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Differences in Prices and Price Risk Across Alternative Marketing Arrangements Used in the Fed Cattle Industry

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Information on prices and price risk differences across marketing arrangements aids fed cattle producers in making choices about marketing methods. As part of the congressionally mandated Livestock and Meat Marketing Study, we investigated fed cattle price and price risk differences across marketing arrangements. The analysis uses data representing cattle purchased by 29 large beef packing plants from October 2002 through March 2005. Results indicate that marketing agreements offered the best tradeoff between price level and price risk. Forward contracts had the lowest average yet highly volatile prices. Auction barn prices were higher than other methods but also the most volatile.

Key words: alternative marketing arrangements, fed cattle, hedonic, price risk, price volatility, prices

Introduction

In 2003, Congress allocated funds to conduct a broad study of the effects of alternative marketing arrangements (AMAs) in the livestock and meat industries. AMAs that result in captive supplies of livestock by packers (i.e., control or ownership of livestock more than 14 days prior to slaughter) have raised particular concerns for many industry participants. The study was completed in early 2007, and the results are being used in discussions about policy changes that are needed to address whether use of particular methods of procuring livestock by packers has adverse effects on the livestock and meat industries. As part of analyzing the broad range of economic effects of AMAs, we investigated how prices and price risk vary across AMAs (Muth et al., 2005, 2007).

In this article, price risk is defined to mean the variances of prices across AMAs when controlling for the characteristics of the cattle lot and plant-specific effects.[1] Information

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[1] An alternative definition of price risk could be based on the likelihood of receiving a lower price for fed cattle sold under particular marketing arrangements as compared with the price that could have been received using a different marketing arrangement. However, it is infeasible to determine the relevant marketing arrangement for making the comparison on every transaction.

on differences in prices and price risk increases transparency in the market and may improve market efficiency. Our study results help explain why different producers and packers use different AMAs.

The primary types of marketing arrangements used for sales of fed cattle to packers can be categorized as cash market arrangements and AMAs. Cash market arrangements include:

- auction barn sales, including video and electronic auction sales;
- use of dealers and brokers; and
- direct trade, which is an individual negotiation between a buyer and seller.

In contrast, AMAs include:

- forward contracts for the future purchase of a specified quantity of cattle two or more weeks in the future,
- marketing agreements for the future purchase of cattle under a long-term ongoing arrangement, and
- packer ownership in which the packer owns the cattle two or more weeks prior to slaughter.

In addition to these key types of arrangements, the producer can own a small number of cattle, can custom slaughter, and can market the resulting beef products. Prices under most cash market arrangements are determined immediately through bidding or negotiation. In contrast, prices under forward contracts and marketing agreements and some direct trade transactions are based on some type of formula. Prices under packer ownership are based on an internal transfer pricing method, which is often established through a publicly reported market price (Muth et al., 2007).

In theory, risk-averse cattle producers may be willing to accept lower prices for cattle under an AMA, all else equal, because participation in an AMA ensures market access and reduces a number of uncertainties, including whether a buyer is available to purchase cattle when they are ready for slaughter. Conversely, beef packers may be willing to pay higher prices for cattle under AMAs because AMAs ensure they will have cattle supplies needed to run the plant at a higher capacity utilization rate and they will have the necessary quality of cattle to meet buyer requirements for beef products. In some cases, however, the transactions costs involved in negotiating and setting up AMAs, particularly for smaller producers, may prevent market participants from entering into AMAs. Yet in the end, whether prices are higher or lower under AMAs is an empirical question.

The purpose of this study is to analyze differences in prices and price risk across AMAs used for the purchase of fed cattle by beef packers, while controlling for other factors affecting these differences. In contrast to previous studies using ordinary least squares (OLS) estimation, our methodology estimates differences in price risk together with price levels, and accounts for the fact that prices of transactions within weeks and across nearby weeks are correlated. Analyses failing to account for the correlation within and across weeks may result in misleading inferences. Accordingly, this research provides suggestions about how transaction price models can be better specified and estimated.

The results of this study may help fed cattle producers decide which types of marketing arrangements to use to sell fed cattle to beef packers. Specifically, the results indicate which types of arrangements have offered the highest prices and lowest variance of prices for a given level of quality over the time period of the data analyzed. While mandatory price reporting (MPR) has greatly increased the transparency of prices in the industry, these data do not provide a means of adjusting for differences in quality across individual transactions or for analyzing price risk across individual transactions. Furthermore, these results contribute to policy discussions regarding the economic benefits of AMAs.

Previous Literature

Previous studies have analyzed the effects of using different types of marketing arrangements on transaction prices for fed cattle, but, in most cases, they focus on the effect of captive supplies on cash market prices rather than on the differences in prices across types of marketing arrangements (e.g., Elam, 1992; Schroeder et al., 1993; Ward, Koontz, and Schroeder, 1998; Schroeter and Azzam, 1999, 2003). While the empirical research, on balance, suggests an inverse relationship between captive supplies and cash-market prices, establishing a causal link has been elusive (Xia and Sexton, 2004). According to Ward, Koontz, and Schroeder (1998), removing a share of cattle from the cash market affects both supply and demand in the cash market. In a competitive market, the effect on price is ambiguous, because it depends on the relative magnitude of the shifts, which is related to the functional forms of demand and supply

Previous studies that have examined differences in prices across types of marketing arrangements used for fed cattle include Williams et al. (1996); Ward, Koontz, and Schroeder (1998); and Schroeter and Azzam (1999). These models are akin to hedonic pricing models in the sense that the price of the product (fed cattle) is modeled as a function of its attributes to determine the implicit prices of various quality products (Rosen, 1974). However, in addition to measures of product attributes, binary variables representing the type of marketing arrangement were also included in the models. Earlier hedonic models of fed cattle prices did not include variables representing the range of marketing arrangements used (e.g., Ward, 1992; Schroeder, 1997) but did provide guidance on the types of quality measures or other variables that are important in explaining differences in fed cattle prices.

