedlot gains. Additionally, genetics differ within a comingled lot of calves, so end points can differ. This potentially reduces the feedlot's ability to market homogeneous pots of cattle (i.e., large groups of cattle that reach Choice grade and avoid yield grade discounts at a similar days-on-feed). The modeling challenge is that there is no set of matching cattle for this barn. Specifically, there are no non-OQBN calves at that sale barn that are comingled. So, if a comingled variable is included, there are no matches for the OQBN calves from that barn. Anecdotally, this has the effect of biasing downward the estimated value of OQBN calves in our data, since comingling reduces the value of lots of calves. The alternative—omitting these calves from the data—results in the loss of valuable information. A hedonic model such as the one used by Williams et al. (2012) separates out the comingling effect with the use of dummy variables for each sale. We test the fragility of our estimate

Table 1. Summary Statistics

	All Lots		Certified Lots Only		Uncertified Lots Only	
Variable	**Mean**	**Std Dev**	**Mean**	**Std Dev**	**Mean**	**Std Dev**
Lot size	7.89	13.84	8.88	11.87	7.48	14.57
Average weight (cwt)	5.31	1.17	5.44	1.15	5.25	1.18
Certified	0.30	0.46	1.00	0.00	0.00	0.00
Weaned	0.66	0.48	1.00	0.00	0.51	0.50
Vaccinated	0.44	0.50	1.00	0.00	0.20	0.40
Dehorned	0.94	0.24	1.00	0.00	0.91	0.29
Brahman influence	0.07	0.25	0.09	0.28	0.06	0.24
Healthy	0.99	0.09	0.99	0.08	0.99	0.09
Color						
Black	0.72	0.45	0.77	0.42	0.69	0.46
Mixed	0.06	0.25	0.06	0.24	0.07	0.25
Red	0.08	0.27	0.06	0.25	0.08	0.27
Red mixed	0.02	0.15	0.02	0.15	0.02	0.15
Hereford	0.02	0.13	0.01	0.12	0.02	0.14
Dairy	0.01	0.11	0.00	0.06	0.02	0.13
White	0.08	0.27	0.06	0.23	0.09	0.29
Other	0.01	0.09	0.00	0.06	0.01	0.10
Flesh						
Average	0.68	0.47	0.63	0.48	0.70	0.46
Thin	0.02	0.15	0.01	0.09	0.03	0.17
Fleshy	0.30	0.46	0.36	0.48	0.27	0.44
Steers	0.51	0.50	0.58	0.49	0.48	0.50
Heifers	0.44	0.50	0.42	0.49	0.45	0.50
Bulls and/or Mixed	0.04	0.21	0.00	0.00	0.06	0.24
Fill						
Average	0.81	0.39	0.82	0.38	0.81	0.39
Gaunt	0.01	0.09	0.00	0.05	0.01	0.10
Full	0.18	0.38	0.18	0.38	0.18	0.38

by re-evaluating premiums with the comingled lots omitted. These results are compared to the results from the full model.

Results

Results for the logistic regressions used to calculate the propensity scores are presented in table 2. Four models are estimated: one for each value-added management practice. The nearest-neighbor matching method uses the propensity to create matches between the treatment group and the control group.

Table 4 presents the average treatment effects from the matching procedure. Assuming all other requirements have been met, the average treatment effect (ATE) of certification alone is \$5.25/cwt ($p \leq 0.001$). This is greater than the range of -\$0.52/cwt for 650lb calves to \$2.81/cwt for 350lb calves found by Williams et al. (2012), toward the high end of the range for certification premiums of \$1.51/cwt to \$5.89/cwt found by Ward, Ratcliff, and Lalman (2003), and higher than the range of \$1.47/cwt to \$4.32/cwt found by Zimmerman et al. (2012). The average treatment effect for the treated (ATT) when the treatment is certification is \$5.38/cwt ($p \leq 0.001$). The average treatment effect for controls (ATC) (calves that are not certified) is \$5.17/cwt and is statistically significant ($p \leq 0.001$). In other words, producers who do not third-party certify their calves would gain

