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Price Discovery in Nebraska Cattle Markets

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Monthly observations on prices from 10 weight/gender classifications of Nebraska beef cattle are studied in an error correction model (ECM) framework. This study attempts a replication of the 2003 paper on Texas prices by Bessler and Davis, where they find medium heifers (600–700 lb) at the center of price discovery. Using the ECM results Nebraska light steers are found to be weakly exogenous, with the innovation accounting results showing marked differences. Industry structure, production choices, and animal type and breeding herd differences between Texas and Nebraska are proposed as plausible reasons for partial (or incomplete) success at replication.

Key Words: Bernanke factorization, cattle prices, cointegration, directed acyclical graphs, error correction, PC algorithm, price discovery

JEL Classifications: C49, Q13

Price Discovery in Nebraska Cash Cattle Markets

This paper presents an attempt at replication of results from a paper on cattle price discovery by Bessler and Davis (2004). We follow Tomek (1993) in distinguishing between *confirmation* and *replication*. The former refers to duplication of results using the exact data and model. The latter refers to finding the "same" results on a different data set in a different but similar setting. The scientific community takes different stands on confirmation and replication. With respect to replication, the community generally desires model results to (broadly speaking) transfer to other "similar" cases. We want, in short, external validity (Campbell and Stanley, 1966). And yet, as we note in this paper, failure to find what we want may, in fact, teach us more about natural phenomena and improve our understanding of how the world actually works. Failure to replicate may actually be a positive outcome, as it may instruct us on where to look for deeper explanations. There appears to be no positive interpretation in our failure to confirm. It is replication that we are focused on in the present study.

Bessler and Davis (2004) study the flow of price information among alternative weight/gender classes in Texas cash (not futures or forward) markets. They use time series methods as recently augmented with methods for modeling the structure of contemporaneous innovations using directed acyclical graphs (DAGs) [see the discussion in Swanson and Granger (1997) and the application in Bessler and Akleman (1998)]. Bessler and Davis (2004) offer evidence that heavy heifer (600–700 lb animals) prices are weakly exogenous (in lagged time). Prices of animals in this gender/weight class showed no response (in future

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time periods) when innovation shocks occurred in prices of other gender/weight classes. In addition, their DAG analysis shows that in contemporaneous time, 700–800 lb heifer prices are "causal" relative to prices of lighter heifer classes and to same weight steer class price. Given these results, they concluded that prices of heavy heifers (both 600–700 lb animals and 700–800 lb animals) are the source of price discovery among alternative weight and gender classes of feeder animals.

They hypothesize that heifers of 600–800 lb are of breeding size and could be used in the cow herd as replacements or moved on with steers to feedlots and slaughtered. This seems a plausible explanation given that cattle inventory is directly related to retained female numbers, as well as cull rates, where the primary control of inventories (other than culling) is retention of new females. Our focus in the present paper is whether similar results hold for Nebraska cattle. We use the same methods as Bessler and Davis (2004) on the same weight classes of cattle over the identical time period.

Methods

We first study the dynamic properties of time ordered observations on 10 price series on heifer and steer prices for Nebraska animals. We expect cointegration across different weight/gender classes. We expect to see an error correction model with k-1 lags as a reasonable generating process of these data:

$$(1) \qquad \Delta P_t = \Pi P_{t-1} + \sum_{i=1}^{k-1} \Gamma_i \Delta P_{t-i} + \mu + e_t; t = 1,\ldots,\mathrm{T}$$

where $e_t \sim Niid(0, \Sigma)$ and Δ is the difference operator ($\Delta P_t = P_t - P_{t-1}$), P_t is a (10×1) vector of prices at time $t = 1, \ldots, \mathrm{T}$, Γ_i is a (10×10) matrix of parameters to be estimated reflecting the short-run relationships between past differences in prices and current differences in prices, Π is a (10×10) (or (10×11) depending on the placement of a constant) matrix of parameters reflecting the relationship between levels of price of different weight or gender classes, which may well have reduced rank ($r < 10$), such that $\Pi = \alpha\beta'$. The matrix β' is a $(r \times 10)$ (or $(r \times 11)$) matrix reflecting the long-run relationships between levels of price series and α is a $(10 \times r)$ matrix of adjustment parameters summarizing how each series adjusts to perturbations in each of the long-run relationships summarized in β'. Contemporaneous information flows are studied in a DAG structure using estimated innovations $\hat{e}$ and their estimated covariances via the matrix, $\hat{\Sigma}$, using PC algorithm (http://www.phil.cmu.edu/projects/tetrad/).