The model developed by Williams et al. (1996) expresses the average delivered liveweight cost of fed cattle as a function of the type of marketing arrangement, lot characteristics (e.g., number of head and yield grade), plant characteristics (e.g., capacity), market structure variables (e.g., regional Herfindahl index), quarterly dummy variables, and output price for beef. Their analysis was conducted as part of the 1996 congressionally mandated study of market concentration in the meat packing industry. The data set included 23 million head of cattle in 182,000 sale lots purchased by 43 plants from April 5, 1992 through April 3, 1993. Only lots with 35 head or more were included in the data set. Results of OLS regression indicated that relative to cash market transactions, prices for cattle sold through forward contracts and transferred under packer ownership were lower, and prices for cattle sold through marketing agreements were higher. However, the differences in prices were at most $0.02 per pound liveweight and were typically much less than $0.01 per pound. The results were

similar when the model was reestimated separately for three regions of the country (states in the High Plains, West, and Midwest).

Using the same data set as Williams et al. (1996), the model estimated by Ward, Koontz, and Schroeder (1998) included 16.5 million cattle in 140,000 sale lots purchased by 28 plants. Their model specified the purchase price for cattle on a carcass weight basis as a function of type of marketing arrangement, reported market prices (e.g., boxed beef cut-out value and the live cattle futures price), lot characteristics (e.g., weight, number of head, and yield grade), trend variables, plant binary variables, and other variables. Results of OLS regression revealed that relative to cash market transactions, carcass weight prices for fed cattle were slightly higher for marketing agreement cattle ($0.10 per cwt), much lower for forward contract cattle ($3.16 per cwt), but not significantly different for packer-fed cattle.

Finally, in their 1999 analysis, Schroeter and Azzam employed a later but more specialized data set for four plants in the Texas panhandle region over the period February 1995 through mid-May 1996. The analysis included information on every lot of cattle over 35 head purchased by four plants over the time period of the data set (33,000 sale lots). The model specified the purchase price for cattle in dollars per pound carcass weight basis as a function of binary variables indicating the plant and marketing method used, lot characteristics (e.g., number of head, yield quality grade, yield grade, and steer versus heifer composition), distance shipped, and other variables. OLS regression results found premiums paid for marketing agreement cattle relative to cash market cattle of $0.52 to $2.26 per cwt and premiums paid for forward contract cattle relative to cash market cattle of $2.00 to $2.46 per cwt with the exception of one plant for which the forward contract variable coefficient was not significantly different from zero. Thus, compared to the earlier investigations, the estimated price differences are substantially larger and the difference for forward contract cattle has the opposite sign.

The previous works described above assumed prices were (conditionally) uncorrelated across transactions and overlooked the possible correlation of prices within weeks and across nearby weeks; consequently, the inferences they drew may be misleading. Moreover, smaller size lots were not included in the data sets used for those analyses, which likely excluded a substantial number of cash market transactions, and hence may have reduced the representativeness of the results. With the specific objective of addressing these shortcomings, the model developed and estimated in the following sections accounts for the within-week and across-week correlation of prices, includes all lots of six or more cattle, differentiates between auction sales and other types of cash market sales, and uses a recent data set collected for the 2007 Grain Inspection, Packer and Stockyards Administration (GIPSA) Livestock and Meat Marketing Study. In addition to taking into account the correlation of prices, the results of modeling the error structure provide useful information about the differences in price risk across marketing arrangements.

Fed Cattle Transactions Data

The data used for our analysis represent all fed cattle purchase transactions for 29 of the largest beef packing plants in the United States from October 2002 through March 2005. These 29 plants are owned by 10 individual companies with most but not all companies owning multiple plants. The data were collected by RTI International under

contract with GIPSA in the spring of 2006. Because of their highly confidential nature, the data were collected and maintained under the provisions of the Confidential Information Protection and Statistical Efficiency Act (CIPSEA) of 2002.[2] Data collected under CIPSEA can be used only for statistical analysis purposes and cannot be used for investigations. Furthermore, results of analyses cannot reveal plant- or company-specific information. The contents of the data set and frequency of AMA use are described below.

Contents of the Data Set

The data set includes 591,000 lots of beef and dairy breed fed cattle averaging 100 cattle per lot for a total of 58 million head of cattle. By region, the data set comprises the following:

- Cornbelt/Northeast region (IA, IL, MI, MN, PA, WI)—five plants that bought 4.5 million head of cattle in 98,000 lots;
- High Plains region (CO, KS, NE, TX)—17 plants that bought 48.5 million head of cattle in 430,000 lots;
- West region (AZ, CA, ID, UT, WA)—seven plants that bought 5.1 million head of cattle in 66,000 lots.

The volume of cattle in the data set represents approximately 85% of the fed cattle slaughtered in the United States during the October 2002 through March 2005 time period based on U.S. Department of Agriculture (USDA) data [USDA/National Agricultural Statistics Service (NASS)]. The data represent an interesting time period in the fed cattle industry because of the disruptions in the market that occurred first in May 2003, when the initial discovery of bovine spongiform encephalopathy (BSE) was made in Canada, and the border was closed to live cattle and beef imports into the United States. Then, in December 2003, the first discovery of BSE was made in the United States; exports of beef from the United States were banned, and many consumers decreased their beef consumption. Thus, considerable variation occurs in the baseline market conditions within this data set, including periods of relatively low and relatively high cattle supplies.

The variables in the data set include location of the plant, transaction dates, seller information, number of cattle in the lot, costs of the lot, weight measures (e.g., live-weight and carcass weight), characteristics of the cattle sold (quality grade, yield grade, and other quality measures), and characteristics of the marketing arrangement used. Fed cattle purchase lots typically range from 10 to 200 cattle per lot.[3] Within an individual lot, the quality and characteristics of cattle may vary substantially depending on breed, distribution of steers versus heifers, whether any cattle are culled cows or bulls, weight range, quality grade, and yield grade. To analyze differences in transaction prices, it is therefore necessary to adjust for differences in the composition and quality of the lot.