Table 2. Logistic Regression Results for Determining Propensity Score

Variable	Certification Parameter Est.	Certification p-value	Weaning Parameter Est.	Weaning p-value	Vaccinating Parameter Est.	Vaccinating p-value	Dehorning Parameter Est.	Dehorning p-value
Intercept	−1.29	< 0.01	−1.83	< 0.01	−3.21	< 0.01	4.09	< 0.01
No. of Head in Lot					0.01	< 0.01	−0.01	0.07
Avg. Weight	0.09	0.01	0.46	< 0.01	−0.34	< 0.01	−0.21	< 0.01
Weaned					5.82	< 0.01	−0.31	0.13
Vaccinated							2.29	< 0.01
Color								
Mixed	−0.12	0.48	0.80	< 0.01	0.45	0.02	−1.29	< 0.01
Red	−0.26	0.13	−0.35	0.02	0.45	0.05	−1.30	< 0.01
Red Mixed	−0.07	0.81	0.30	0.31			−2.00	< 0.01
Hereford			−1.10	< 0.01	−0.19	0.70	−1.61	< 0.01
Dairy			−0.40	0.28	−1.74	0.01	−3.78	< 0.01
White	−0.45	0.01	−0.31	0.04	−0.01	0.96	−0.61	0.06
Other	−1.12	0.07	−1.33	< 0.01	0.30	0.69	−1.93	< 0.01
Flesh								
Thin	−1.18	< 0.01	−0.76	< 0.01	−0.75	0.14	0.52	0.34
Fleshy	0.48	< 0.01	0.57	< 0.01	0.25	0.03	0.11	0.63
Heifers	−0.14	0.10	−0.10	0.24	−0.25	0.02	0.19	0.29
Bull					−2.90	< 0.01	−0.53	0.09
Fill								
Gaunt			−0.33	0.50	−1.52	0.07	−0.66	0.33
Full	−0.40	< 0.01	0.28	0.04			−0.02	0.93
Likelihood Ratio (p-value)	67.20 (<0.01)		342.27 (<0.01)		1576.71 (<0.01)		268.37 (<0.01)	

Notes: Blank cells in table 2 are a result of either there being no calves with that characteristic receiving the treatment or because the characteristic is included as a part of the treatment.

Table 3. Impact of Various Practices on Premiums Received by Producers Using a Nearest-Neighbor Matching Method and Omitting Comingled Lots of Cattle ($/cwt)

Treatment	Average Treatment Effect[a] Premium	Average Treatment Effect[a] p-value	Average Treatment Effect for Treated[b] Premium	Average Treatment Effect for Treated[b] p-value	Average Treatment Effect for the Control[c] Premium	Average Treatment Effect for the Control[c] p-value
OQBN Certification	6.44	<0.001	6.22	<0.001	6.57	< 0.001
Weaned Calves	5.23	<0.001	5.31	<0.001	5.12	< 0.001
Vaccinated Calves	6.38	<0.001	6.18	<0.001	6.54	0.001
Dehorned	7.81	<0.001	8.01	<0.001	4.89	0.025

Notes: [a]The ATE is the treatment effect for all observations and is equivalent to the marginal effect in a hedonic model.
[b]The average treatment effect for the treated (ATT) yields the premium received by producers who adopt a management practice.
[c]The average treatment effect for the control (ATC) is the premium that nonadopters would have received had they adopted a management practice.

$5.17/cwt more by certifying their calves in the OQBN program, assuming they have already met all of the qualifications. The ATT and ATC for certification are not statistically different from one another. Table 3 shows the premium estimates when comingled lots of cattle are omitted. The ATE, ATT, and ATC for certification when comingled calves are omitted are $6.44/cwt, $6.22/cwt, and $6.57/cwt. Each of these values is higher than when comingled cattle are included, suggesting that the certification premium estimates are conservative and supporting the hypothesis that comingling reduces sale value.

