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Calf and Yearling Prices in the Western United States: Spatial, Quality, and Temporal Factors in Satellite Video Auctions

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This paper investigates spatial, quality, and temporal factors impacting prices of calves and yearlings in the western United States using satellite video auction data and a hedonic regression framework. Prices received by western ranchers are discounted by approximately the costs of shipping cattle to the Midwest for processing. Other key results include identifying the presence of temporal price premiums for seller-offered forward contracts, providing new estimates of the marginal value associated with key quality attributes and management practices and finding support for the price benefits of third-party quality certification. We also link variability in estimated valuations for value-added attributes to the stage of the cattle cycle.

Key words: cattle inventory, cattle prices, hedonic regression, transportation cost

Introduction

The U.S. cattle market is evolving rapidly, causing changes in the factors that influence cattle prices (MacDonald and McBride, 2009). In particular, the cattle-feeding and meat-processing sectors have become increasingly consolidated (Morrison Paul, 1999, 2000; Ward, 2002; U.S. Government Accountability Office, 2009) and concentrated geographically in the central portion of the country, where five states market about 80% of all fed cattle in the United States (Johnson and Becker, 2009).

Table 1 provides additional detail on the regional distribution of calves, cattle on feed, and steer and heifer slaughter in the United States. Beef cattle production is a minor industry in the Northeast but is important elsewhere. By a considerable margin, the greatest intensity of cattle on feed and slaughtered is in Federal Region 7, consisting of Iowa, Kansas, Missouri, and Nebraska. The second greatest intensity is Federal Region 6, primarily in Oklahoma and Texas. By contrast, calf inventory is much more diffuse among the ten Federal regions, with the Southeast (Region 4) and the West, especially Region 9 (Arizona, California, Hawaii, and Nevada) having a large calf inventory relative to cattle on feed or slaughtered.

Location may thus place cattle producers in the West and Southeast at a disadvantage, relative to their counterparts in the Midwest, due to costs of transporting cattle to feeding and processing facilities (Clary, Dietrich, and Farris, 1986; Goodwin and Schroeder, 1991; Andersen et al., 2002) and, possibly, due to less competition among buyers to procure cattle in these regions (Cothern et al.,

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Table 1. Cattle Inventories and Slaughter by Geographic Area

	Calf Inventory (Head)	Cattle on Feed (Head)	Steers and Heifers Slaughtered (Head)
Region 1 (CT, ME, MA, NH, RI, & VT)	80,800	-	13,100
Region 2 (NJ & NY)	239,500	26,000	32,100
Region 3 (DE, MD, PA, VA, & WV)	712,000	124,000	345,300
Region 4 (AL, FL, GA, KY, MS, NC, SC, & TN)	2,240,000	20,000	54,900
Region 5 (IL, IN, MI, MN, OH, & WI)	2,000,000	1,305,000	1,906,600
Region 6 (AR, LA, NM, OK, & TX)	3,479,000	2,775,000	4,239,500
Region 7 (IA, KS, MO, & NE)	2,315,000	6,000,000	12,353,800
Region 8 (CO, MT, ND, SD, UT, & WY)	705,000	1,498,000	2,931,700
Region 9 (AZ, CA, HI, & NV)	1,267,000	681,000	971,300
Region 10 (AK, ID, OR, & WA)	638,600	540,000	907,800
Other States[1]		56,000	
Total	**13,676,900**	**13,025,000**	**23,756,100**

Notes: Calf inventory and cattle on feed inventory are snapshot on January 1, 2015, from Quick Stats. Federally inspected slaughter is 2014 annual total from U.S. Department of Agriculture, National Agricultural Statistics Service (2015). Cattle on feed inventory does not inventory for all states.
[1] States not reported individually are aggregated into "Other States."

1991; Andersen et al., 2002; Johnson and Becker, 2009).[1,2] For example, the number of feedlots in California declined from over fifty to just a handful over a three-decade period (Andersen et al., 2002).

Evidence suggests that western and southeastern ranchers receive lower prices relative to their Midwest counterparts (Blank, Forero, and Nader, 2009; Zimmerman et al., 2012), but to date there has been no quantification of the magnitude of such discounts as a function of cattle's distance from the Midwestern hub of feeding and processing and no determination of whether lower prices are solely due to spatial factors or also involve elements of imperfect competition.

In addition, the livestock sector has become increasingly vertically coordinated and focused on a broad array of quality considerations that involve not just physical characteristics of the animal but also how it was raised and what inputs it received (Sexton, 2013). Emerging quality attributes, such as whether an animal was raised in a humane manner and under "natural" conditions are so-called "credence attributes" that cannot be observed directly by buyers, making certification of these attributes an important consideration (Roe and Sheldon, 2007).

This paper investigates spatial, quality, and temporal factors impacting the pricing of calves and yearlings in the western United States using data from a satellite video auction and a hedonic regression framework. Video auctions operate much like traditional auctions but have the potential to generate a much larger pool of potential buyers from across the country. Video auctions also provide rich data on the characteristics of cattle offered in lots for sale, making these markets well suited to analyzing the marginal valuation of animal characteristics and attributes following the hedonic framework.[3] Cattle sold in video auctions are located at ranches across multiple states, so

[1] The question of whether regional differences in competition exist relates to the longstanding issue of spatial integration of live cattle markets. If regional markets for feeder cattle are integrated, price differences that are not due to transportation costs or quality considerations should be transitory. Most analyses of spatial market integration in the U.S. cattle sector have, however, focused on fed cattle, reaching a broad consensus that regional markets for fed cattle are integrated (Bailey and Brorsen, 1989; Schroeder and Goodwin, 1990; Goodwin and Schroeder, 1991; Schroeder, 1997; Pendell and Schroeder, 2006).

[2] Early studies of video auction pricing found mild evidence of buyer oligopsony power (Bailey, Brorsen, and Fawson, 1993; Bailey, Brorsen, and Thomsen, 1995).

[3] A possible downside to analysis based on video auction data, which would limit the generality of results, is a selection problem if cattle sold at video auctions are not representative of the cattle inventory. For example, in the early days of video auctions, Bailey, Peterson, and Brorsen (1991) found evidence that cattle sold in video auctions tended to be of higher quality than cattle sold elsewhere.

video-auction data also provide an opportunity to analyze sales by producers at different locations, examine spatial pricing patterns, and test hypotheses pertaining to regional price differences.

Early studies of satellite video auction markets focused on market definition and competitive behavior of buyers (Bailey, Brorsen, and Fawson, 1993; Bailey, Brorsen, and Thomsen, 1995; Fawson, Bailey, and Glover, 1996; Brorsen, Von Bailey, and Thomsen, 1997) and price differences between video and conventional auctions (Bailey and Peterson, 1991; Bailey, Peterson, and Brorsen, 1991). More recently, studies of video auction data have analyzed the price impacts of newer value-added management and marketing practices. Key examples include King et al. (2006), who examined the price impacts of various vaccination programs and Blank et al. (2006), Kellom et al. (2008), and Blank, Forero, and Nader (2009), who studied impacts of age and source verification of calves, vaccination programs, weaning, and other management practices.[4] The most comprehensive and recent analysis of video auction prices is by Zimmerman et al. (2012), who estimated annual hedonic regression models of feeder cattle prices for 2001–2010, focusing on value-added production practices and changes in the marginal valuation of these practices over time.

Relative to the Zimmerman study and other prior studies of cattle pricing using the hedonic framework, this study makes a number of contributions: (i) it provides a detailed analysis of the spatial and competitive dimensions of calf and yearling prices that are a central concern to western ranchers; (ii) it isolates the price impacts of forward contracting sales of cattle, finding in most cases the somewhat surprising result that forward contracting earns a seller premium;[5] (iii) it provides the most up-to-date information on price premiums associated with a comprehensive set of value-added practices, with the inclusion of data through 2013;[6,7] (iv) it links a persistent year-to-year variation in the premiums earned for value-added practices to the stage of the cattle cycle, following the insights of Crespi, Xia, and Jones (2010); and (v) it offers new information on the marginal value of third-party certification (versus producer certification) of various value-added practices. Although our data pertain specifically to the western United States, results regarding spatial discounts should also be relevant to calves and yearlings raised in the Southeast, while results regarding forward contracting, value-added practices, and certification should apply broadly across production regions.