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[2] The text of the public law can be found online at http://www.eia.doe.gov/oss/CIPSEA.pdf.

[3] Smaller lots of cattle are typically off-quality cattle that are not quality graded.

The fed cattle prices in the data set represent the total cost to the packer for each lot of cattle. The total cost of a lot includes the cost of the cattle in the lot, shipping costs (which may be paid by the packer or by the producer), sales commission costs, miscellaneous costs (e.g., feed), and price adjustments for quality. We used the per lot total cost to compute the carcass weight price per pound by dividing the total cost by the total carcass weight of each lot. Because of substantial variation in reporting of costs by packers, we used the total costs of the lot rather than the cattle cost to compute averages. Cattle cost typically comprises 97% to 99% of the total cost of the lot. Plant-level binary variables are included in the analysis to allow for differences in the accounting and reporting of the total cost of each lot across companies in the data set. To eliminate odd lots that are not representative of typical transactions, we excluded transactions with prices below \$0.86 and above \$1.98 per pound carcass weight. These values were determined by taking \$0.10 below the minimum and \$0.10 above the maximum price ranges reported by MPR over the time period of the data. This data preparation step eliminated approximately 0.03% of the transactions in the data set.

Frequency of Marketing Arrangement Use for Fed Cattle

Table 1 provides a summary of the numbers of lots and transactions for each of the major types of marketing arrangements. For confidentiality reasons, auction barn sales are combined with the use of brokers and dealers, and the packer ownership category is combined with other miscellaneous types. Cash market transactions represent 61.7% of the head sold over the October 2002 through March 2005 time period. Marketing agreements were the primary AMA, representing 28.8% of the head sold. Packer ownership, which is combined with the miscellaneous other category, represents less than 5% of the head sold, and forward contracts represent 4.5% of head sold. Based on the differences in the percentages of lots versus head, auction sale lots tended to be smaller than average, and marketing agreement and forward contract lots tended to be somewhat larger than average.

In comparison to these estimates, Williams et al. (1996) found that for the 1992–1993 time period of their data, 82.3% of fed cattle lots were purchased on the cash market, 8% were purchased using a marketing agreement, 7% were purchased using a forward contract, and 2.7% were packer fed. Using data from the same time period, Ward, Koontz, and Schroeder (1998) did not report overall percentages of transactions by type of marketing arrangement, but they indicated that, on average, for each 28-day period forward from the transactions date, 5.2% of fed cattle were available under marketing agreements, 5.8% were available under forward contracts, and 5.7% were under packer ownership. Thus, the share of cattle sold through marketing agreements increased substantially, while the use of the cash market declined compared to the time period included in our analysis. While these trends are also evident in the 1995–1996 data used by Schroeter and Azzam (1999), the percentages are not directly comparable because their data represent only four plants in Texas.[4]

[4] The specific estimates for four Texas plants in Schroeter and Azzam (1999) are 71.3% cash market, 21% marketing agreements, 5.2% forward contract, and 2.5% packer owned.

Table 1. Summary of Fed Cattle Purchase Methods, October 2002–March 2005

Purchase Method	Number of Lots	Percent of Lots (%)	Number of Head	Percent of Head (%)
Auction Barns, Dealers, and Brokers	44,237	7.5	2,426,488	4.2
Direct Trade	338,254	57.2	33,396,016	57.5
Forward Contract	23,047	3.9	2,626,217	4.5
Marketing Agreement	158,705	26.8	16,748,315	28.8
Packer Fed/Owned, Other, or Missing	27,167	4.6	2,869,405	5.0
Total	591,410	100.0	58,066,441	100.0

Model Development

We used a parsimonious reduced-form model to analyze how purchase prices for fed cattle vary among different types of marketing arrangements for cattle of similar quality. The intention of the model is to provide information on the association between use of marketing arrangements and fed cattle prices. However, because of the reduced-form nature of the model, we are unable to draw conclusions regarding a possible causality relationship.

The complete model for estimating price differences and modeling the structure of the error term for capturing differences in price risk and the interdependencies in the data is specified as follows:

$$(1)\quad PRICE_{ti} = \beta_0 + \boldsymbol{\beta}_1\mathbf{D\_AMA}_{ti} + \boldsymbol{\beta}_2\mathbf{CATTLE\_CH}_{ti} + \boldsymbol{\beta}_3 d\_beefcattle_{ti} * \mathbf{D\_AMA}_{ti} + \boldsymbol{\beta}_4\mathbf{D\_PLANT}_{ti} + \boldsymbol{\beta}_5\mathbf{D\_MONTH}_{t} + u_{ti},$$

$$(2)\quad u_{ti} = v_t + \varepsilon_{ti},$$

$$(3)\quad \mathrm{Cov}(v_t, v_s) = \begin{cases} \sigma_v^2 & \text{if } t = s, \\ \rho\sigma_v^2 & \text{if } |t - s| = 1, \\ 0 & \text{if } |t - s| > 1, \end{cases}$$

and

$$(4)\quad \mathrm{Var}(u_{ti}) = \exp\left(\delta_0 + \boldsymbol{\delta}_1\mathbf{D\_AMA}_{ti} + \boldsymbol{\delta}_2\mathbf{CATTLE\_CH}_{ti} + \boldsymbol{\delta}_3 d\_beefcattle_{ti} * \mathbf{D\_AMA}_{ti} + \boldsymbol{\delta}_4\mathbf{D\_MONTH}_{t} + \varsigma_{ti}\right),$$

where $t, s = 1, \ldots, T$ indexes delivery week for each lot of fed cattle, and $i = 1, \ldots, I_t$ indexes transactions (i.e., fed cattle lots purchased by packers) with delivery date in week t.