Description of the Data

All prices were extracted from the University of Nebraska's Extension Service circular #883, "Crop and Livestock Prices for Nebraska Producers (1960–2006)" by Mark and Malchow (1998). We used the price data for steers and heifers weighing 400 lb to slaughter weight. These prices are grouped by gender into five classes. The first four are determined by weight in 100 lb increments, with the fifth being choice slaughter animals (steers and heifers). As in the original Bessler and Davis (2004) study we consider these data over the period of January 1992 through May 2003. The data are transformed into logarithmic form to reduce the magnitude of the variations without changing the overall appearance and characteristics of the data. Table 1 offers descriptive statistics on the logarithm of each price series. Lighter weight animals have higher mean values relative to heavier animals. Steers have higher mean values than their corresponding weight-class heifers. Feeder cattle (all classes between 400–800 lb) prices find their minimum values in 1996 and their maximum values in 2001. These dates on minimum and maximum values are not replicated for the slaughter weight animals (1100 lb steers and 1000 lb heifers). Here minimums occur in 1998, maximums in 1993.

We plot the logarithm of prices in Figure 1 (steer prices are in the left column and heifer prices in the right column). Slaughter steer and heifer prices are at the top of the figure with the lighter weight animals below, ending with 400–500 pound steer and heifer prices at the bottom. None of the graphed price data appear to be attracted to their historical mean values (or

Table 1. Descriptive Statistics on Logarithms of Cattle Prices, Monthly Data: January 1992–May 2003

Series	Mean	Standard Deviation	Minimum (Date)	Maximum (Date)
Steers 1100 lb	4.23	0.08	4.07 (1998:09)	4.41 (1993:03)
Heifers 1000 lb	4.23	0.08	4.06 (1998:09)	4.41 (1993:03)
Steers 700–800 lb	4.37	0.13	3.95 (1996:04)	4.58 (2001:07)
Heifers 700–800 lb	4.31	0.13	3.88 (1996:04)	4.51 (2001:08)
Steers 600–700 lb	4.41	0.14	3.94 (1996:04)	4.88 (2001:07)
Heifers 600–700 lb	4.34	0.14	3.94 (1996:04)	4.57 (2001:07)
Steers 500–600 lb	4.50	0.15	4.13 (1996:07)	4.74 (2001:06)
Heifers 500–600 lb	4.39	0.16	3.91 (1996:04)	4.64 (2001:06)
Steers 400–500 lb	4.54	0.18	4.02 (1996:04)	4.81 (2001:06)
Heifers 400–500 lb	4.45	0.18	3.96 (1996:04)	4.72 (2001:06)

Units of Measure (before logarithm transformation) \$/100 lb.

midpoints); each series moves for long periods of time in either an upward or downward direction. This visual pattern supports the notion that each is nonstationary in its mean. Furthermore, it appears that the price movements between genders of the same weight classes move in unison. Finally, price movements between weight classes appear closely related as well, supporting the idea that they may be cointegrated.

Results

An Augmented Dickey-Fuller (ADF) test is used to test the null hypothesis that each series is nonstationary. The results of the test are found in Table 2. The upper panel of the table refers to ADF tests on the levels of each series; the lower panel refers to tests on the first differences of each series. All series on feeder class animals were found to be nonstationary in levels and stationary in first differences, making each class series integrated of order one (denoted as I(1)). Table 2 also shows the results of the Ljung-Box Q-test using the innovations from the ADF test. No test result indicates severe autocorrelation in the residuals of the ADF test. All p values on the Q-statistics are greater than 0.05. An interesting result from Table 2 is that slaughter animals, 1100 lb steers and 1000 lb heifers, show evidence of stationarity in levels (ADF t-statistics are less than -2.89). We follow Juselius (1995) and keep the slaughter series in the set of studied series to be modeled as in Equation (1). If each is stationary in levels, this will result in two stationary relations in the cointegration space (one for each stationary series). Below, we test for this stationarity result and reject it.

The lag length for the error correction model or ECM (the k in Equation (1) above) is determined from the specification derived from an unrestricted vector autoregression. Table 3 lists the outcome of Schwarz and Hannan and Quinn loss metrics on various lag lengths, with and without monthly (seasonal) dummy variables, associated with fit unrestricted vector autoregressions on the 10 logged price series.