Table 4. Impact of Various Practices on Premiums Received by Producers Using a Nearest-Neighbor Matching Method ($/cwt)

	Average Treatment Effect[a]		Average Treatment Effect for Treated[b]		Average Treatment Effect for the Control[c]		ATC-ATT[d]	
Treatment	**Premium (# of Matches)**	**p-value**	**Premium (# of Matches)**	**p-value**	**Premium (# of Matches)**	**p-value**	**Premium**	**p-value**
OQBN Certification	5.248	≤0.001	5.379	≤0.001	5.168	≤0.001	-0.212	0.835
	(3055)		(1468)		(1587)			
Weaned Calves	5.234	≤0.001	4.925	≤0.001	5.804	≤0.001	0.879	0.266
	(3163)		(1670)		(1493)			
Vaccinated Calves	6.785	≤0.001	5.400	≤0.001	8.024	≤0.001	2.623	0.171
	(6849)		(3470)		(3379)			
Dehorned	5.262	0.001	5.362	0.020	3.773	0.037	-1.589	0.444
	(4875)		(4334)		(541)			

[a]The ATE is the treatment effect for all observations and is equivalent to the marginal effect in a hedonic model.
[b]The average treatment effect for the treated (ATT) yields the premium received by producers who adopt a management practice.
[c]The average treatment effect for the control (ATC) is the premium that nonadopters would have received had they adopted a management practice.
[d]ATC–ATT is the difference between the average treatment effect for the control and the average treatment effect for the treated. The p-value is obtained using a bootstrap.

Table 5. 95% Confidence Interval of the Impact of Various Practices on Premiums Received by Producers Using a Nearest-Neighbor Matching Method ($/cwt)

	Average Treatment Effect[a]		Average Treatment Effect for Treated[b]		Average Treatment Effect for the Control[c]		Hedonic	
Treatment	**Lower**	**Upper**	**Lower**	**Upper**	**Lower**	**Upper**	**Lower**	**Upper**
OQBN Certification[d]	3.43	7.06	3.31	7.45	3.13	7.20	−0.35	0.55
Weaned Calves	3.89	6.57	3.54	6.31	4.03	7.58	1.05	3.05
Vaccinated Calves	4.68	8.88	3.95	6.85	4.54	11.51	0.24	2.64
Dehorned	2.16	8.36	2.07	8.65	0.25	7.29	1.86	4.44

Notes: [a]The ATE is the treatment effect for all observations and is equivalent to the marginal effect in a hedonic model.
[b]The average treatment effect for the treated (ATT) yields the premium received by producers who adopt a management practice.
[c]The average treatment effect for the control (ATC) is the premium that nonadopters would have received had they adopted a management practice.
[d]Certification premium for the hedonic model is calculated at a mean weight of 529 lbs. using Monte Carlo integration.

Table 6. Select Results from Re-estimating Hedonic Pricing Models Using Data from Three Matched Samples

	Wean		Vaccinate		Horns	
Variable	**Estimate**	**p-value**	**Estimate**	**p-value**	**Estimate**	**p-value**
Intercept	56.08	< 0.01	58.88	< 0.01	54.49	< 0.01
Log(head)	3.02	< 0.01	2.73	< 0.01	2.69	< 0.01
Average weight	−15.14	< 0.01	−16.38	< 0.01	−15.31	< 0.01
Average weight squared	0.82	< 0.01	0.93	< 0.01	0.84	< 0.01
Vaccinate	1.49	0.02	1.26	0.03	1.19	0.07
Wean	2.24	< 0.01	2.33	< 0.01	2.42	< 0.01
Certify	19.21	0.02	17.31	0.04	30.81	< 0.01
Weight × cert	−6.22	0.04	−4.91	0.10	−9.39	< 0.01
Weight squared × cert	0.49	0.06	0.35	0.17	0.71	0.01
Red	−3.78	< 0.01	−2.60	< 0.01	−2.45	< 0.01
Hereford	−6.42	< 0.01	−7.77	< 0.01	−8.33	< 0.01
White	−2.44	< 0.01	−0.64	0.42	−0.94	0.28
Dairy	−25.74	< 0.01	−36.49	< 0.01	−34.69	< 0.01
Other	−7.44	< 0.01	−10.94	< 0.01	−11.47	< 0.01
Black mix	−3.33	< 0.01	−1.93	0.06	−2.04	0.13
Red mix	−5.03	< 0.01	−4.42	< 0.01	−4.26	< 0.01
Brahman	−4.28	< 0.01	−4.09	< 0.01	−3.84	< 0.01
Heifer	−12.14	< 0.01	−11.58	< 0.01	−11.19	< 0.01
Bull	−4.82	< 0.01	−2.58	0.01	−4.80	< 0.01
Horns	−3.06	< 0.01	−2.66	< 0.01	−2.65	< 0.01
Likelihood Ratio (p-value)	2991.3 (<0.01)		2852.5 (<0.01)		2511.3 (<0.01)	