In equation (1), $PRICE_{ti}$ is the transaction price for each lot on a per pound carcass weight basis, $\boldsymbol{\beta}$ is a vector of parameters to estimate, and u_{ti} is a random error term. In addition, $\mathbf{D\_AMA}_{ti}$ is a vector of binary variables indicating the type of marketing arrangement used for purchase of the lot, including direct trade (d_direct_{ti})[5] (as the base group), auction barns ($d\_auction_{ti}$), forward contracts ($d\_forward_{ti}$), packer-owned and other arrangements (d_packer_{ti}), and marketing agreements ($d\_marketing_{ti}$).

$\mathbf{CATTLE\_CH}_{ti}$ is a vector of cattle characteristics, including whether the fed cattle are a beef or dairy breed ($d\_beefcattle_{ti}$), the number of head in the lot ($numberofhead_{ti}$), the percentage of Yield Grade 4 or 5 cattle in the lot ($yg45\_pct_{ti}$), the percentage of cattle with Quality Grade of Prime or Choice in the lot ($primechoice\_pct_{ti}$), the percentage of cattle that were classified as heavyweight or lightweight in the lot according to the definition of heavyweight or lightweight used by each individual packer ($outweight\_pct_{ti}$), and the percentage of cattle that were eligible for a branded or a certification program in the lot ($branded\_pct_{ti}$). All of these "characteristics" variables measure different aspects of quality of the lot of fed cattle. We also include the interaction term of $d\_beefcattle_{ti} * \mathbf{D\_AMA}_{ti}$ so that the price premium/discount associated with each marketing arrangement is allowed to be different for beef cattle and dairy cattle (fed dairy steers).

Finally, we also incorporated 28 plant binary variables ($\mathbf{D\_PLANT}_{ti}$) to control for the plant-level unobserved fixed effects, such as location, installed capital equipment, and type of accounting system, and 29 binary variables to identify the year and month in which the cattle were slaughtered ($\mathbf{D\_MONTH}_t$).[6] The monthly binary variables control for differences in market conditions, seasonality, trends, and other possible unobserved effects related to each month. In particular, these monthly binary variables help control for the effect of the market disruptions that occurred as a result of the BSE discoveries in Canada and the United States during this period.[7]

Table 2 provides the definitions, means, standard deviations, minimums, and maximums of the variables included in the model, with the exception of the plant and monthly binary variables. In addition to the percentages of cattle lots sold using each type of marketing arrangement, the summary statistics also reveal that 78% of the lots are primarily beef breed cattle (and thus 22% of the lots are primarily fed dairy breed cattle), and that an average lot has 99 head of cattle, 64% of Prime or Choice grade cattle, 33% heavyweight or lightweight (i.e., outside of the packer's desired weight range) cattle, and 19% of cattle eligible for branded or certification programs.

Equation (2) decomposes the error term u_{ti} into two components: a transaction-specific random error term, ε_{ti}, and an unobserved weekly effect, v_t, which is constant for all transactions with delivery date in week t. The unobserved weekly effect could include, for example, announcements regarding foreign trade of cattle and beef that may temporarily decrease the supply of cattle or decrease the demand for U.S. beef, extreme

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[5] Transactions through dealers or brokers are combined with the transactions through direct trade because they account for a very small fraction of the total transactions (less than 1%) and are another type of cash market purchase.

[6] For example, binary variable D_MONTH_1 has a value of one for October 2002, and D_MONTH_{30} has a value of one for March 2005.

[7] Note that this specification differs from Ward, Koontz, and Schroeder (1998) in that it does not include the set of market prices—boxed beef prices, beef by-product prices, live cattle futures prices, and lagged cash market prices. Instead, we include monthly dummy variables to account for current market conditions and thus avoid multicollinearity associated with including these variables.

Table 2. Descriptive Statistics for the Variables in the Price Difference Model for Fed Cattle Purchase Transactions, October 2002–March 2005

Variable	Definition	Mean	Std. Dev.	Min.	Max.
price	Transaction price in $/pound carcass weight	1.31	0.14	0.86	1.98
d_direct	Direct trade purchase (1 = yes, 0 = no)	0.58	0.49	0.00	1.00
d_auction	Auction purchase (1 = yes, 0 = no)	D[a]	D	0.00	1.00
d_forward	Forward contract purchase (1 = yes, 0 = no)	0.04	0.20	0.00	1.00
d_packer	Packer-owned procurement (1 = yes, 0 = no)	D	D	0.00	1.00
d_marketing	Marketing agreement procurement (1 = yes, 0 = no)	0.28	0.45	0.00	1.00
d_beefcattle	Mostly beef breed cattle in the lot (1 = yes, 0 = no)	0.78	0.42	0.00	1.00
numberofhead	Number of head in the lot (100s)	0.99	0.89	0.06	15.21
yg45_pct	% Yield Grade 4 or 5 cattle in the lot	0.08	0.10	0.00	1.00
primechoice_pct	% Prime or Choice cattle in the lot	0.64	0.24	0.00	1.00
outweight_pct	% heavyweight or lightweight cattle in the lot	0.33	0.37	0.00	1.00
branded_pct	% cattle eligible for branded or certification program in the lot	0.19	0.23	0.00	1.00

[a] D indicates results suppressed to maintain confidentiality.

weather events that temporarily reduce the ability to deliver cattle to slaughter plants, and immigration labor raids that temporarily reduce the ability of slaughter plants to operate. We assume v_t and ε_{ti} are uncorrelated with the explanatory variables and uncorrelated with each other. We separately model the weekly effect in the error term because the U.S. fed cattle market is generally a weekly market (i.e., packers arrange their procurement and production activities week by week).

Both the covariance in equation (3) and the variance in equation (4) are conditional on the explanatory variables in equation (1). The structure of equations (3) and (4) is intended to capture two potential features of the high-frequency data used. First, transaction prices (conditional on the explanatory variables) may be correlated within the same week and across neighboring weeks, even though we have controlled for the monthly fixed effects. Second, the variance of transaction prices (conditional on the explanatory variables) may vary over time, by AMA choice, or by some other explanatory variables—i.e., we may have a heteroskedasticity problem.