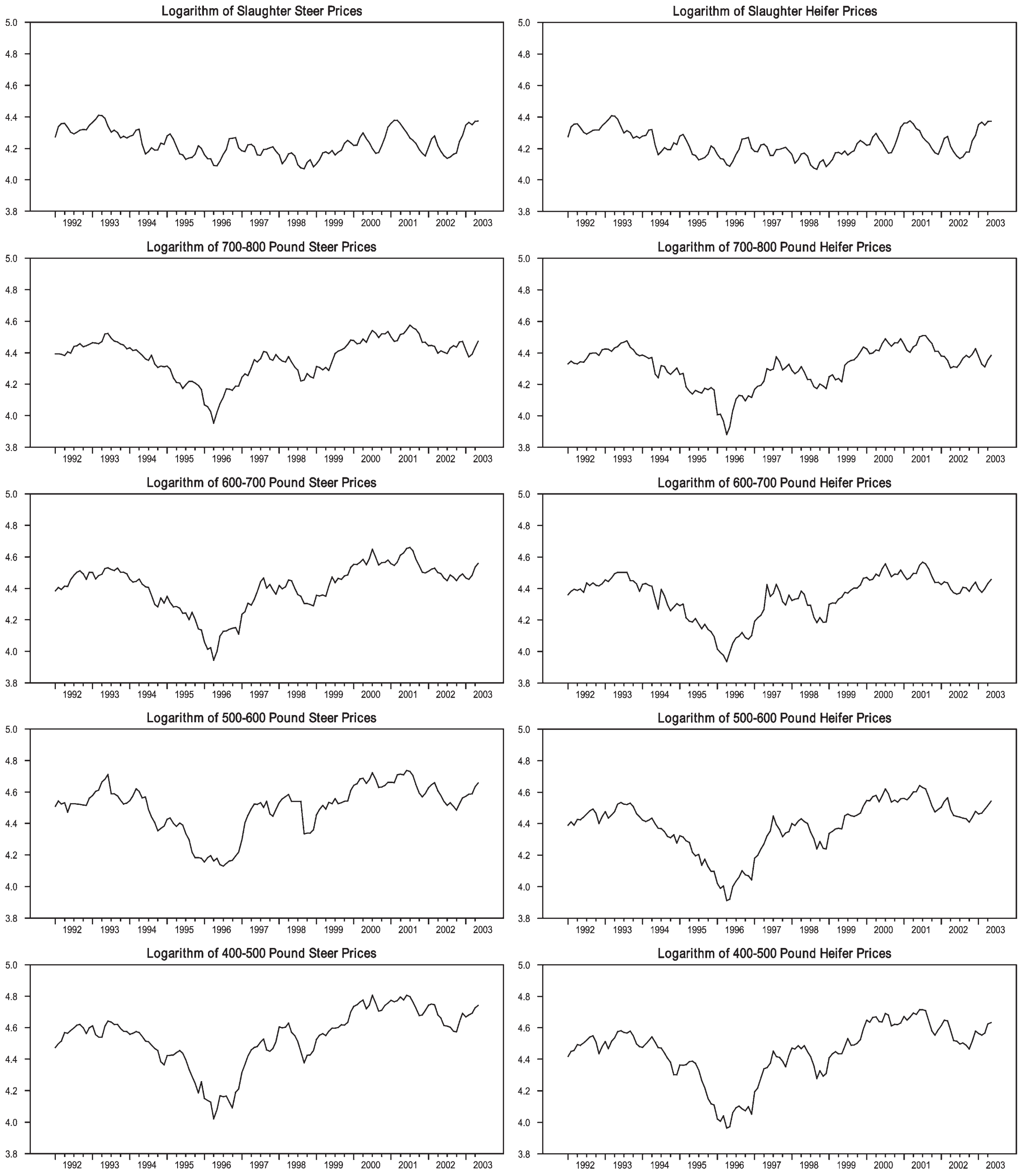

Figure 1. Time Series Plots of Logarithms of Levels of Nebraska Cattle Prices, Monthly Observations: January 1992–May 2003

The measures in Table 3 summarize fit on the 10 different models. Half of the models incorporate 11 seasonal variables, with the remaining half having no seasonal variables. Both groups of models use a constant with zero through four lags (we looked at up to six lags but report results on up to four lags in Table 3). The model with the lowest Schwarz and Hannan and Quinn loss metrics had no seasonal variables, a constant, and prices lagged a single time period.

Table 4 presents results on the number of cointegrating vectors using the trace test. Here we test for the constant inside the cointegrating

Table 2. Tests for NonStationarity of Logarithms of Prices and First Differences of Logarithms of Prices for Nebraska Cattle Prices, Monthly Data: January 1992–May 2003

	Augmented Dickey-Fuller	
Series (lb)	t-test (k)	Q (*p*-value)
	(Levels)	
Steers (1100)	−3.50 (1)	32.13 (0.46)
Heifers (1000)	−3.45 (1)	37.37 (0.24)
Steers (700–800)	−1.58 (1)	39.16 (0.18)
Heifers (700–800)	−1.93 (1)	27.37 (0.70)
Steers (600–700)	−1.34 (1)	25.52 (0.78)
Heifers (600–700)	−1.61 (1)	30.86 (0.52)
Steers (500–600)	−1.63 (5)	41.83 (0.11)
Heifers (500–600)	−1.32 (1)	27.95 (0.67)
Steers (400–500)	−1.55 (2)	42.83 (0.10)
Heifers (400–500)	−1.69 (3)	41.31 (0.13)
	(First Differences)	
Steers (1100)	−7.39 (3)	38.67 (0.19)
Heifers (1000)	−6.43 (3)	42.85 (0.10)
Steers (700–800)	−7.66 (1)	39.87 (0.16)
Heifers 700–800)	−8.34 (1)	27.18 (0.71)
Steers (600–700)	−7.49 (1)	25.74 (0.77)
Heifers (600–700)	−8.71 (1)	30.72 (0.53)
Steers (500–600)	−5.24 (4)	43.26 (0.09)
Heifers (00–600)	−7.19 (1)	27.70 (0.68)
Steers (400–500)	−5.34 (2)	45.15 (0.06)
Heifers (400–500)	−5.22 (2)	44.05 (0.08)