The ATE for weaning calves is \$5.23/cwt ($p \leq 0.001$), which is greater than the \$2.05/cwt premium found by Williams et al. (2012) and the \$4.50/cwt premium found by Zimmerman et al. (2012). Confidence intervals were calculated for the treatment effects as well as for the hedonic model used by Williams et al. (2012) for weaning, vaccinating, and dehorning. As seen in table 5, the confidence intervals have no overlap between the three treatment effect estimates and the hedonic estimate for weaning. As shown in table 6, when the hedonic model from Williams et al. (2012) is applied to the subset of data used for estimating weaning treatment effects, the premium for weaning is \$2.24/cwt, slightly higher than the premium reported by Williams et al. (2012). The ATT for weaning is \$4.93/cwt ($p \leq 0.001$) and the ATC for weaning is \$5.80/cwt ($p \leq 0.001$). The treatment effects for weaning indicate that producers who do not currently wean their calves would receive the highest premium if they had weaned their calves, but the difference in ATC and ATT is not statistically significant. When lots containing comingled cattle are omitted, the ATE, ATT, and ATC for weaning are \$5.23/cwt, \$5.31/cwt, and \$5.12/cwt, respectively. Here we find mixed results in comparison to the results with comingled cattle included. Whether this is due to some actual difference in buyer behavior in response to comingling or is due to a modeling artifact is unclear.

The ATE, ATT, and ATC for vaccinating calves are \$6.79 ($p \leq 0.001$), \$5.40/cwt ($p \leq 0.001$), and \$8.02/cwt ($p = 0.001$). When comingled cattle are excluded, the ATE is \$6.38/cwt, the ATT is \$6.18/cwt, and the ATC is \$6.54/cwt. Each of these premiums is greater than the premium of \$1.44/cwt ($p = 0.05$) for vaccinating reported by Williams et al. (2012) and \$1.68/cwt ($p = 0.10$) for one vaccination reported by Zimmerman et al. (2012). As with weaning, there is no overlap in the confidence intervals between the treatment effects using matching and the premium estimate from Williams et al.'s 2012 hedonic model. When the hedonic model from Williams et al. (2012) is applied to the subset of data used for estimating vaccination treatment effects, the premium for vaccinating is slightly lower than the value reported by Williams et al. (2012) at \$1.26/cwt. The

Table 7. Estimate and 95% Confidence Interval for Certification By Weight Group ($/cwt)

	Average Treatment Effect[a]			Average Treatment Effect for Treated[b]			Average Treatment Effect for the Control[c]		
Treatment	**Mean**	**Lower**	**Upper**	**Mean**	**Lower**	**Upper**	**Mean**	**Lower**	**Upper**
< 450 lbs.	9.46	4.48	14.43	10.09	3.74	16.43	9.13	3.96	14.31
450–550 lbs.	3.98	−0.03	8.00	4.70	0.92	8.49	3.48	−1.48	8.43
550–650 lbs.	4.29	1.64	6.93	4.45	1.21	7.71	4.15	1.21	7.10
> 650 lbs.	4.75	1.71	7.78	4.03	0.93	7.12	5.27	1.90	8.65

Notes: [a]The ATE is the treatment effect for all observations and is equivalent to the marginal effect in a hedonic model.
[b]The average treatment effect for the treated (ATT) yields the premium received by producers who adopt a management practice.
[c]The average treatment effect for the control (ATC) is the premium that nonadopters would have received had they adopted a management practice.

difference between premiums with and without comingled cattle indicates that premium estimates are sensitive to comingling. Both the hedonic model of Williams et al. (2012) and our matching samples models show a discount for comingling.