Equation (3) assumes that the conditional covariance of prices between any two transactions delivered in the same week is σ_v^2, the conditional covariance of prices between two transactions delivered in neighboring weeks is $\rho\sigma_v^2$, and the conditional covariance of transaction prices is zero otherwise. Therefore, equation (3) reflects an autoregressive structure across weeks as well as a random-effect structure within a week in the model's error term. Equation (4) assumes that the variance of transaction prices depends on the choice of marketing arrangement, cattle characteristics, and delivery year and month.

If the correlation within and across weeks or heteroskedasticity exists but we failed to model them, our inferences would be invalid.

The parameters in equation (4) are also of interest because they show how price variance is correlated with the explanatory variables, and price variance is used as a measure of price risk in our model. Equation (4) defines what we mean by price risk (i.e., the difference between the observed transaction price and the predicted transaction price from the mean equation). A large number of variables in equation (1) explain the systematic variation in transaction prices across lots. The unexplained variation in price is modeled in equation (4) and can be associated with characteristics of each transaction, including the marketing method. This measure of risk is short term and similar to basis risk.

In the model described by equations (1)–(4) we are particularly interested in the parameters $\boldsymbol{\beta}_1$, $\boldsymbol{\beta}_3$, $\boldsymbol{\delta}_1$, and $\boldsymbol{\delta}_3$. The $\boldsymbol{\beta}_1$ and $\boldsymbol{\beta}_3$ parameters indicate the average price differences associated with AMAs, holding other explanatory variables fixed. The $\boldsymbol{\delta}_1$ and $\boldsymbol{\delta}_3$ parameters indicate the differences in price variance associated with AMAs, holding $\mathbf{CATTLE\_CH}_{ti}$ and $\mathbf{D\_MONTH}_t$ fixed.

Prior to estimating the complete model, we tested the following three null hypotheses for the existence of heteroskedasticity and/or correlation in the error term:

- HYPOTHESIS 1. H_0: $\boldsymbol{\delta}_1 = \boldsymbol{\delta}_2 = \boldsymbol{\delta}_3 = \boldsymbol{\delta}_4 = 0$ vs. H_1: H_0 not true;
- HYPOTHESIS 2. H_0: $\sigma_v^2 = 0$ vs. H_1: $\sigma_v^2 > 0$;
- HYPOTHESIS 3. H_0: $\rho\sigma_v^2 = 0$ vs. H_1: $\rho\sigma_v^2 > 0$.

If the null hypothesis for hypothesis 1 is not rejected, we would not have to model heteroskedasticity. If the null hypothesis for hypothesis 2 is not rejected, we would not have to model the price correlation among transactions within the same week. If the null hypothesis for hypothesis 3 is not rejected, we would not have to model the price correlation between neighboring weeks. The following steps were conducted to test the three hypotheses:

1. Estimate equation (1) by OLS, which yields the residuals $\{\hat{u}_{ti}: t = 1,...,T;\ i = 1,...,I_t\}$.

2. To test null hypothesis 1, regress $\log(\hat{u}_{ti}^2)$ on the regressors in equation (4) to obtain estimates of $\boldsymbol{\delta}$, and use an F-test to test the joint significance of the regressors.

3. Estimate σ_v^2 by computing

$$\hat{\sigma}_v^2 = \left(\sum_{t=1}^{T} \sum_{i \neq j} \hat{u}_{ti}\hat{u}_{tj} \right) \Big/ \left(\sum_{t=1}^{T} I_t(I_t - 1)/2 \right),$$

estimate the variance of σ_v^2 by computing

$$\hat{V}(\hat{\sigma}_v^2) = \left(\sum_{t=1}^{T} \sum_{i \neq j} (\hat{u}_{ti}\hat{u}_{tj})^2 \right) \Big/ \left(\sum_{t=1}^{T} I_t(I_t - 1)/2 \right) - \hat{\sigma}_v^4,$$

and then use a t-test to test null hypothesis 2:

$$t = \hat{\sigma}_v^2 \Big/ \sqrt{\hat{V}(\hat{\sigma}_v^2)}\,.$$

4. Estimate $\rho\sigma_v^2$ by computing

$$\hat{\eta} = \left(\sum_{t=1}^{T-1} \sum_{i=1}^{I_t} \sum_{j=1}^{I_{t+1}} \hat{u}_{ti}\hat{u}_{t+1,j} \right) \Big/ \left(\sum_{t=1}^{T-1} I_t I_{t+1} \right),$$

estimate the variance of $\hat{\eta}$ by computing

$$\hat{V}(\hat{\eta}) = \left(\sum_{t=1}^{T-1} \sum_{i=1}^{I_t} \sum_{j=1}^{I_{t+1}} (\hat{u}_{ti}\hat{u}_{t+1,j})^2 \right) \Big/ \left(\sum_{t=1}^{T-1} I_t I_{t+1} \right) - \hat{\eta}^2,$$

and then use a t-test to test null hypothesis 3:

$$t = \hat{\eta} \Big/ \sqrt{\hat{V}(\hat{\eta})}\,.$$

Each of the three null hypotheses is rejected at the 1% significance level. The estimates of σ_v^2 and ρ are reported at the bottom of table 3. The results of these tests support modeling both heteroskedasticity and correlation in the error term. This dependence in the error terms has not been considered in previous research using transaction prices and suggests the statistical significance of some of those previous findings may be overstated.