Notes: The Augmented Dickey-Fuller test is on the null hypothesis that the natural logarithm of levels (levels panel) or first differences of the natural logarithm of levels (first difference panel). Price data from the market class listed in the far left-hand column are nonstationary. The test for each series is based on an ordinary least squares regression of the first differences of the logarithm of prices from each market on a constant, k lags of the dependent variable, and one lag of the levels of the logarithm of prices (levels panel) and a regression of the second difference of the logarithm of each series on k lags of the second difference of the logarithm of each series and one lag of the first differences of the logarithm of prices (first differences panel). The value for k is determined by minimizing the Schwarz-loss metric on values of k ranging from 1 to 6. The t-statistic is associated with the estimated coefficient on the lagged levels variable from this regression in the levels panel and the lagged first difference variable in the first difference panel. Under the null hypothesis the statistic is distributed in a nonstandard t. Critical values are given in Fuller (1976). The 5% critical value is –2.89. We reject the null for observed t values less than this critical value.
The associated Q-statistic is the Ljung-Box statistic on the estimated residuals from the above-described regression. Under the null hypothesis of white noise residuals, Q is distributed chi-squared with 32 degrees of freedom. The *p*-value associated with the Q-statistic is given in parentheses. We reject the null hypothesis for large values of Q or for low *p*-values (i.e. *p*-values less than 0.05).

Table 3. Loss Metrics on the Order of Lags (k) in a Levels Vector Autoregression on Log Prices for Nebraska Cattle and 11 Seasonal Dummy Variables, Monthly Data: January 1992–May 2003

Lags = k	SL	Φ
	Constant and No Lags of Prices and No Seasonals	
0	−71.77	−71.90
	Constant, No Lags of Prices and 11 Seasonals	
0	−70.49	−72.00
	Constant, k Lags of Prices and No Seasonals	
1	−77.57 *	−78.95 *
2	−75.33	−77.96
3	−72.88	−76.76
4	−70.49	−75.63
	Constant, k Lags of Prices and 11 Seasonals	
1	−75.50	−78.26
2	−73.22	−77.23
3	−70.71	−75.97
4	−68.38	−74.90

Notes: The models considered are vector autoregressions of the logarithms of the ten cattle prices with lags of 0 (no lags) through 4, each equation in the panel has either no, or 11 seasonal monthly variables. Metrics considered are Schwarz-loss (SL) and Hannan, and Quinn's Φ measure on lag length (k) of a levels vector autoregression:
$SL = \log(|\Sigma|) + (10k + 2n + 1) \times (\log T)/T$,
$\Phi = \log(|\Sigma|) + (2.00)(10k + 2n + 1) \times (\log(\log T))/T$
where Σ is the error covariance matrix estimated with 10k + 11 + 1 (the "11" represents the 11 seasonal dummy variables, the "1" represents the constant) regressors in each equation, T is the total number of observations on each series, the symbol " | | " denotes the determinant operator, and log is the natural logarithm. We select that model that minimizes the loss metric. The asterisk ("*") indicates minimum of each column. We report only results on lags of prices for lags 1, 2, 3, and 4. Results on other lags of prices, up to 6, are available from the authors.

space and for the constant outside the cointegrating space, following the sequential testing pattern laid out in Johansen (1992). [The first note in the table summarizes this sequential testing.] Here we find seven cointegrating vectors with the constant inside the cointegration space. Recent literature has pointed out problems with relying solely on the trace test to select cointegration rank (Wang and Bessler,

Table 4. Tests of Cointegration among Logarithms of Prices for Cattle from 10 Market Classes, Monthly Data: January 1992–May 2003

R	T*	C(5%)*	*D**	T	C(5%)	*D*
=0	447.04	244.56	R	446.64	232.60	R
≤1	361.92	203.34	R	361.52	192.30	R
≤2	283.92	165.73	R	282.71	155.75	R
≤3	213.11	132.00	R	212.75	123.04	R
≤4	154.48	101.84	R	154.13	93.92	R
≤5	110.53	75.74	R	110.19	68.68	R
≤6	68.93	53.42	R	68.60	47.21	R
≤7	31.24	34.80	F#	30.92	29.38	R
≤8	15.20	19.99	F	14.97	15.34	F
≤9	1.69	9.13	F	1.46	3.84	F