The ATE for calves that have been dehorned is $5.26/cwt (p=0.001), greater than the premium of $3.15/cwt (p≤ 0.001) reported by Williams et al. (2012), $1.70/cwt found by Bulut and Lawrence (2007), and $0.04–$1.61/cwt found by Zimmerman et al. (2012). Applying the hedonic model from Williams et al. (2012) to the subset of data used for estimating dehorning treatment effects, we find a premium for dehorning of $2.65/cwt. The ATT for dehorning is $5.36/cwt (p= 0.02) and the ATC for dehorning is $3.77/cwt (p= 0.037). There is a significant amount of overlap between the confidence intervals using each method, suggesting that although the mean of Williams et al.'s 2012 hedonic premium is lower than the matching estimates, it may not be statistically different. When lots of comingled cattle are excluded, the ATE, ATT, and ATC are $7.81/cwt, $8.01/cwt, and $4.89/cwt. Each of these values is greater than when comingled cattle are included.

Certification premiums and their associated 95% confidence intervals are also estimated by weight class. As shown in table 7, the mean certification premium for calves under 450 lbs. is $9.46/cwt, more than double that of calves in heavier weight groups. Although the mean value of the premium for each weight class is greater for the smallest group of calves than all other groups, this difference is not statistically significant. However, with the exception of cattle weighing 450–500 lbs., the certification premium is statistically different from zero for all weight classes.

Conclusions

Hedonic pricing models are commonly used to investigate the contribution of various characteristics to the price of a product, but they do not account for selection bias. We employ a matched sampling method to reduce selection and find the premium for OQBN certification, weaning, vaccinating, dehorning, and castrating calves. Observations from the treatment group are matched with observations from the control group using a nearest-neighbor matching method. The average treatment effect (ATE), average treatment effect for the treated (ATT), and the average treatment effect for the control (ATC) are each calculated from the matches and are corrected for bias using a linear regression. To compare to previous research, ATE is directly compared to marginal effects from hedonic models.

Results show a certification premium of $5.25/cwt for ATE, $5.38/cwt for ATT, and $5.17/cwt for ATC. The ATE is higher than the range of -$0.52/cwt to $2.81/cwt reported by Williams et al. (2012) and the range of $1.47 to $4.32 found by Zimmerman et al. (2012). The large discrepancy between the results in this paper and results reported by Williams et al. (2012) (despite using the same dataset) suggests that bias in hedonic pricing models may exist. It appears that OQBN program participants have predetermined whether or not they will receive premiums for certifying and respond accordingly to market incentives. While Williams et al. (2012) and Zimmerman et al. (2012) include an interaction variable to account for changes in the certification premium as weight changes, we do not account for weight. Weight impacts premiums for preconditioning programs, but it also impacts premiums for individual characteristics. For example, the penalty for castration increases with weight because of increased death loss if heavier bull calves are castrated. Lighter (i.e., younger) calves are more prone to respiratory disease and viral diarrhea, so preconditioning is likely to add more value to them than it would add to older, heavier calves.

An ATE of $5.23/cwt for weaning suggests that buyers value weaned calves more than previous research has indicated. For example, Zimmerman et al. (2012) report a value of $3.47/cwt and Williams et al. (2012) report a value of $2.05/cwt. The ATT for weaning is $4.93/cwt and the ATC for weaning is $5.80/cwt. While inconsistent with our expectations and not statistically significant, the difference between the ATT and the ATC for weaning suggests that the opportunity cost outweighs the benefits of weaning for producers in the control group. For example, some producers may have an off-farm income source that increases the opportunity cost of time. Other producers may find that allocating those resources toward increasing their herd size is more profitable than allocating additional time, hay, or pasture to weaning calves. Another reason that producers in the control group might elect to forgo additional premiums is that they may have crops as well. Winter wheat is typically planted in Oklahoma in September and October, at the same time that many producers choose to wean calves. The high opportunity cost of delaying planting may cause producers with both cattle and crops to sell unweaned calves.