Estimation Results

Equation (1) was estimated using OLS. The estimates for the parameters are reported in the second column of table 3, with standard errors in column 3. In addition, the estimated coefficients and standard errors for the heteroskedasticity model, $\boldsymbol{\delta}$, are reported in columns 4 and 5. The variance of $\boldsymbol{\beta}$ in equation (1) is estimated by computing $\hat{V}(\hat{\boldsymbol{\beta}}) = (\mathbf{X}'\mathbf{X})^{-1}\mathbf{X}'\hat{\boldsymbol{\Omega}}\mathbf{X}(\mathbf{X}'\mathbf{X})^{-1}$, where $\mathbf{X} = [X'_{11}, ..., X'_{1I_1}, X'_{21}, ..., X'_{2I_2}, ..., X'_{T1}, ..., X'_{TI_T}]'$, with

$$\mathbf{X}_{ti} = \left[1, \mathbf{D\_AMA}_{ti}, \mathbf{CATTLE\_CH}_{ti}, d\_beefcattle_{ti}, \mathbf{D\_MONTH}_t\right],$$

and $\hat{\boldsymbol{\Omega}}$ is the estimated variance of the vector of error term

$$\mathbf{u} = \left[u_{11}, ..., u_{1I_1}, u_{21}, ..., u_{2I_2}, ..., u_{T1}, ..., u_{TI_T}\right]'$$

whose structure is described in equations (2)–(4). Specifically, $\hat{\boldsymbol{\Omega}}$ is a square matrix of order

$$I = \sum_{t=1}^{T} I_t,$$

and its (k, l) element $\hat{\boldsymbol{\Omega}}_{k,l}$ equals $\hat{\text{cov}}(u_{ti}, u_{sj})$, where

$$k = i \text{ and } l = j \text{ if } t = s = 1,$$

$$k = \sum_{m=1}^{t-1} I_m + i \text{ and } l = j \text{ if } t > 1 \text{ and } s = 1,$$

$$k = i \text{ and } l = \sum_{m=1}^{s-1} I_m + j \text{ if } t = 1 \text{ and } s > 1, \text{ and}$$

$$k = \sum_{m=1}^{t-1} I_m + i \text{ and } l = \sum_{m=1}^{s-1} I_m + j \text{ if } t > 1 \text{ and } s > 1.$$

Table 3. Parameter Estimates for the Price Difference Models of Fed Cattle Purchase Transactions, October 2002–March 2005

	Price		Log(var(**u**))	
Variable[a]	Coefficient	Std. Error	Coefficient	Std. Error
d_auction	0.016	0.0011	0.92	0.053
d_forward	-0.047	0.0008	0.56	0.025
d_packer	-0.012	0.0017	-0.32	0.073
d_marketing	-0.006	0.0005	-0.22	0.013
d_beefcattle	0.027	0.0003	-0.16	0.010
*d_beefcattle*d_auction*	0.093	0.0016	0.54	0.055
*d_beefcattle*d_forward*	-0.00002[b]	0.0008	0.52	0.032
*d_beefcattle*d_packer*	0.013	0.0018	0.22	0.075
*d_beefcattle*d_marketing*	0.012	0.0004	0.02[b]	0.016
numberofhead	0.005	0.0001	-0.10	0.004
yg45_pct	-0.073	0.0010	0.70	0.033
primechoice_pct	0.062	0.0005	-0.23	0.012
outweight_pct	-0.021	0.0005	0.31	0.009
branded_pct	0.027	0.0006	-0.16	0.014
σ_v^2	0.00072			
ρ	0.27			
No. of Observations (lots)	571,608		571,608	
R^2	0.7744		0.1260	

[a] Other variables not reported here include an intercept, monthly binary variables, and plant binary variables.
[b] Coefficient is insignificant at the 5% level. All other variables are significant at the 5% level.

Thus,

$$\hat{\boldsymbol{\Omega}}_{k,l} = \begin{cases} \exp(\mathbf{X}_{ti}\hat{\boldsymbol{\delta}}) & \text{if } t = s,\ i = j, \\ \hat{\sigma}_v^2 & \text{if } t = s,\ i \neq j, \\ \hat{\rho}\hat{\sigma}_v^2 & \text{if } |t - s| = 1, \\ 0 & \text{otherwise.} \end{cases}$$

We use OLS rather than the more efficient feasible generalized least squares (FGLS) or maximum-likelihood estimation (MLE) for three reasons. First, OLS is more robust to model specification than FGLS or MLE. MLE requires specifying the joint distribution of error term, which means we would have to impose a much stronger assumption on the error term than our current version. FGLS imposes a weaker assumption than MLE; however, it would yield inconsistent estimates for the coefficients if the error structure is misspecified. Second, both MLE and FGLS are computationally difficult because of the size of the data set and the complexity of the error structure.[8] Third, efficiency is not a substantial concern here given our large sample size. The results are described in more detail below.

[8] Estimation of the model using FGLS would require inverting a 571,608 × 571,608 matrix.

Price Difference Equation Results

The results of estimation suggest that, while holding other explanatory variables fixed, (*a*) beef breed direct trade cattle were priced $0.027 per pound higher than dairy breed direct trade cattle, (*b*) cattle with higher yield grades or higher quality grades received a higher average price, (*c*) a 10% increase in cattle eligible for product branding in a lot was associated with a $0.027 per pound higher average price, and (*d*) the prices of lightweight or heavyweight cattle were discounted. In addition, average prices were slightly higher for larger cattle lots. These differences are relative to an average price of $1.31 per pound carcass weight for the transactions in the data set and indicate the average magnitude of premiums and discounts being paid to producers.

Tables 4 and 5 summarize the estimated average price differences among AMAs for beef cattle and dairy cattle, respectively. Standard errors were estimated as described by equations (2)–(4). All the differences were individually significant at the 5% level, based on Wald tests. The average prices were closest among the direct trade, marketing agreement, and packer-owned transactions, with the estimated differences ranging from $0.001 to $0.012 per pound carcass weight. These estimates are relatively similar to the estimates of $0.001 for marketing agreement and $0.0001 for packer-owned transactions relative to all cash market transactions reported by Ward, Koontz, and Schroeder (1998). The auction barn transaction price was estimated to be about $0.109 higher for beef breed cattle (see table 4) and $0.016 higher for dairy breed cattle (see table 5) than for the corresponding direct trade cattle, although both direct trade and auctions are cash market procurement methods. Also (again similar to Ward, Koontz, and Schroeder), transaction prices associated with forward contract transactions were the lowest among all the procurement methods. This result may suggest that farmers who choose forward contracts were willing to give up some revenue to secure market access and fix the price at least two weeks before delivery.