Conceptual Background

Lancaster (1966) posited that goods comprise bundles of characteristics or attributes. Individual products within a product category are, hence, differentiated based upon the contents of their characteristics/attributes vector. Rosen (1974) set forth the basic framework for the hedonic pricing model.[8] Let Y denote a product and $Y_1, \ldots, Y_m$ denote a sample of m elements from the product category. Each product, Y_i, is defined by its characteristic bundle. Price, P_i, of product i is specified as a function of its characteristics vector: $P_i = f(\boldsymbol{X}_i)$, where $\boldsymbol{X}_i = \{X_i^1, \ldots, X_i^n\}$ and $X^1, \ldots, X^n$ are

[4] Age and source verification enables the animal to be sold in export markets, potentially adding to its value. Schumacher, Schroeder, and Tonsor (2012) provide a comprehensive discussion and analysis of the market benefits of age and source verification, which they estimated had a value to feedlots of \$5.84/cwt, based on a mail survey.

[5] Zimmerman et al. (2012) include a variable for the number of days between sale and delivery for each lot of cattle, but they do not explore the implications for price premiums or discounts associated with forward contracting. They also restrict their analysis to sales in the September-December time period, making it difficult to fully evaluate the implications of forward contracts.

[6] Schulz, Dhuyvetter, and Doran (2015) recently provided information on the value of preconditioning for calves, as well as other lot characteristics, based on December-February Iowa auction sales data from 2008–2014.

[7] Price premiums received for value-added activities are likely to adjust over time as a function of changing adoption rates (Gillespie, Kim, and Paudel, 2007; Bulut and Lawrence, 2007), as well as changes in preferences of consumers and downstream buyers that influence demand for specific product attributes (Abidoye et al., 2011).

[8] Use of hedonic pricing models for feeder cattle predates even Rosen's 1974 formal development of the framework. Williamson, Carter, and Gaines (1961) reported an analysis of price that included only sex, weight, and breed as explanatory variables. Later studies incorporated the influence of market forces and additional animal characteristics and include Faminow and Gum (1986), Schroeder et al. (1988), Lambert et al. (1989), Coatney, Menkhaus, and Schmitz (1996), and Avent, Ward, and Lalman (2004).

characteristics or attributes that collectively define product Y. The coefficient estimates from the hedonic regression model, β_j, represent the marginal effect or value of characteristic j in determining the price of product Y.

How the β_j are determined in the marketplace at any point in time is not transparent, and most studies of cattle pricing within the hedonic framework have given little consideration to the matter. In the long run, the supply of particular traits and characteristics is likely very elastic, as ranchers adopt profitable practices and eliminate ones that are unprofitable. Thus, a long-run equilibrium value for the β_j would be ranchers' marginal costs of supplying the trait, or, if value were not sufficient to cover the marginal costs, the trait would not be supplied.

However, at any point in time, the supply of value-added traits is fixed, and their valuation is determined by the strength of bidding for them. For simplicity, consider multiple lots of cattle, each with a set of common characteristics, $\boldsymbol{X}$, which all buyers agree has total value V_t for an auction held at time t. In addition, some lots also embody the characteristic X_j, while others do not. Suppose there are K potential buyers of the lot, and let $B_j^1, \ldots, B_j^k$ represent the values that these potential buyers ascribe to characteristic j at time t. Because the buyers may target different market segments for their finished products or use different production practices, their valuations are unlikely to be identical, but they are likely to be positively correlated, or "affiliated" in auction theory parlance.

Buyers, of course, are not bidding on each characteristic but rather on the bundle of characteristics that comprises the lot of cattle. In an ascending (English) auction, the maximum bid for the lot of cattle would be $P^* = V + B_j^*$, where B_j^* is the second-highest buyer valuation. However, the actual sales price will probably be less than P^* because buyers are capacity constrained in terms of the number of cattle that they can acquire and hold at a particular time, and closely substitutable lots of cattle are available for sale in the same time period at the same or competing auctions. Thus, buyers will not bid up to their valuations if they believe they can acquire a sufficient supply to stock their operations at a lower bid. If buyers sense that cattle are plentiful relative to the industry's capacity to absorb them, they can afford to bid conservatively on particular lots, knowing they have a good opportunity to fill their capacity through other available lots if needed. The opposite is likely to be true when the number of available cattle is limited relative to the capacity of downstream buyers to inventory them, and bidders are likely to be pushed closer to their valuations in these settings. This simple logic suggests that the β_j may be influenced by the cattle cycle, a hypothesis we subsequently test.

Spatial Considerations

The video auction data enable us to quantify the magnitude of spatial price discounts received by western ranchers and compare those discounts to available information on actual shipping costs. The standard presumption regarding transportation in agricultural product markets is that sellers bear shipping costs, either directly by incurring hauling costs or indirectly through price discounts, for getting their products to buyers' facilities (i.e., free-on-board (FOB) pricing).[9] With FOB pricing, the net price received by sellers will differ continuously across space. In reality, however, agricultural product pricing often does not follow the FOB paradigm. For example, uniform-delivered (UD) pricing, wherein the buyer nominally bears transportation costs and sellers receive the same price regardless of location, is common in agricultural markets, including for fed cattle in some cases (Graubner, Balmann, and Sexton, 2011).

Any departure from FOB pricing constitutes price discrimination, with UD pricing representing an extreme form. Spatial price discrimination generally involves freight absorption by buyers (Graubner, Balmann, and Sexton, 2011), which is tantamount to discrimination in favor of distant sellers, not the reverse. Freight absorption is only possible under imperfect competition in cattle

[9] For example, the classic text on agricultural product markets by Bressler and King (1970) assumes FOB pricing throughout.

procurement because arbitrage among competitive buyers will otherwise eliminate pricing systems involving freight absorption.[10]

Forward-Contracted Sales

Whereas feeder cattle auctions have traditionally required shipment of cattle to a sales yard and immediate post-sale shipment to the buyer's facility, video auctions provide an opportunity for sellers to offer forward contracts (Fawson, Bailey, and Glover, 1996), with delays in delivery for up to several months in some cases, although immediate delivery (defined to be within one month of sale) is also a common option.

Forward contracting for live cattle has traditionally involved buyer-offered contracts, has a long history (Elam, 1992), and has been studied quite extensively, with two general conclusions emerging: First, prices in a spot market have a tendency to converge to levels higher than those in the forward market (Elam, 1992; Schroeder et al., 1993; Krogmeier et al., 1997). Second, the structure of a forward market influences relative price levels (Menkhaus et al., 2003; Frank and Garcia, 2011), for example, anonymous bidding raises prices (Hamm, Purcell, and Hudson, 1985).

Video auctions enable producers/sellers to offer forward contracts. The price-determination mechanism for these contracts involves competitive bidding among multiple buyers and thus may offer advantages to sellers over traditional buyer-offered forward contracts, which often are presented at a fixed price on a take-it-or-leave-it basis. The seller also has price protection in these settings, either through setting a reserve price or being allowed to bid during the auctioning of the cattle to guarantee an acceptable price.[11]

The price impact, if any, of seller-offered, forward-contracted sales relative to spot sales (i.e., delivery within one month) is unclear *ex ante*. Buyer and seller acquire, respectively, the security of a future acquisition or sale, so premiums or discounts on such transactions will depend in part upon the values buyers and sellers attach to this security as well as their aversion to risk. In particular, buyers—either feedlots or processors—gain assurance of securing a flow of animals to their facilities necessary to operate them at efficient capacity, a factor in the case of processing facilities that recent research has established as perhaps the paramount consideration (Muth et al., 2005; U.S. Government Accountability Office, 2009). This "convenience yield" (Hull, 2000) may assume greater importance when stocks of animals in the production pipeline are low, the prospect of a shortage of live animals relative to feeding or processing capacity is high, and market prices are expected to trend upward.

Data and Estimation Strategy

Western Video Market (WVM) holds live-cattle auctions broadcast via satellite each month except February. We restricted our analysis to steers, thus excluding heifers and split loads. WVM provided data on 6,500 lots of calves and 8,016 lots of yearlings sold in all of their auctions held from 1997 through 2013. The number of lots sold per year ranged from 154 in 1998 to 530 in 2007 for calves and from 234 in 1997 to 620 in 2005 for yearlings. In total, the data included 888,438 calves and 1,300,440 yearlings.[12] Most of our analysis focuses on the most recent ten-year period, 2004–2013. However, all seventeen years of data are used in an analysis of the variability over time in premiums for value-added practices.

[10] The presence of FOB pricing, however, is not conclusive of a competitive procurement market because the FOB price itself could be depressed below the competitive level in the presence of buyer oligopsony power (Zhang and Sexton, 2001; Graubner, Balmann, and Sexton, 2011).