The estimate for ATE of $6.79/cwt for vaccinating is larger than the $1.44/cwt found by Williams et al. (2012) and $1.68/cwt found by Zimmerman et al. (2012). We find an ATE of $5.26/cwt for dehorning calves, again higher than the premium of $3.15/cwt found by Williams et al. (2012) and the discount of $0.28/cwt for calves with horns found by Zimmerman et al. (2012). The ATT for vaccinating calves is $5.40/cwt and the ATC for vaccinating calves is $8.02/cwt. These estimates are higher than the $1.44/cwt found by Williams et al. (2012) and $2.03/cwt for two rounds of vaccinations reported by Zimmerman et al. (2012). The ATT and ATC for vaccinating are inconsistent with our expectation that adopters will receive higher premiums. Similar to the premiums for weaning, this inconsistency may be explained by the opportunity cost. For spring-born calves, vaccinations are typically administered in September or October, which fall during Oklahoma's winter wheat planting season. The ATT for dehorning is $5.36/cwt and the ATC for dehorning is $3.77/cwt, while Bulut and Lawrence (2007) estimate a premium of $1.70/cwt. The ATT and ATC for dehorning are consistent with expectations that producers have predetermined their premiums and self-select into the treatment group. Both practices are confirmed to add value to calves marketed through sale barns, but premiums are higher in this research than in previous research. Higher estimates for vaccinating and weaning suggest that estimates from hedonic models may be biased downward.

Re-estimating premiums excluding comingled lots of cattle yields mixed results. Premium estimates for certification and dehorning are greater when comingled cattle are omitted. Re-estimating premiums for weaning yields estimates that are higher for the ATE and ATT and lower for the ATC. Similarly, re-estimating premiums for vaccinating yields estimates that are higher for the ATT but lower for the ATE and ATC than when comingled lots are included. Mixed results indicate that, while premium estimates are sensitive to the omission of comingled lots, we cannot conclude that comingling will reduce premiums for value-added management practices.

This research not only estimates value-added premiums for all producers, but also estimates premiums for two subgroups of producers: adopters and nonadopters. Our results suggest that cow-calf producers from all groups gain additional revenue by participating in the OQBN certification program. With a $5.17/cwt certification premium for nonadopters and an average weight of 525 pounds, uncertified producers would gain an extra $27.14 per head in revenue just by certifying their calves in the OQBN certification program. This is in addition to the premiums for weaning, vaccinating, and castrating as part of the requirement for OQBN certification, although it should be noted that these premiums are not likely additive and interaction terms could provide insight into the additivity of premiums. One reason for nonadoption is that the opportunity cost of certification outweighs the benefit for some nonadopters. Some producers have off-farm jobs or other activities and simply do not have the time to invest in certifying cattle. Others may have crops that need planting at the same time that value-added management practices should be adopted. Scarce labor may instead be allocated to increasing herd size. Each of these scenarios potentially increases the opportunity cost of adoption. This presents an opportunity for extension personnel to design ways to reduce the opportunity cost of certification and increase the adoption rates of value-added practices. Increasing adoption rates of value-added practices increases revenue for cow-calf producers and ensures a larger supply of cattle with characteristics that buyers prefer, resulting in a beneficial outcome for both buyers and sellers.

Hedonic pricing models have advantages over matching samples models, namely the ease of interpreting results and additivity of coefficients. However, hedonic models are also susceptible to bias as a result of misspecification or self-selection. Propensity score models are less susceptible to misspecification and have been found to reduce selection bias relative to hedonic models. While our propensity score model could be improved with producer demographics, the matching samples method employed here adds to the tools available to researchers interested in the price impacts of value-added management activities. Results suggest that self-selection bias may be present in some hedonic models of these impacts.

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