The findings that auction barn prices were the highest and forward contract prices were the lowest could be due, in part, to the unique time period of the analysis, including the stage of the cattle cycle and the closure of the border with Canada after the discovery of BSE in May 2003. Our model compares the prices among procurement methods for the cattle delivered in the same month but does not control for the pricing dates related to individual transactions. Transaction prices are correlated with the expectation of market conditions at the delivery date based on the information available at the pricing date. Pricing dates and delivery dates systematically differed among procurement methods. According to the portion of the data for which pricing dates were available (approximately 40% of the records), on average, forward contract cattle were priced 12 days ahead of delivery date, direct trade cattle were priced six days ahead, and auction barn cattle were priced only two days ahead of the kill date.[9] Consider a forward contract lot and an auction barn lot that are delivered at the same time. If a positive market shock (e.g., the closure of the border with Canada) occurred before the pricing time of auction barn cattle but was not expected at the time when forward contract cattle were priced, then forward contract cattle would be priced lower than auction barn cattle because of the unexpected random market shock.

[9] Note that the pricing date is different from the date on which the contract was signed. For example, forward contracts are typically signed a few months prior to slaughter, but prices may be set according to a formula closer to the slaughter date and possibly after the slaughter date, if valuation is based on a carcass weight using a grid.

Table 4. Estimated Average Price Differences Among AMAs for Fed Beef Cattle Purchase Transactions, October 2002–March 2005 ($/lb. carcass weight)

Marketing Arrangement	Auction	Direct Trade & Dealer/Broker	Forward Contract	Marketing Agreement	Packer Owned
Auction	—	0.109	0.156	0.103	0.108
Direct Trade & Dealer/Broker	-0.109	—	0.047	-0.006	-0.001
Forward Contract	-0.156	-0.047	—	-0.053	-0.048
Marketing Agreement	-0.103	0.006	0.053	—	0.005
Packer Owned	-0.108	0.001	0.048	-0.005	—

Table 5. Estimated Average Price Differences Among AMAs for Dairy Breed Fed Cattle Purchase Transactions, October 2002–March 2005 ($/lb. carcass weight)

Marketing Arrangement	Auction	Direct Trade & Dealer/Broker	Forward Contract	Marketing Agreement	Packer Owned
Auction	—	0.016	0.063	0.022	0.028
Direct Trade & Dealer/Broker	-0.016	—	0.047	0.006	0.012
Forward Contract	-0.063	-0.047	—	-0.041	-0.035
Marketing Agreement	-0.022	-0.006	0.041	—	0.006
Packer Owned	-0.028	-0.012	0.035	-0.006	—

Somewhat similar conditions existed for the time period of the data analyzed by Ward, Koontz, and Schroeder (1998) in that cattle prices rose because of extreme weather conditions in the winter of 1992, resulting in limited cattle supplies.[10] If the time period represented in the data were long enough, a positive shock would not bias the estimation results because positive shocks should be offset by negative shocks in the long run. However, this may not be true in this case because the represented time period is relatively short. Specifically, if the unexpected market shock were systematically positive during our represented period, failing to control for market expectations at the pricing date would bias the estimates of price differences among procurement methods. Nevertheless, we believe the effect of this bias is limited, because the largest average pricing date difference among procurement methods is a maximum of 12 days. To investigate the possible bias in the results due to the unique time period of analysis, we examined the average two-week price difference in the Nebraska cash market for steers. This difference was found to be both economically and statistically insignificant (the mean value of the difference is $0.0018 per pound dressed weight, and the p-value of the t-test is 0.78). Therefore, we expect the bias, if it exists, is small.

The primary findings of the price difference model is that marketing agreement, packer-owned, and negotiated cash cattle are all priced at similar levels. While dairy breed fed cattle sold under a marketing agreement are discounted slightly relative to direct trade, the opposite occurs for beef breed fed cattle. Although price differences may be a reason for using particular AMAs, other reasons, such as allowing for market access, also affect the decision to use AMAs.

[10] In contrast, Schroeter and Azzam (1999) found that forward contract prices were higher relative to cash market prices because prices were trending downward during the time period of their analysis.

Heteroskedasticity Equation Results

The primary conclusions regarding price risk from the estimated coefficients in the fourth column of table 3 indicate that compared with direct trade, the price variances were much higher for auction barn transactions and forward contracts and lower for packer-owned and marketing agreement transactions, holding cattle characteristics (**CATTLE_CH**$_{ti}$) and month of sale (**D_MONTH**$_t$) fixed. In comparing these coefficients, variances of prices clearly do not represent all types of risk faced by market participants. In particular, producers using forward contracts may face higher price risk if market conditions change after negotiating the contract, but they may also face lower revenue risk, they may have secured market access, and they may have the ability to obtain better financing terms with lenders.

Other parameter estimates suggest that price variances were (*a*) lower for fed beef cattle than fed dairy cattle, (*b*) lower for cattle that are eligible for a branded and certification program, (*c*) lower for cattle of higher yield grade (i.e., a lower yield grade number) and quality grade, (*d*) lower for cattle within the regular weight range, and (*e*) lower for cattle sold in large lots. To summarize, cattle possessing desirable characteristics obtained not only higher average prices but also secured lower price risk.

The estimated differences (percentage higher or lower) in price variance among marketing arrangements for fed beef cattle and for fed dairy cattle are reported in tables 6 and 7, respectively. All the difference estimates were individually significant at the 5% level based on Wald tests. Among the five marketing arrangement categories, auction barn transactions were associated with the highest average price but also the highest price risk, even after accounting for systematic factors such as quality and month. Thus, it appears that selling through auction barns should appeal more to less risk-averse cattle feeders.[11] In addition, prices under forward contracts were more risky than direct trade or marketing agreements because prices were lower and price risk was higher.