[11] Each company running a video auction has trading rules that influence which type of seller price protection is available. Companies not allowing a "minimum bid" to be set allow rancher/sellers to bid on their own cattle and, if the rancher is the winning bidder, set a minimum fee to be paid to the company by the rancher.

[12] WVM (www.wvmcattle.com) is headquartered in northern California. Founded in 1989, it now sells approximately one-quarter of a million cattle every year. WVM serves all market niches in sixteen western states.

Table 2. Summary Statistics for Lots of Calves and Yearlings, 2004–2013

	Calves (N = 4,444)		Yearlings (N = 5,175)	
Variables	**Mean**	**S.D.**	**Mean**	**S.D.**
Price ($/cwt)	130.90	21.97	109.50	15.31
Weight (cwt)	5.676	0.366	8.490	0.486
Natural	0.332	0.471	0.258	0.437
Certified Angus Beef (candidates)	0.223	0.416	0.184	0.388
Age and Source Verified	0.316	0.465	0.226	0.418
Number of Head in Lot	134.2	92.78	153.8	157.2
Miles to Omaha, NE (100s)	10.67	4.774	13.97	4.367
Preconditioned	0.720	0.449		
Weaned	0.450	0.498		
Fed on Hay			0.453	0.498
Fed on Pasture			0.371	0.483
Black Hided	0.758	0.429	0.765	0.424
Charolais	0.048	0.215	0.029	0.166
Hereford	0.098	0.298	0.101	0.301
Continental	0.001	0.033	0.000	0.020
Mixed Breed Cattle	0.094	0.292	0.105	0.306
Purchased 1 Month before Delivery	0.159	0.366	0.405	0.491
Purchased 2 Months before Delivery	0.223	0.416	0.151	0.358
Purchased 3 Months before Delivery	0.202	0.402	0.043	0.202
Purchased 4+ Months before Delivery	0.261	0.439	0.038	0.191
Lots with Some Variability	0.292	0.455	0.306	0.461
Lots with High Variability	0.569	0.495	0.613	0.487
Less than One Load (<48,000 lbs) in Lot	0.110	0.313	0.056	0.229

Prices for calves and yearlings were analyzed separately based upon the results of Anderson and Trapp (2000), who found that feeder cattle of differing weights were considered different market segments within the industry. All calf lots had a flesh score of medium, a frame score of medium or medium-large, and average weights of 500–625 pounds. This weight range was chosen to focus on the price effects of management of calves at weaning. Yearling lots had average weights of 750–925 pounds. Lots with animals weighing between 625 and 750 pounds were excluded from the study, as were Holsteins or cattle of Mexican origin.

The terms of trade for video auctions state that cattle are priced based on their anticipated weight at the time of transfer of the animals, with adjustment factors specified *ex ante* for weights that depart from the expectation by a threshold amount (what is known in the industry as the "slide"). In particular, price per pound is adjusted downward for lots that exceed their expected weight.

Construction of Variables

Summary statistics for 2004–2013 for the variables included in the hedonic regression model for calves and yearlings are contained in table 2. The distance variable (*Miles to Omaha, NE*) was expressed as the driving distance in hundreds of miles from Omaha to the location of the ranch selling the lot of cattle, computed via Google Maps. Use of Omaha is consistent with its central location in terms of processing capacity and results of prior research, which has found Nebraska, and Omaha in particular, to be the key hub in price setting for the cattle market (Tomek, 1980; Koontz, Garcia, and Hudson, 1990; Schroeder, 1997).

The sale data also reported the date of delivery for each lot. By comparing the sale and delivery dates, we derived a series of forward contracting dummy variables. Most forward deliveries were set for four months or less from the sale date; we therefore created four indicator variables to identify

Table 3. Summary of Lots Participating in Value-Added Programs, 2009–2013

	Calves				
	2009	**2010**	**2011**	**2012**	**2013**
Value-Added Programs					
Age & Source Verified	169	155	186	155	118
WVM Natural	109	112	103	104	139
Verified Natural	0	3	4	14	16
Non-Hormone Treated Cattle (NHTC)	15	19	25	32	37
Global Animal Partnership (GAP)	0	0	3	12	14
Preconditioned	397	350	310	293	349
WVM Vaccination Programs					
Calf Vac	5	3	11	12	10
Weaned Calf Vac	28	36	41	29	33
Zoetis Vaccination Programs					
PreVAC/PreVAC+	6	9	9	8	12
WeanVAC	10	5	14	13	16
Total Lots (Calves)[a]	**481**	**400**	**369**	**354**	**374**
	Yearlings				
	2009	**2010**	**2011**	**2012**	**2013**
Value-Added Programs					
Age & Source Verified	167	162	153	166	100
WVM Natural	160	160	127	122	80
Verified Natural	2	7	10	25	34
Non-Hormone Treated Cattle (NHTC)	27	34	39	74	49
Global Animal Partnership (GAP)	0	0	4	40	45
WVM Vaccination Programs					
Feeder Vac	52	43	43	36	35
Zoetis Vaccination Programs					
StockerVAC	23	9	13	27	13
Total Lots (Yearlings)[a]	**806**	**728**	**656**	**542**	**363**

Notes: [a] The sum of the lots participating is not equal to the total lots sold because a lot may embody multiple value-added programs.

forward contracting for one month, two months, three months, and four or more months, with a baseline of cash sales (lots delivered the same month as the sale).

Estimation of separate models for calves and yearlings enables us to specify variables to represent characteristics of lots that are potentially important for determining the value of each type of animal. However, several indicator variables were common to both the calf and yearling models. A value of 1.0 for *Certified Angus Beef* indicates a steer that is a certified Angus beef candidate. *Natural* = 1.0 indicates that the seller certifies the steer has been raised without implants or antibiotics. *Age and Source Verified* = 1.0 indicates that the seller is participating in one of two U.S. Department of Agriculture programs (Process Verified Program or Quality System Assessment Program) that certify production practices for buyers primarily targeting export markets.[13]

The *number of head* in a lot is a potentially important factor in determining price, with smaller lots generally being discounted (Bailey, Peterson, and Brorsen, 1991; Zimmerman et al., 2012;

[13] While the age-source verified program began in 2004, it wasn't until 2006 that the number of lots with this trait was sufficient to estimate the associated premium on an annual basis.

Schulz, Dhuyvetter, and Doran, 2015). A common practice (e.g., Zimmerman et al., 2012; Schulz, Dhuyvetter, and Doran, 2015) is to include number of head and number of head squared in the regression model to account for the presumed nonlinear effect of lot size on price. Our experience with these variables indicated considerable instability in the coefficients on the linear and squared terms, which led to wide variability in the predicted "optimal" lot size for models run over different time periods.[14]

The key element of lot size appears to be the ability to fill a truck with cattle—about 48,000 lbs, a factor which may explain the instability in coefficients for lot size since larger lots of, say, size Z may not be desirable unless Z/48,000 is close to an integer value. We therefore experimented with dummy variables intended to capture lot sizes based on number of cattle and their weight that approximated different numbers of truckloads. Ultimately we found that the only significant effect was for lots containing less than 48,000 lbs of cattle.[15]

Weight and *Weight Squared* are the average lot weight per head and its square, variables which test for premiums or discounts related to the size of the steers in a lot. For calves, *Weaned* = 1.0 indicates a steer weaned prior to sale, compared to the baseline of an unweaned calf.[16] *Preconditioned* = 1.0 indicates that a steer has received a respiratory vaccine.[17]

For yearlings, the lot characteristics examined also included indicator variables to denote the feeding regimen for the animals in the lot, where *Fed on Pasture* = 1.0 denotes steers that had been fed on pasture only and *Fed on Hay* = 1.0 denotes steers fed on hay only, each compared to the baseline of steers fed on both pasture and hay. Steers fed hay may adapt better to feedlot conditions, making such animals more valuable to some buyers.

Newer Value-Added Management Characteristics

Beginning in 2009, WVM began keeping detailed records on a variety of value-added management and health practices employed by ranchers participating in the auction. These programs were analyzed in separate regressions run over only the 2009–2013 period. Table 3 provides details on the lots of calves and yearlings that were sold using one or more of the value-added health and management programs discussed in this section.