Note: The number of cointegrating vectors (r) is tested using the trace test with the constant inside and outside the cointegrating vectors. The test statistic (T) is the calculated trace test associated with the number of cointegrating vectors given in the left-hand-most column. The critical values (C(5%)) are taken from Table B.2 (inside) and Table B.3 (outside) in Hansen and Juselius (1995, p. 80–81). The tests results presented in columns marked by an asterisk are associated with a constant within the cointegrating vectors. The unasterisked columns are associated with tests on no constant inside the cointegrating vectors, but a constant outside the vectors. The column labeled "D" gives our decision to reject (R) or fail to reject (F), at a 5% level of significance, the null hypothesis of the number of cointegrating vectors ($r = 0$, $r \leq 1, \ldots, r \leq 9$). Following Johansen (1992), we stop testing at the first F (failure to reject) when starting at the top of the table and moving sequentially across from left to right and from top to the bottom. # indicates the stopping point. Here we fail to reject the hypothesis that we have seven or fewer cointegrating vectors with constants in the cointegrating vectors.

2005). This literature suggests complementing the trace results (as given in Table 4) with values of Schwarz or Hannan and Quinn loss metrics calculated at alternative numbers of cointegrating vectors. In Figure 2 we plot such metrics for specification from one to ten cointegrating vectors, both with and without the seasonal dummy indicator variables. The metrics calculated without seasonal dummy variables lie below those calculated with seasonal variables. Hannan and Quinn metric is minimized at seven cointegrating vectors, while Schwarz loss is minimized at one cointegrating vector. As Hannan and Quinn is a consistent selection metric (see again Wang and Bessler (2005) and references given therein) and it agrees with the trace test, we use the form of Equation (1) with seven cointegrating vectors in the remainder of this study.

Given the results from Table 2, it is possible that two of the seven cointegrating vectors that appear to generate the Nebraska data are stationary slaughter series (1000 lb heifers and 1100 lb steers), as each cointegration relation is a stationary relation in the data. Table 4 summarizes chi-squared tests on this hypothesis (that each series is stationary). This test entertains the null hypothesis of stationarity, whereas the augmented Dickey-Fuller test summarized in Table 2 entertained the null of nonstationarity. In Table 5 we see rejections of stationarity for all series.

A chi-Squared test is used to determine which, if any, weight/gender class are not in the cointegrating space. Table 6 shows a summary of these tests. The null hypothesis, that a specific weight/gender class is not in the cointegrating space, is rejected for each weight/gender class. An additional chi-squared test is used to determine if any of the weight/gender classes are weakly exogenous. The results of this test are in Table 7. The hypothesis that a given weight/gender class is weakly exogenous is rejected (at a 5% level of significance) in every instance except for 400–500 lb steers. The interpretation of this test, along with the rejection of exclusion found in Table 6, is that in Nebraska light steers are at the center of price discovery. These prices (as well as all other gender and weight classes) are part of the long-run equilibrium among Nebraska cattle prices and all weight and gender classes except these light steers respond to perturbations in that equilibrium.

To study further the dynamic structure of cattle prices in Nebraska, we explore how each series responds to innovations in every other series and the relative importance of each series in explaining (accounting for) the variation in the other series. Following Bessler and Davis (2004) we report results on innovation accounting on each series. This requires that we express the estimated version of Equation (1) in its moving average form with orthogonalized contemporaneous (structural) innovations. We use PC algorithm applied to observed innovations

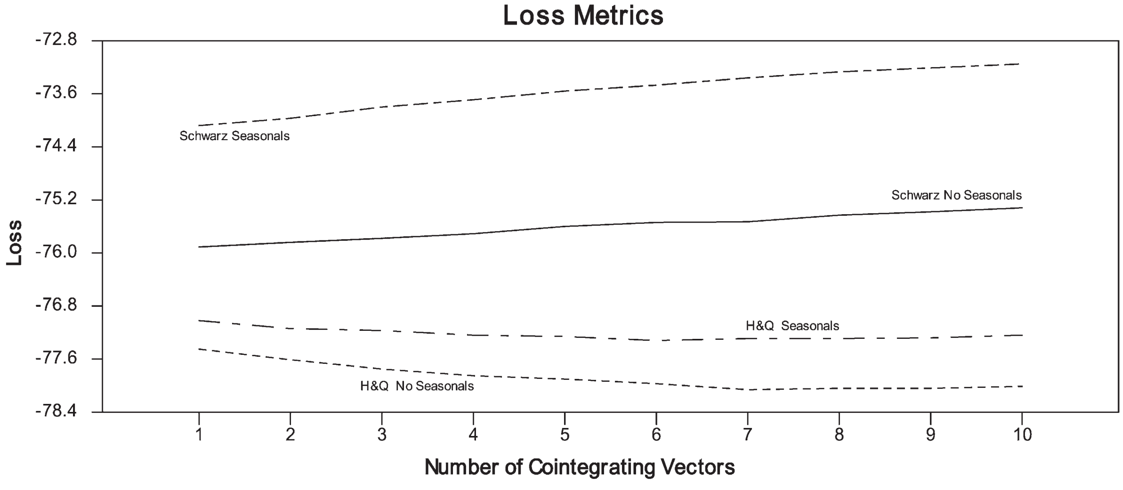

Figure 2. Loss Functions on the Number of Cointegrating Vectors on an Error Correction Model Fit on the Logarithms of 10 Nebraska Cattle Prices, Monthly Observations: January 1992–May 2003

to generate this structural form on innovations. The level of significance is appropriate for the data sample size at the 0.20 level. In Figure 3 we present the generated causal graph.