In comparing auction barn transactions to forward contracts, the average price difference ($0.156 per pound for beef cattle and $0.063 per pound for fed dairy cattle) could be considered a risk premium to compensate feeders who sell their cattle in auction barns for bearing more price risk (46% higher variance for beef cattle and 43% higher variance for fed dairy cattle) and for assuming more market access risk. Packer-owned fed dairy cattle had slightly lower average prices ($0.012 per pound carcass weight) and lower price variance (27% lower) than those under direct trade, while packer-owned fed beef cattle had slightly higher average prices ($0.001 per pound carcass weight) and lower price variance (10% lower) than direct trade. This result is consistent with the fact that internal transfer prices for packer-owned cattle usually are based on a reported average cash market price.

Transactions through marketing agreements are associated with lower price risk (18% lower variance for fed beef cattle and 20% lower for fed dairy cattle) than those through direct trade. Given that average prices for marketing agreement cattle and direct trade cattle are very similar, and marketing agreements help secure market access while direct trade does not, it appears that a risk-averse feeder has less incentive to use direct trade when marketing agreements are available. However, marketing agreements

[11] Although less risk-averse cattle feeders may prefer use of auctions, we note that some cattle feeders may simply use auctions because they sell small lots of cattle that would be difficult to contract.

Table 6. Estimated Price Variance Differences (% higher or lower) Among Marketing Arrangements Used for Purchasing Fed Beef Cattle, October 2002–March 2005

Marketing Arrangement	Auction	Direct Trade & Dealer/Broker	Forward Contract	Marketing Agreement	Packer Owned
Auction	0	331	46	426	376
Direct Trade & Dealer/Broker	-77	0	-66	22	11
Forward Contract	-32	194	0	260	225
Marketing Agreement	-81	-18	-72	0	-10
Packer Owned	-79	-10	-69	11	0

Note: The differences are computed as the price variance of each AMA listed in the left column divided by the price variance of each AMA listed in the top row minus one.

Table 7. Estimated Price Variance Differences (% higher or lower) Among Marketing Arrangements Used for Purchasing Dairy Breed Fed Cattle, October 2002–March 2005

Marketing Arrangement	Auction	Direct Trade & Dealer/Broker	Forward Contract	Marketing Agreement	Packer Owned
Auction	0	151	43	213	246
Direct Trade & Dealer/Broker	-60	0	-43	25	38
Forward Contract	-30	75	0	118	141
Marketing Agreement	-68	-20	-54	0	11
Packer Owned	-71	-27	-59	-10	0

Note: See footnote to table 6 above.

require a strong bilateral relationship between feeder and packer and might not be available for all feeders.

From a methodological standpoint, the correlation of transaction prices within the week and across weeks is important. The estimates of σ_v^2 and ρ in equation (3) are individually significant at the 1% level. The estimated average correlations of prices within the week and across weeks are 16% and 4.3% respectively. Thus, ignoring these correlations may result in higher levels of significance of the estimated model parameters and cause inferences to be misleading.

Summary and Conclusions

Fed cattle producers and beef packers may choose among several cash and AMAs to conduct transactions. Factors affecting their choices include whether prices are on average higher, lower, or more or less volatile for each type of arrangement. We conducted an econometric analysis of the relationship between fed cattle transaction prices and use of marketing arrangements, while controlling for differences in cattle quality and delivery month and accounting for the within-week and across-nearby-week correlation in prices. The analysis used a recent data set for the October 2002 through March 2005 time period and included sale lots of six or more cattle purchased by the 29 largest beef packing plants in the United States.

The results indicate that relative to direct trade, which is the most frequently used marketing arrangement for fed cattle, prices for fed cattle sold through auctions were higher, but also had substantially higher price risk. Prices for cattle sold under forward contracts or marketing arrangements or cattle transferred under packer ownership were all lower than cattle for direct trade, but only prices under forward contracts were more volatile. The results for forward contracts are likely explained by the time period of the analysis, in which fed cattle prices were trending upward. Also, prices under forward contracts are set earlier than for the other types of arrangements. Marketing agreements appeared to provide the best tradeoff between price level and price risk compared with direct trade, because prices were within $0.01 per pound carcass weight for both beef and dairy breed fed cattle but were 18% to 20% less volatile. Although use of marketing agreements for fed cattle has increased substantially compared to the previous analysis by Ward, Koontz, and Schroeder (1998), estimated price differences are similar when compared to cash market transactions. However, our results break out separate price difference estimates for direct trade versus auction transactions, and show that cash market transactions are not homogeneous. Furthermore, previous research on fed cattle pricing has not shown the specific tradeoffs between price levels and price volatility that producers and packers must consider when choosing among types of marketing arrangements.

Our results also revealed that larger and higher quality lots were associated with higher average prices and lower variances of prices. Packers are willing to pay more for larger lots because they reduce their transactions costs and improve scheduling of their operations. The quality measures used in the analysis included the percentage of cattle in Yield Grade 4 or 5, in Choice or Prime Quality Grade, outside of the desired weight range, and eligible for product branding. All measures were statistically significant, indicating that packers pay more for better quality cattle and have less variation in prices while holding fixed the type of marketing arrangement used and the month of purchase.

Further analyses of these data are investigating more directly the relationship between the use of AMAs, which would typically be considered captive supply arrangements, and cash market prices (Muth et al., 2007). In particular, the questions of interest include whether individual packers bid less aggressively in the cash market when they have a higher proportion of their supplies precommitted under AMAs and whether a higher use of AMAs across the industry is associated with reduced cash market prices. Additional analyses are also investigating the direct relationship between fed cattle quality and the use of different types of marketing arrangements or valuation methods (i.e., liveweight, carcass weight with a grid, and carcass weight without a grid) (Muth et al., 2007). In this case, the question of interest is whether packers are using AMAs to ensure higher and more consistent quality of fed cattle purchases.

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