WVM has created three vaccination programs, each of which is owner certified via signed affidavit. Two of these programs, *WVM Calf Vaccination Program* and *WVM Weaned Calf Vaccination Program*, are relevant for calves sold in the auction. The *WVM Calf Vaccination Program* requires a 7- or 8-way vaccine (clostridial/blackleg vaccine), two 4-, 5-, 6-, or 9-way vaccines (IBR/BVD/PI_3/BRSV), and Pasteurella.[18] The *WVM Weaned Calf Vaccination Program* requires the same vaccines as the calf program with the additional administration of a 7- or 8-way vaccine and at least one treatment for parasites; it also requires steers to have been weaned more than thirty days.[19] The *WVM Feeder Vaccination Program*, relevant for yearlings in the data, has the same vaccination and parasite control protocols as the weaned calf program and requires that the steers have been weaned at least sixty days. Any commercial brand of vaccine can be used in the WVM programs.

[14] Zimmerman et al. (2012) reported optimal lot sizes in the range of 300–400 head, but the associated coefficients were not among those reported in the paper, making it unclear whether these authors found similar instability in the coefficient estimates for their annual models. Schulz, Dhuyvetter, and Doran (2015) found an optimal lot size of 130 for calves sold in regular auctions in Iowa, but only 24 head at a specialized auction for preconditioned calves.

[15] This result is consistent with what prior studies found to be optimal for local auction markets (Faminow and Gum, 1986; Schroeder et al., 1988).

[16] We experimented with separate indicator variables to indicate whether a calf has been weaned for more or less than thirty days prior to sale but found no significant difference in valuation between the two, leading ultimately to their consolidation in a single variable.

[17] Calves receiving either two kill vaccines or one modified live vaccine for IBR/BVD/PI_3/BRSV are denoted as *Preconditioned*.

[18] Parasite control administration is optional with this program. The program also requires that vaccines be administered 2–6 weeks prior to shipment.

[19] This program requires that the first set of shots be given at branding and the second set be given prior to or at weaning.

In addition to these owner-certified WVM vaccination programs, WVM supports four Zoetis SelectVAC® programs, which have elements of third-party certification, by including participation in these programs in the WVM catalog. In order to participate in one of these programs, cow-calf operators must enroll their herds with Zoetis and document the use of Zoetis-brand vaccines.[20] Three of the four Zoetis SelectVAC® programs are relevant for calves in the WVM data: i) *Zoetis PreVAC*, ii) *Zoetis PreVAC+*, and iii) *Zoetis WeanVAC*. The vaccines required under the *Zoetis PreVAC* program are the same as those stipulated by the *WVM Calf Vaccination Program*, but the vaccines must be the Zoetis brand.[21] The *Zoetis PreVAC+* program is the same as the *Zoetis PreVAC* program, with the additional requirement that calves have a second IBR/BVD/PI_3/BRSV vaccine. Very few calves sold at the WVM auction were enrolled in the *PreVAC+* program, so lots participating in either the *PreVAC* or the *PreVAC+* program were grouped together.

The *Zoetis WeanVAC* program requires the same vaccines as the *PreVAC+* program with the additional requirements that calves be treated at least once for parasites (with DECTOMAX® or VALBAZEN®) and that the calves be weaned at least forty-five days. The fourth Zoetis program, relevant for the yearlings in the data, is the *Zoetis StockerVAC* program, which requires the same vaccine and administration protocols as the *WeanVAC* program but requires that animals be weaned sixty or more days prior to shipment.

As in Zimmerman et al. (2012), separating the price premiums associated with weaning of calves in the presence of these vaccination programs that also require weaning (i.e., *WVM Weaned Calf Vaccination Program* and *Zoetis WeanVac Program*) is not possible due to the combining of these protocols. Further, the difference in number of days a lot of calves has been weaned (i.e., 30 versus 45 days) is embedded in the vaccination program indicator variables, and its impact cannot be estimated separately.

Beginning in 2009, WVM also began delineating lots of calves and yearlings with an expanded set of value-added management programs used by sellers. *WVM Natural* is an owner-certified program that requires the seller to sign an affidavit verifying that the lot has never been fed or injected with any antibiotics (including most boluses), fed any antibiotic ionophores, implanted with any synthetic hormones, or given any feed or supplement containing animal by-products. Alternatively, some sellers chose to have their lots certified as natural by a third-party certifier. Lots that are *Verified Natural* are subject to the same restrictions as the *WVM Natural* program with more stringent record-keeping requirements; these operations must also participate in compulsory on-site audits to verify that the ranch is compliant, and each animal must carry an electronic identification (EID) tag.[22] *Non-Hormone Treated Cattle* (*NHTC*) is a third-party certification that ensures that animals are not given hormonal growth promotants at any time during their lives.[23] *NHTC* certification is necessary for all beef exported to the European Union.

The *Global Animal Partnership* (*GAP*) is a nonprofit alliance that has established a five-step, third-party-certified animal-welfare program.[24] This is a product-label authorization program to provide meat products certified under the *GAP* five-step program at retail.

In addition to these spatial, temporal, quality, and management variables of primary interest, the regression model also incorporated delivery month times year (i.e., a separate fixed effect for

[20] Thus, the Zoetis programs have a third-party certification that the WVM owner-certified programs lack. Participants in Zoetis' programs must submit evidence to Zoetis that their vaccines were purchased; Zoetis then provides a certification document.

[21] Both the PreVAC and PreVAC+ programs require that vaccines be administered 2–6 weeks prior to shipment and recommend parasite control with DECTOMAX® or VALBAZEN® and that steers be implanted with SYNOVEX® C.

[22] One third-party certifier, Verified Beef, states that the cost of participating is an initial enrollment and audit fee of $1,000 per ranch, annual re-enrollment cost of $750 per ranch, and travel expenses associated with the auditor's visit to the ranch (http://www.verifiedbeef.net/Files/NHTC_Packet.pdf).

[23] Much like the *Verified Natural* certification, operations are certified and required to keep extensive records. All animals must have an EID tag.

[24] Currently there are only two third-party certification firms in the U.S. approved for *GAP*: IMI Global and EarthClaims, LLC.

each month in the data) and breed fixed effects as controls.[25] The inclusion of this suite of temporal fixed effects eliminates the need to consider variables pertaining to "macro" conditions in the cattle market, which might influence prices over time but are not the focus of this study. The Eicker-Huber-White process was used to obtain heteroskedasticity-consistent standard error estimates.

Estimation Results

Estimation results for 2004–2013 are presented in tables 4 and 5 for calves and yearlings, respectively. In addition to the full ten-year period, results are reported for each two-year interval.

Impact of Distance from Center of Processing Region

The variable *Miles to Omaha* was significant at the 0.01 level in each of the calves and yearlings regressions. In the calf price equation, the coefficient on *Miles* is -0.820 over the full ten-year period, indicating that the price received by ranchers over the sample period was discounted by about 82 cents/cwt for each hundred miles the ranch was located from Omaha, NE, other factors constant. The estimated effect of distance was somewhat smaller for yearlings—a coefficient of −0.688 or a discount of 69 cents/cwt per hundred miles from Omaha. With one exception, the 2010–2011 calves regression, the coefficient on *Miles* was relatively stable in the biennial regressions.

A clearer sense of the impact of spatial discounts is obtained by examining the impacts of *Miles* in some major ranching areas located at different distances from Omaha. For this purpose we chose Casper, Wyoming (623 miles from Omaha), Elko, Nevada (1,158 miles from Omaha), and Redding, California (1,642 miles from Omaha). Table 6 indicates the estimated annual discount in price based on the 2012–2013 models in each of these locations relative to a hypothetical ranch located proximate to Omaha for otherwise identical 48,000 lb truckloads of calves or yearlings.[26]

The key consideration regarding these spatial discounts is their linkage to actual reported costs of shipping western cattle to the Midwest. The tighter this linkage, the stronger the evidence that discounts received by western ranchers merely reflect the workings of FOB pricing and a competitive marketplace given that, among alternative spatial pricing structures, only FOB pricing is consistent with competitive market conditions. The column titled "FOB (cwt)" in table 6 contains estimates of actual shipping costs for feeder cattle for each location based upon estimates provided by UC Cooperative Extension for a medium haul ($4.10 per mile), applicable to Casper, Wyoming, and long hauls ($3.50 per mile), applicable to Elko, Nevada, and Redding, California. For each location in the table, the computed price discount per hundredweight, based on the regression models, compares very closely to the estimated actual shipping costs and lies within the 95% confidence intervals of the estimated price discounts for both calves and yearlings at each location.