A reviewer has properly pointed out that our use of the word "causal" is perhaps different than that used by many (if not most) applied economists. Here our prior theory is the simple notion that prices for assets differing by form (and perhaps space), traded in public markets, should not be unrelated. As we study observational data (nonexperimental data) the imposition of *ceteris paribus* theory is deemed inappropriate (Haavelmo, 1944, 14–25). The machine learning algorithms of Pearl (2000) and Spirtes, Glymour and Scheines (2000) and applied in Bessler and Akleman (1998) and Bryant, Bessler and Haigh (2009), as well as the original Bessler and Davis (2004) study, are used to empirically define the structure behind current period surprises in these cattle price series.

The arrows and edges in both panels of Figure 3 show the flow of information, or causal structure, of the contemporaneous innovations. Several points are of note. First, the algorithm is not able to assign causal flow between slaughter weight steers and heifers. In Figure 3 we see the communication flow between slaughter weight animals and feeder weight animals is through 700–800 lb heifers. In this same figure, we further note the presence of two bidirected edges, indicating the possibility of an omitted variable. These edges are both placed between heifers and steers: between innovations in prices of 400–500 lb heifers and 500–600 lb steers and between 500–600 lb steers and 700–800 lb heifers.

To provide a more complete picture of the dynamic relationships among the various beef cattle prices, we turn our attention to innovation accounting techniques (Sims). The results from the forecast error variance decomposition and the impulse response analysis can be found in Table 10 and Figure 4, respectively. Table 10 lists the forecast error variance decomposition for the 10 market classes at time horizons 0, 1, and 12 months. Table 10 shows the partition of the uncertainty associated with current price shocks of itself and all other nine weight/gender classes expressed as a percent. Several things seem to standout very clearly from these decompositions. In Table 10 we see that feeder animals contribute very little to price uncertainty (error variance) in slaughter animals, just over 12%. At all horizons studied, innovations in either slaughter heifers or slaughter steers account for just under 88% of the uncertainty in these series. Steers in the 700–800 lb category

Table 5. Tests of Stationarity of Each Market Class of Cattle Prices from the Cointegration Space, Monthly Data: January 1992–May 2003

Market Class (lb)	Chi-Squared Test	*p*-value	Decision
	Steers		
400–500	37.37	0.00	R
500–600	37.38	0.00	R
600–700	37.40	0.00	R
700–800	37.39	0.00	R
1100	37.43	0.00	R
	Heifers		
400–500	37.37	0.00	R
500–600	37.39	0.00	R
600–700	37.38	0.00	R
700–800	37.40	0.00	R
1000	37.44	0.00	R

Notes: Tests are on the null hypothesis that the logarithm of the particular series listed in the far left-hand column is stationary in its levels. The Decision heading relates to the decision to reject (R) or fail to reject (F) the null hypothesis at a 5% level of significance. Under the null hypothesis, the test statistic is distributed chi-squared with four degrees of freedom.

Table 6. Tests of Exclusion of Each Market Class of Cattle Prices from the Cointegration Space, Monthly Data: January 1992–May 2003

Market Class (lb)	Chi-Squared Test	*p*-value	Decision
	Steers		
400–500	51.50	0.00	R
500–600	37.43	0.00	R
600–700	52.61	0.00	R
700–800	43.45	0.00	R
1100	32.69	0.00	R
	Heifers		
400–500	27.16	0.00	R
500–600	39.05	0.00	R
600–700	52.63	0.00	R
700–800	35.16	0.00	R
1000	33.16	0.00	R

Notes: Tests are on the null hypothesis that the particular series listed in the far left-hand column is not in the cointegration space. The Decision heading relates to the decision to reject (R) or fail to reject (F), the null hypothesis at a 5% level of significance. Under the null hypothesis, the test statistic is distributed chi-squared with seven degrees of freedom (exclusion from the entire cointegration space would imply seven zero restrictions, as, based on results from Table 4 and Figure 3, we have seven cointegrating vectors).

do offer some nontrivial contribution at the 12 month horizon for both slaughter steers (11.63%) and slaughter heifers (16.35%).

Innovations arising in the prices of slaughter animals do not explain large proportions of the uncertainty in feeder cattle prices at any of the three horizons; it is information arising in 700–800 lb steer prices, 400–500 lb steer prices, and 500–600 lb heifer prices that account for a preponderance of the variation in feeder cattle prices at all horizons studied. The two relatively light weight feeder animals, 400–500 lb steers and 500–600 lb heifers, account for just over 44% of the price uncertainty in all feeder cattle prices.