These results, on balance, provide rather strong support for an FOB pricing structure for feeder cattle in the West and, thus, are consistent with a competitive procurement market. Even if western cattle are not shipped directly to the Midwest and instead go to stocker operations or feedlots located elsewhere, most of these cattle must eventually travel to the Midwest for processing, and thus buyers at these intermediate market stages pay less for western cattle, recognizing that the prices they receive subsequently for sales to processors will be discounted by transportation costs, shrink, and

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[25] The breeds included were Angus and other black-hided breeds (which increased steadily in share from 50% (34%) in 1997 for calves (yearlings) to 85% (90%) by the end of our data period), Charolais, Hereford, Continental, and mixed cattle. Herefords (mixed cattle) comprised about 18% (24%) of the calves sold in the auction and 28% (34%) of the yearlings sold in 1997. The shares of Herefords and mixed cattle sold in the auction decreased steadily over time. Charolais and Continental breeds comprised a very small share throughout the sample period. Angus and other back-hided yearlings earned a statistically significant price premium relative to each of the other breeds. Premiums associated with *Certified Angus Beef* should be interpreted as additional value earned through the certification program over and above the premium earned by noncertified Angus and other black-hided animals.

[26] The 2012–13 models were used for this purpose to obtain a better match with reported actual shipping costs. The coefficient on *Miles* for these models is larger for yearlings than for calves.

Table 4. Ten-Year and Biennial Calf Regressions

Variables	(1) 2004–2013	(2) 2004–2005	(3) 2006–2007	(4) 2008–2009	(5) 2010–2011	(6) 2012–2013
Miles to Omaha, NE (100s)	−0.820***	−0.760***	−1.139***	−0.760***	−0.364***	−0.891***
	(0.0267)	(0.0466)	(0.0480)	(0.0500)	(0.0685)	(0.101)
Preconditioned	0.808***	0.360	1.339***	0.157	1.149**	3.042***
	(0.205)	(0.347)	(0.375)	(0.339)	(0.551)	(0.958)
Age and Source Verified	1.719***		2.210***	1.672***	2.134***	2.316***
	(0.225)		(0.495)	(0.331)	(0.430)	(0.686)
Certified Angus Beef (candidates)	1.609***	1.490***	1.516***	1.138***	1.265**	2.204**
	(0.226)	(0.441)	(0.433)	(0.402)	(0.501)	(0.860)
Natural	1.135***	0.586	0.957***	1.135***	1.142**	1.384**
	(0.205)	(0.386)	(0.370)	(0.389)	(0.457)	(0.686)
Weaned	3.618***	2.936***	2.569***	3.576***	4.360***	3.974***
	(0.249)	(0.450)	(0.483)	(0.472)	(0.567)	(0.739)
Lots with Some Variability	−1.349***	−0.287	−0.957*	−1.382***	−2.269***	−4.139***
	(0.290)	(0.485)	(0.517)	(0.449)	(0.621)	(1.227)
Lots with High Variability	−1.483***	−0.927*	−1.573***	−1.983***	−1.267**	−2.993***
	(0.278)	(0.490)	(0.488)	(0.451)	(0.511)	(1.095)
Weight (100s of lbs)	−68.61***	−86.90***	−59.95***	−43.29***	−87.85***	−85.27***
	(8.168)	(16.37)	(13.94)	(13.48)	(18.86)	(25.85)
Weight Squared (100s of lbs)	5.015***	6.575***	4.294***	3.052**	6.610***	6.262***
	(0.720)	(1.441)	(1.228)	(1.189)	(1.662)	(2.288)
Purchased 1 Month before Delivery	2.696***	3.491***	2.330**	1.574	2.674*	5.419***
	(0.568)	(0.910)	(0.993)	(1.295)	(1.606)	(1.604)
Purchased 2 Months before Delivery	2.639***	1.727**	3.676***	4.396***	2.543*	1.615
	(0.537)	(0.879)	(0.929)	(1.192)	(1.354)	(1.579)
Purchased 3 Months before Delivery	1.937***	2.494***	3.133***	5.073***	−0.903	0.823
	(0.503)	(0.830)	(0.907)	(1.133)	(1.154)	(1.441)
Purchased 4+ Months before Delivery	1.937***	−0.0452	4.422***	8.534***	−4.036***	1.096
	(0.482)	(0.870)	(0.931)	(0.995)	(0.911)	(1.238)
Less than One Load (<48,000 lbs) in Lot	−1.315***	−1.389**	−1.299**	−1.014*	−2.167***	−0.969
	(0.334)	(0.617)	(0.636)	(0.611)	(0.705)	(0.926)
Constant	354.2***	407.0***	342.6***	268.2***	403.0***	448.7***
	(23.12)	(46.31)	(39.58)	(38.25)	(53.29)	(72.59)
Observations	4,444	1,048	974	947	766	709
R-squared	0.929	0.660	0.726	0.695	0.905	0.637
Breed FE	YES	YES	YES	YES	YES	YES
Year-Month FE	YES	YES	YES	YES	YES	YES

Notes: Single, double, and triple asterisks (*, **, ***) indicate significance at the 10%, 5%, and 1% level. Robust standard errors in parentheses.

mortality associated with shipments to the Midwest. Absent the establishment of new processing facilities in the West, these results suggest that western ranchers face a chronic disadvantage in price relative to their Midwest counterparts.[27]

Price Impacts of Producer/Seller-Offered Forward Contracting

The forward-contracting indicator variables, *Purchased X Months before Delivery*, where $X = 1, 2, 3, 4+$, denote forward contracts sold from one to four or more months prior to delivery

[27] We emphasize that these results pertain to price and revenue but not necessarily to profitability, the examination of which would require cost considerations beyond the scope of this paper. For example, the lower prices received by western ranchers might be expected to weaken rental markets for grazing lands in the West relative to the Midwest, reducing costs for western cattle ranchers relative to their counterparts in the Midwest. The extent to which price discounts for western cattle impact rental rates for grazing lands is likely region-specific based on competition from other activities for use of those same lands.

Table 5. Ten-Year and Bienniel Yearling Regressions

Variables	(1) 2004–2013	(2) 2004–2005	(3) 2006–2007	(4) 2008–2009	(5) 2010–2011	(6) 2012–2013
Miles to Omaha, NE (100s)	−0.688***	−0.558***	−0.763***	−0.591***	−0.621***	−0.959***
	(0.0151)	(0.0325)	(0.0297)	(0.0233)	(0.0347)	(0.0497)
Age and Source Verified	1.052***		0.127	0.979***	0.937**	0.648
	(0.176)		(0.344)	(0.266)	(0.400)	(0.521)
Certified Angus Beef (candidates)	1.174***	1.270***	2.431***	1.300***	0.492	0.219
	(0.178)	(0.483)	(0.336)	(0.234)	(0.403)	(0.776)
Natural	3.039***	4.760***	2.829***	1.341***	3.088***	4.069***
	(0.178)	(0.451)	(0.302)	(0.261)	(0.408)	(0.553)
Fed on Hay	1.522***	1.542***	1.346***	2.329***	0.749	−0.909
	(0.244)	(0.431)	(0.382)	(0.559)	(0.679)	(1.135)
Fed on Pasture	1.279***	1.872***	1.271	1.777*	0.0890	−0.310
	(0.333)	(0.675)	(0.794)	(1.004)	(0.622)	(0.832)
Less than One Load (<48,000 lbs) in Lot	−0.400	0.0899	−0.117	−0.157	−0.827	−0.488
	(0.291)	(0.884)	(0.577)	(0.550)	(0.635)	(0.560)
Lots with Some Variability	−0.655***	−0.946**	−0.637	−0.246	−1.052*	0.419
	(0.253)	(0.447)	(0.525)	(0.429)	(0.617)	(1.068)
Lots with High Variability	−0.772***	−0.950**	−0.615	−0.518	−0.728	−0.465
	(0.242)	(0.433)	(0.526)	(0.411)	(0.551)	(0.999)
Purchased 1 Month before Delivery	0.275	0.390	−1.234***	2.068***	0.674	0.418
	(0.196)	(0.395)	(0.354)	(0.397)	(0.537)	(0.537)
Purchased 2 Months before Delivery	0.695***	−0.274	−1.691***	4.098***	1.632***	−1.073
	(0.246)	(0.477)	(0.481)	(0.486)	(0.571)	(0.810)
Purchased 3 Months before Delivery	1.085**	0.179	−1.575	8.848***	−0.407	−1.515
	(0.439)	(0.764)	(1.051)	(0.750)	(0.800)	(1.545)
Purchased 4+ Months before Delivery	1.017*	1.339	1.328	10.34***	−2.426***	2.683
	(0.600)	(1.140)	(1.783)	(0.999)	(0.755)	(2.236)
Constant	107.6***	105.7***	114.7***	99.15***	104.7***	151.5***
	(1.355)	(1.540)	(1.473)	(1.554)	(2.600)	(1.986)
N	5,175	1,174	1,158	1,097	1,004	742
R-squared	0.919	0.625	0.659	0.803	0.885	0.735
Breed FE	YES	YES	YES	YES	YES	YES
Year-Month FE	YES	YES	YES	YES	YES	YES

Notes: Single, double, and triple asterisks (*, **, ***) indicate significance at the 10%, 5%, and 1% level. Robust standard errors in parentheses.

Table 6. Spatial Discounts by Location for Calves and Yearlings

	Miles to Omaha, NE	FOB (cwt)	Spatial Discount (cwt) Calves	Spatial Discount (cwt) Yearlings
Casper, WY	623	$5.32	$5.55	$5.96
Elko, NV	1,158	$8.44	$10.32	$11.08
Redding, CA	1,642	$11.97	$14.63	$15.71

Table 7. Premiums for Forward Contracting

	Calves		Yearlings	
	Average Price Difference	Standard Deviation of Price Difference	Average Price Difference	Standard Deviation of Price Difference
1 Month	3.04	6.57	0.20	3.79
2 Months	3.24	7.55	1.39	5.47
3 Months	2.65	8.00	4.60	6.73
4+ Months	1.93	10.73	5.57	7.79

of the cattle. The coefficients are positive and statistically significant at the 0.01 level in each instance in the 2004–2013 models for calves. All of the forward contracting variables for yearlings are positive, but they are not statistically different from zero in two cases (1 month and 4+ months). Most coefficients in the biennial models are also positive and significant, with some exceptions.

The coefficients themselves, however, do not provide estimates of the premiums or discounts associated with forward contracts versus spot sales. Forward-contracted cattle are sold based on their anticipated weight at delivery. We thus need to compare the forward-contracted auction price at time t to an estimate of the price the forward-contracted lot would have received if it had been sold at video auction in its delivery month as a spot transaction, time $t+X$ for an X-month forward contract.

To make this comparison, we first compute the predicted price for each forward-contracted lot in the data set using the pooled 2004–2013 model and then compute the predicted price for the same lot if it had been sold as a "spot" transaction in its delivery month. Thus, for each lot, i, we compute the predicted price, $\widehat{P_{i,t}}$, from the empirical model and the predicted price if the same lot had been sold instead as a spot sale in its delivery month, $t+X$, (i.e., $\widehat{P_{i,t+X}}$).

This approach assumes the relevant alternative to a X-month forward contract for the seller would have been to sell in month $t+X$ as a spot sale. This approach allows the analysis to incorporate the month times year fixed effects that account for seasonal and other inter-temporal effects in the market.[28] The difference between the actual predicted price for a lot and its predicted price for a spot sale in the delivery month represents the estimated premium or discount received from forward contracting the lot.[29]

The results from this analysis of forward contracting are presented in table 7. Forward-contracted calves and yearlings each earned a price premium on average for each of the four possible contract lengths. For calves the average premium ranged from \$1.93 for four or more months forward contracted to \$3.24 for two months. For yearlings the range was \$0.20 for a one-month forward contract to \$5.57 for four or more months. However, considerable variation exists in the estimated premiums, as reflected in the standard deviations reported in table 7.[30]

On balance these results provide rather consistent evidence that a premium existed on average for seller-offered forward-contracted calves and yearlings over this time period. The ability to lock in a sale or purchase at a fixed price is beneficial to both buyers and sellers, depending on each party's aversion to risk. Beyond simple risk aversion, however, downstream buyers also benefit from guaranteeing in advance a supply of cattle to their facilities, which is perhaps the crucial factor in determining operating efficiency and unit cost. Given downstream buyers' clear incentive to lock in supplies of cattle through these various mechanisms, it should not be surprising to find that, on average, they pay a price premium on forward-contracted cattle and, thus, provide an opportunity for sellers to gain a price premium relative to spot sales.

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[28] For example, August is a comparatively high-price month for calves and October is a low-price month, so figuratively "reselling" a lot of calves in October that were in reality sold in August for delivery in October (FC2) enables us to control for these temporal effects, thereby focusing solely on the price impact due to forward contracting.

[29] Of course, an alternative would be to compare the actual forward-contracted sales price, $P_{i,t}$, to the predicted spot price in the delivery month, $\widehat{P_{i,t+X}}$. We prefer using predicted prices because it affords common treatment of estimation error, but, given that those errors net to zero, the choice is really of little consequence for the results.

[30] Unanticipated changes in market conditions and price expectations between the sale and delivery month will cause variability in the forward-contracting premium. We also conducted tests to determine whether the year-to-year variability in the coefficients on the forward contract variables could be explained by stages of the cattle cycle, hypothesizing that premiums for forward-contracted cattle would be less (or discounts would be larger) during times when the cattle inventory was relatively high. To test this hypothesis, we used annual models estimated for 1997–2013 (seventeen models in total) and stacked the regression coefficients for the four forward-contracting variables and regressed the coefficients on the January inventory of beef cattle for that year as well as indicator variables to denote yearlings versus calves and the different lengths of forward contracts. The coefficient on cattle inventory was negative as predicted but not statistically significant—$t=1.12$, making it impossible to reject the null hypothesis of no effect on forward contracting premiums/discounts due to the cattle cycle.

Variables to Measure Quality and Management Practices

Tables 4 and 5 identify a number of quality and management variables that attract a statistically significant price premium. For calves, weaning is a very important practice that generated an estimated premium of $3.62/cwt over the ten-year period; the premium was relatively stable across each of the five biennial regressions. Our estimates are smaller than those of Schumacher, Schroeder, and Tonsor (2012) ($5.35/cwt) and Williams et al. (2014) ($5.23/cwt) but consistent with Williams et al. (2012) ($2.05/cwt) and Zimmerman et al. (2012) ($3.47/cwt in 2010).

Certified Angus Beef candidates earned an average premium of $1.61/cwt over and above the premium afforded black-hided cattle that were not part of the program. Operator certification of *Natural* beef earned a premium over the ten-year period, with a coefficient of $1.14/cwt in the pooled model. *Age and Source Verified* resulted in an average premium of $1.72/cwt, and this premium was quite consistent across the biennial regressions. *Preconditioned* earned a smaller average premium of $0.81/cwt, but this premium was highly variable across the biennial regressions.

Variability in lots earned a consistent discount, with little difference in the discounts across moderate- and high-variability lots—$1.35/cwt for lots with some variability versus $1.48 for lots with high variability. This is consistent with Zimmerman et al. (2012), who found that lots classified as very uneven were discounted $1.67/cwt. These discounts were relatively stable for the first four biennial models but were dramatically higher for the 2012–2013 model.

Throughout the weight range specified in the data for calves, 500–625 lbs, larger animals received a lower price *ceteris paribus* (i.e., the price-weight relationship given the quadratic specification is declining throughout the weight range in the data). This result is not surprising, because smaller calves generally have a greater opportunity for weight gain and thus profit potential, *ceteris paribus*. Finally, small lots that were unable to fill a 48,000 lb truckload were discounted over the sample period by $1.32/cwt, and this effect was relatively stable across most of the biennial regressions.[31]

The results for yearlings in table 5 reveal the same average premium for *Certified Angus Beef* as for calves, $1.18/cwt, but the premium is much more variable in the biennial regressions for yearlings and is not statistically significant in the 2010–2011 and 2012–2013 models. Ranchers who certified that their yearlings were raised *Natural* earned a substantial average premium of $3.04/cwt, although the premium varied considerably in the biennial models. *Age and Source Verified* earned a smaller average premium, $1.05/cwt, compared to the premium afforded calves, and the premium failed to attain statistical significance in two of the biennial regressions.

Feeding practices for yearlings yielded somewhat ambiguous results. *Fed on Hay* earned a statistically significant premium of $1.53/cwt compared to the baseline of a yearling fed on both hay and pasture, but this premium was highly variable in the biennial models. Yearlings fed solely on pasture also, and somewhat paradoxically, earned a small premium relative to the default, although this premium was not statistically significant in three of the five biennial models. Variability in lots of yearlings was penalized by price discounts that were smaller than those for calves. The discounts tended to be similar in magnitude for moderate and high variability. The coefficient associated with small lots of yearlings that were unable to constitute a 48,000 lb truckload was negative in the pooled model and in all but one biennial model, but none was statistically significant.