The impulse-response functions were derived from a single positive, one-time-only innovation shock to each individual weight/gender class. The graphs of these impulse-response functions are illustrated in Figure 4. These graphs offer a similar story to that told by the decompositions in Table 10. Here, the innovations are normalized by dividing each response by the historical standard deviation of the innovation series. Because of the small size of the individual graphs, the axes are nearly impossible to read. Our purpose for these figures is to provide a visual representation, thus enabling a physical interpretation of the effects that new information and shocks have as they transverse through the market. Almost all responses from all innovations are positive. As with forecast error variance decompositions, innovations in 400–500 lb steer prices and 500–600 lb heifer prices show the dominant influence on all feeder cattle prices. Slaughter cattle prices show strong positive responses to slaughter cattle price innovations with, perhaps, some strength from 700 to 800 lb steer price innovations. As explained in the footnote to Table 10, the assignment of responses to innovations in slaughter steer or heifer prices is a bit arbitrary as we cannot identify the exact form of the causal structure between these two series in contemporaneous time (either innovations in slaughter steer price causes innovations in slaughter heifer price or vice-versa. We are not able to say which.) The impulse

Table 7. Tests on Weak Exogeneity on 10 Market Classes for Nebraska Cattle, Monthly Data: January 1992–May 2003

Market Class (lb)	Chi-Squared Test	*p*-value	Decision
	Steers		
400–500 lb	10.92	0.14	F
500–600 lb	36.66	0.00	R
600–700 lb	25.82	0.00	R
700–800 lb	15.31	0.03	R
1100 lb	16.96	0.02	R
	Heifers		
400–500 lb	21.13	0.00	R
500–600 lb	34.60	0.00	R
600–700 lb	20.05	0.01	R
700–800 lb	22.30	0.00	R
1000 lb	18.60	0.01	R

Notes: Each test is on the null hypothesis that the particular series listed in the far left column is weakly exogenous, i.e. that series does not respond to perturbations in the cointegrating space. The heading "Decision" relates to the decision to reject (R) or fail to reject (F) the null hypothesis at a 5% level of significance. Under the null hypothesis, the test statistic is distributed chi-squared with seven degrees of freedom. The null hypothesis, that market class i does not respond, implies seven zero restrictions (on the alpha matrix of the error correction representation, see text for further discussion).

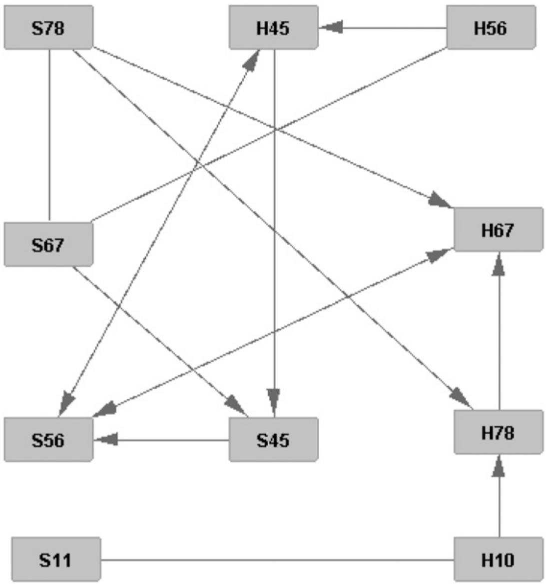

Figure 3. Causal Flows in Contemporaneous Time Among Innovations from an Error Correction Model Fit with Prices from 10 Nebraska Cattle Market Classes (The notation reflects that the variables studied are innovations from an error correction model fit to 137 observations on logarithmic transformations of prices from 10 alternative weight classes on cattle marketed in Nebraska from 1992–2003. Direction is based on PC algorithm applied at the 0.2 significance level. For example, the symbol "H45" represents innovations on (new information found in) the 400–500 lb heifer class animal marketing. The symbol "S11" represents innovations (new information discovered in) the 1100 lb steer class.)

responses offered in Figure 4 assign the causation from slaughter heifers to slaughter steers. If we reverse the causation, the impulses look identical to Figure 4, except the responses in the first two columns show more dominant influence of slaughter steers at all horizons.

Nebraska versus Texas Results

The Bessler and Davis (2004) study rejects weak exogeneity at a p value of 0.85 for 600–700 lb heifers, while we find in Nebraska a rejection of weak exogeneity of this class of animals at the 0.01 level. In the present study, the evidence suggests that prices for all classes of heifers do respond to perturbations (deviations from) the long run equilibrium (cointegration) relations.

For Nebraska the hypothesis that a given weight/gender class is weakly exogenous is rejected (at a 5% level of significance) in every instance except for 400–500 lb steers. This finding is different than that of Bessler and Davis (2004) which showed the prices of 600–700 lb heifers and both genders of slaughter weight cattle being weakly exogenous.