As noted, coefficients for many of the value-added attributes of calves and yearlings exhibit considerable variability across the biennial regression models in tables 4 and 5. These differences

[31] Notably, our contacts at WVM indicated it was common practice for sellers of partial loads of cattle to compensate the buyer directly for incremental shipping costs incurred as a consequence. Thus, the finding of a discount in the purchase price means many sellers are incurring a double penalty for selling small lots.

Table 8. Premium as a Percentage of Sales Price

	Calves					
	2004–2013	**2004–2005**	**2006–2007**	**2008–2009**	**2010–2011**	**2012–2013**
Preconditioned	0.72%	0.37%	1.02%	0.13%	0.96%	2.45%
Age-Source Verified	1.24%	-	2.16%	1.51%	1.64%	1.11%
Certified Angus Beef	1.11%	0.99%	1.20%	0.83%	0.81%	1.39%
Natural	1.09%	0.93%	0.62%	1.11%	0.87%	0.79%
Avg. Price (per cwt)	130.90	124.87	122.47	111.43	138.41	169.16
	Yearlings					
	2004–2013	**2004–2005**	**2006–2007**	**2008–2009**	**2010–2011**	**2012–2013**
Age-Source Verified	0.73%	-	0.01%	1.01%	0.81%	0.49%
Certified Angus Beef	1.33%	1.60%	2.22%	1.44%	0.51%	0.17%
Natural	2.72%	4.33%	2.72%	1.55%	2.64%	2.94%
Avg. Price (per cwt)	109.48	105.23	103.80	97.01	114.33	136.36

across time in coefficient estimates are statistically significant in nearly all instances.[32] Similar variables in the annual models of Zimmerman et al. (2012) also evince considerable variability in their coefficients. Given that cattle prices have changed considerably over the time period being considered, table 8 summarizes these premiums as a percentage of the average price for cattle sold during that time period. Use of percent premiums essentially deflates the dollar-value premium by the average sales price in each of the biennial models. The percent premiums, however, still display considerable intertemporal variation. For example, in the calf models, the preconditioned premium ranges from 0.13% in 2008–2009 to 2.45% in 2012–2013.

We propose and test the hypothesis that at least some portion of this variability is due to stages of the cattle cycle and in particular the proposition that buyers will be less motivated to bid up to their valuations for particular lots during periods when cattle inventories are high.[33] The test proceeds by first estimating the hedonic regression model using annual data for the seventeen years of data from 1997–2013. This process yields seventeen sets of regression coefficients similar to the table 4 results for the pooled 2004–2013 model and the biennial models.[34] The seventeen estimated regression coefficients for four key value-added variables for calves (*Age and Source Verified*, *Certified Angus Beef*, *Natural*, and *Preconditioned*) and three value-added variables for yearlings (the same variables as for calves, excluding *Preconditioned*) were stacked and treated as dependent variables in a regression model, with ninety-nine total observations (some of the attributes are not present in the data for all seventeen years).

Explanatory variables for this model included (a) fixed effects indicator variables for the specific value-added attribute; (b) following Crespi, Xia, and Jones (2010), the January *Cattle Inventory* in millions of head to account for the stage of the cattle cycle;[35] and (c) a *calves* dummy variable or *calves x attribute* interactions to account for differences in the coefficients for calves versus

[32] In order to test statistically the hypothesis that the value-added characteristics exhibit significant variability over time, for each value-added attribute we estimated a restricted version of the model in which a single coefficient represents the average premium for that characteristic over the sample period (2004–2013) and an unrestricted model wherein we allow the estimate of the value-added attribute to vary for each year of the sample. We then use an F-test to compare the coefficients across the unrestricted and restricted models. Test results show that the annual coefficient estimates are significantly different from the pooled coefficient estimate in the restricted model in all but one case (certified angus beef premium for yearlings).

[33] The logic of this argument is related to the work of Crespi, Xia, and Jones (2010), who found both conceptual and empirical support for the proposition that markdowns for cattle due to processor buyer power will be exacerbated by larger stocks of cattle in inventory. Their argument hinges on an element of buyer power being present in the marketplace, whereas we emphasize the effect of large stocks relative to downstream capacity on bidders' incentives to bid up to their valuations for specific lots of cattle. This argument is not dependent on buyer oligopsony power.

[34] These results are not reported but are available upon request from the authors.

[35] During this seventeen-year period, January cattle inventory varied from a low of 90,095,200 in 2013 to a high of 101,655,700 in 1997.

Table 9. Analysis of Variability in Estimated Marginal Valuations

Variables	(1)	(2)
Age Source Verified	8.766**	8.846**
	(4.130)	(3.799)
Certified Angus Beef	8.706**	9.280**
	(4.185)	(3.887)
Natural	9.177**	10.530***
	(4.292)	(3.999)
Preconditioned	8.270*	9.002**
	(4.276)	(3.877)
Calves x Age Source Verified		1.339***
		(0.184)
Calves x Certified Angus Beef		0.383
		(0.303)
Calves x Natural		−1.258***
		(0.477)
Cattle Inventory (Million Head)	−0.077*	−0.085**
	(0.043)	(0.040)
Calves	−0.067	
	(0.256)	
Observations	99	99
R-squared	0.660	0.725

Notes: Single, double, and triple asterisks (*, **, ***) indicate significance at the 10%, 5%, and 1% level. Robust standard errors in parentheses.

yearlings. To account for the fact that the dependent variables are regression coefficients, which are themselves estimates of an unknown true value, the analysis reports robust standard errors following the suggestion of Lewis and Linzer (2005).

Results are contained in table 9. The key explanatory variable is *Cattle Inventory*, which is negative and statistically significant at least at the 0.10 level in both models, with an incremental million head of cattle associated with an \$0.08 – \$0.09 reduction in the premium paid on value-added attributes, on average.[36] Thus, the data provide support for the proposition that value-added premiums are attenuated in periods when the cattle inventory is high, providing a partial explanation for the considerable year-to-year variability in some of the premiums.

Newer Value-Added Practices and Third-Party Certification

Tables 10 and 11 examine the impacts of the emerging value-added practices and of third-party certification programs used by cow-calf operators for calves and yearlings, respectively. Table 3 indicates the number of lots in the data associated with each of the emerging value-added practices. The limited number of lots participating in some of these practices is a concern in interpreting the estimated coefficients.

Column 1 of tables 10 and 11 is a replication for the 2009–2013 time period of the base model reported in tables 4 and 5 to provide a basis for comparison to the models containing the emerging value-added variables. Coefficients for the variables discussed in association with tables 4 and 5

[36] Other papers in the literature (e.g., Marsh, 1999) suggest that beef cow inventory is more representative of trends in the cattle cycle. Thus, we estimated the same models included in table 9 using beef cow inventory in January as the primary explanatory variable of interest. The coefficients on the beef cow inventory variables are negative and significant at the same levels as for *Cattle Inventory*, with an incremental million head of beef cows associated with a reduction in premiums paid for value-added attributes of \$0.16–\$0.18, on average. We elected to report the smaller coefficient estimates based on *Cattle Inventory* in the interests of conservatism in reporting this new linkage from the cattle cycle to the prices ranchers receive for their cattle and also because *Cattle Inventory* yielded a slightly better statistical fit than the beef cow inventory variable.

Table 10. Value-Added Management Practices Regression, Calves 2009–2013

Variables	(1) Base Model	(2) Value-Added Programs
Miles to Omaha, NE (100s)	−0.613***	−0.639***
	(0.0466)	(0.0473)
Weight (100s of lbs)	−76.78***	−73.25***
	(13.59)	(13.65)
Weight Squared (100s of lbs)	5.663***	5.347***
	(1.198)	(1.203)
Less than One Load (<48,000 lbs) in Lot	−1.535***	−1.648***
	(0.529)	(0.520)
Preconditioned	1.481***	1.378***
	(0.406)	(0.407)
Age and Source Verified	1.843***	1.659***
	(0.320)	(0.327)
Certified Angus Beef (candidates)	1.705***	1.785***
	(0.362)	(0.363)
Weaned	4.156***	3.879***
	(0.414)	(0.439)
WVM Calf Vaccination Program		−0.163
		(0.912)
WVM Weaned Calf Vaccination Program		1.574***
		(0.605)
Zoetis PreVAC/PreVAC+		1.683*
		(0.882)
Zoetis WeanVAC Program		2.584**
		(1.077)
Natural	1.195***	
	(0.346)	
Western Video Market Natural		1.015***
		(0.351)
Verified Natural		−1.093
		(1.780)
Non-Hormone Treated Cattle		−0.354
		(0.792)
GAP		6.505***
		(2.246)
Lots with Some Variability	−2.519***	−2.562***
	(0.527)	(0.526)
Lots with High Variability	−1.757***	−1.828***
	(0.473)	(0.474)
Constant	359.1***	350.2***
	(38.36)	(38.57)
Observations	1,922	1,922
R-squared	0.947	0.948
Forward Contracting Fixed Effects	YES	YES
Breed Fixed Effects	YES	YES
Year-Month Fixed Effects	YES	YES

Notes: Single, double, and triple asterisks (*, **, ***) indicate significance at the 10%, 5%, and 1% level. Robust standard errors in parentheses.

Table 11. Value-Added Management Practices Regression, Yearlings 2009–2013

Variables	(1) Base Model	(2) Value-Added Programs
Miles to Omaha, NE (100s)	−0.670***	−0.668***
	(0.023)	(0.0232)
Age and Source Verified	1.072***	0.686***
	(0.252)	(0.254)
Certified Angus Beef (candidates)	0.783***	0.830***
	(0.263)	(0.262)
Non-Hormone Treated Cattle		2.189***
		(0.567)
Natural	2.871***	
	(0.257)	
Western Video Market Natural		2.512***
		(0.269)
Verified Natural		3.325***
		(0.981)
Global Animal Partnership		0.466
		(0.868)
WVM Feeder Vaccination Program		−0.064
		(0.308)
Zoetis StockerVAC Program		0.724
		(0.652)
Less than One Load (<48,000 lbs) in Lot	−0.818**	−0.753**
	(0.379)	(0.378)
More than One Load (>50,000 lbs) but Less than Two (<96,000 lbs)	−0.654***	−0.609***
	(0.235)	(0.236)
Fed on Hay	0.682	0.782
	(0.550)	(0.552)
Fed on Pasture	0.529	0.661
	(0.514)	(0.518)
Lots with Some Variability	−0.842**	−0.945**
	(0.401)	(0.402)
Lots with High Variability	−0.925**	−0.957***
	(0.367)	(0.368)
Constant	97.150***	97.170***
	(0.817)	(0.801)
Observations	2,331	2,331
R-squared	0.947	0.948
Forward Contracting Fixed Effects	YES	YES
Breed Fixed Effects	YES	YES
Month-Year FE	YES	YES

Notes: Single, double, and triple asterisks (*, **, ***) indicate significance at the 10%, 5%, and 1% level. Robust standard errors in parentheses.

are very robust to the addition of the new variables. With regard to those variables, the evidence presented in column 2 of tables 10 and 11 is rather mixed. For calves (table 10) the *WVM Calf Vaccination Program* did not generate a large or statistically significant premium, but its counterpart *Zoetis PreVAC/PreVAC+* did generate a statistically significant premium of about $1.68/cwt. The *WVM Weaned Calf Vaccination Program*, generated a statistically significant premium of $1.57/cwt, while its Zoetis counterpart, the *Zoetis WeanVac Program*, generated an even larger premium of \$2.58/cwt.[37] This result is consistent with Zimmerman et al. (2012), who estimated a \$2–\$4/cwt premium associated with a similar vaccination protocol. The *WVM Weaned Calf Vaccination Program* and the *Zoetis WeanVac Program* prescribe a similar treatment regimen, so the difference between the point estimates can be interpreted as an estimate of the value ascribed to third-party certification. Thus, buyers may be willing to pay approximately an additional \$1.00/cwt for third-party certification, although we cannot be certain that the true impact is not zero, as noted in footnote 37. This is smaller than the \$2.37/cwt estimate from Schumacher, Schroeder, and Tonsor (2012).

WVM Natural signifies operator certification of the absence of implants or antibiotics and embodies the same practices as the *Natural* designation from earlier auctions but with a more formal operator-certification protocol. *Verified Natural* embodies practices similar to *WVM Natural* but with mandatory recordkeeping and third-party audit. For the regression in column 1 of tables 10 and 11, and the 2010–2011 and 2012–2013 biennial regressions in tables 4 and 5, the variable *Natural* consists of *WVM Natural* and *Verified Natural* (i.e., those are the two "natural" designations used by WVM from 2009 onward).

The premium associated with *Verified Natural* is not statistically significant for calves, perhaps due to the limited number of lots with this designation. Further, with reference to table 4, we see that the premium earned for the enhanced natural designations from 2009 onward is not noticeably greater than the premiums for *Natural* from earlier years.[38] However, the third-party certification of animal welfare practices, *Global Animal Partnership* (*GAP*), yielded a large and statistically significant premium of \$6.51/cwt for the model in column 2. Calves that are *Age-Source Verified* earn a statistically significant premium of \$1.84/cwt. This is consistent with the Zimmerman et al. (2012) premium estimate of \$1.67/cwt in 2010.

Turning now to results for yearlings in table 11, neither the WVM nor the Zoetis vaccination program is associated with a statistically significant premium. *WVM Natural* earned a premium of about \$2.51/cwt. *Verified Natural* generated a positive premium of \$3.33/cwt. As was true for calves, there is no evidence that these enhanced certifications for natural beef earned producers a greater premium than the operator-certified *Natural* designation from earlier years.

The third-party certification of *Non-Hormone Treated Cattle* generated a positive and significant premium of \$2.19/cwt for yearlings, in contrast to the insignificant result for calves. *GAP* has a positive coefficient but, in contrast to the model for calves, it is not statistically significant.

The strongest evidence in favor of an incremental premium for third-party certification of value-added practices is comparison of the operator-certified WVM programs to the otherwise comparable Zoetis programs, which are certified through Zoetis. In each of the three comparisons, the Zoetis program yielded a higher premium, although only the calf premiums were statistically significant. However, third-party certification of adoption of natural production practices did not yield any incremental premium, based on the limited observations in the data. It is not possible to separate third-party certification from the value of the practice itself for *GAP* and *Non-Hormone Treated Cattle* because there is no operator-certified comparison in the data.

Concluding Comments

Hedonic pricing models for cattle have existed since 1961, but their importance and potential usefulness to industry participants and advisors is enhanced by the proliferating set of variables that may add to or detract from an animal's value and by the presence of satellite video auctions

[37] In the calf models, we are not able to reject statistically that the effects of the *WVM Calf Vaccination Program* and *Zoetis PreVAC/PreVAC+* are equal or that the effects of the *WVM Weaned Calf Vaccination* and the *Zoetis WeanVac Program* are equal.

[38] When testing the equality of the coefficients associated with *WVM Natural* and *Verified Natural*, we are not able to reject the hypothesis that the coefficient estimates are statistically equal in both the calf and yearling models.

that, by necessity, acquire and maintain detailed records on characteristics of the lots of cattle sold under their auspices.

Relative to prior analyses of video auction data, this study has offered several contributions. It documents the nature of spatial price discounts received by western ranchers due to the paucity of processing capacity in the West, finding that the discounts closely match reported shipping costs and, thus, are consistent with FOB pricing and competitive procurement. Second, this study is the first to isolate the presence of price premiums for seller-offered forward contracts at video auctions. Although the premiums exhibited considerable variability (table 6), they were positive on balance, and the coefficients supporting the premiums were statistically significant for most of the forward contracts considered. This result, although perhaps surprising, is consistent with the well-known desire of downstream buyers to lock up commitments of cattle to ensure operation of their facilities at efficient capacity.

We also provide the most up-to-date estimates of the marginal value associated with various quality attributes and management practices. Estimates of comparable variables in our study and the recent Zimmerman et al. (2012) study, which used data from the Superior Livestock Auction, are generally similar and consistent. In addition, we sought to understand the considerable year-to-year variability in estimated coefficients for both studies and were successful in linking the variability to the stage of the cattle cycle as measured by the January cattle inventory. We also explored the value of third-party versus operator certification of specific production practices, finding mild support for the benefits of third-party certification, especially as it applied to vaccination regimes. The limited number of available observations for some of the emerging practices makes this area fertile for further research.

In summary, our results suggest a chronic locational disadvantage for western ranchers relative to counterparts in the central part of the country due to the paucity of processing capacity in the West. This disadvantage heightens the imperative for western ranchers to be on the forefront of adopting practices that can add value to their cattle. In that regard, we hope this study, through identifying and quantifying premiums associated with forward contracting and value-added production and management practices, can help western ranchers and their advisors obtain maximum value and return from their operations.

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