Just as in the Texas study the PC algorithm is not able to assign causal flow between slaughter weight steers and heifers. In Figure 3 we see the flow of information between slaughter weight animals and feeder weight animals is through 700–800 lb heifers, just as Bessler and Davis (2004) did in Texas. The price information surprises (innovations) in heavier weight heifers generally cause surprises in prices for lighter weight heifers. In this same figure, we further note the presence

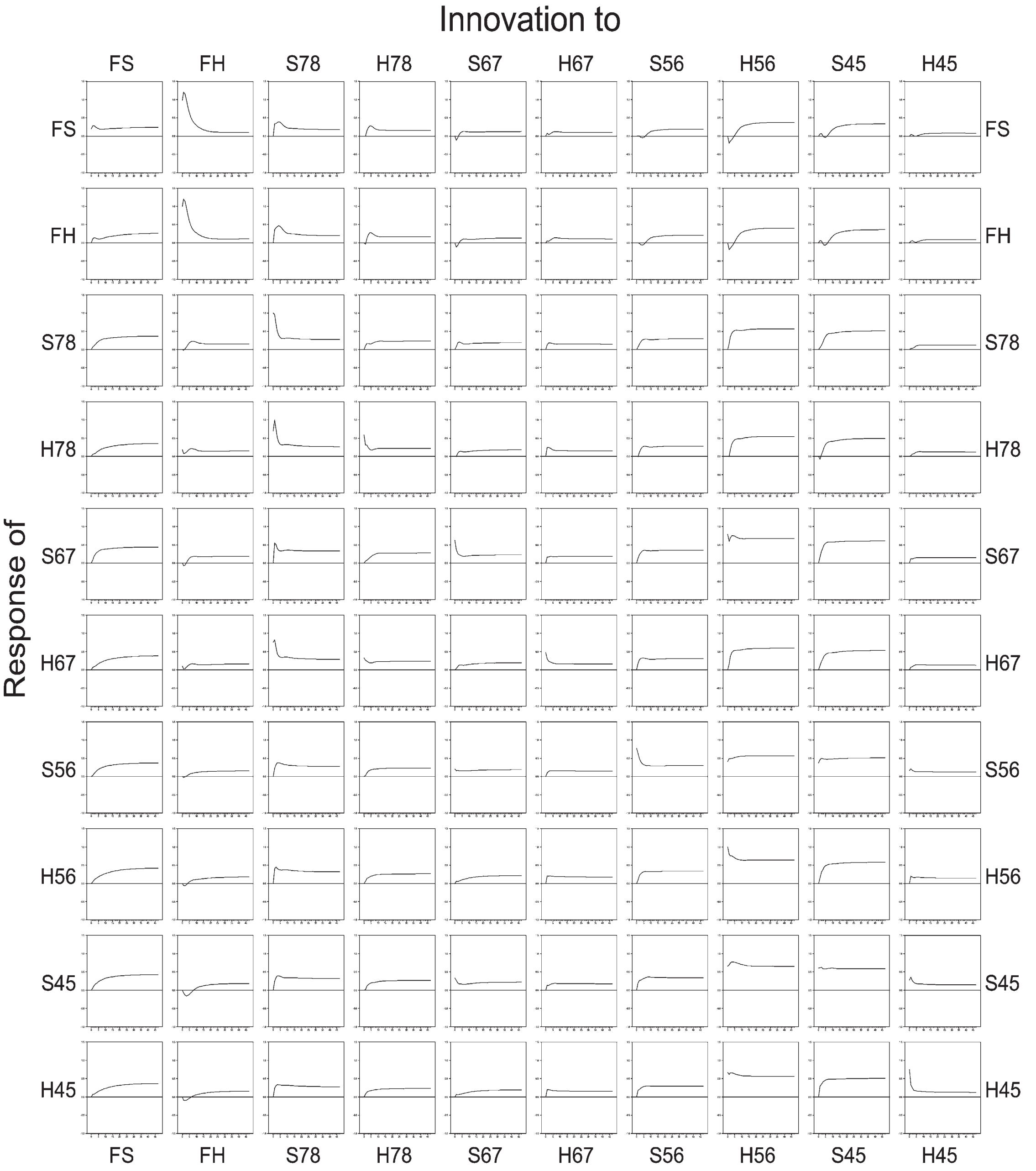

Figure 4. Responses of 10 Nebraska Cattle Prices to a Single Innovation (Shock) in Each Series

of two bidirected edges, indicating the possibility of an omitted variable. These edges are both placed between heifers and steers: between innovations in prices of 400–500 lb heifers and 500–600 lb steers and between 500–600 lb steers and 600–700 lb heifers. Bessler and Davis (2004) find only one bidirected edge between 700–800 lb steers and 700–800 lb heifers. They hypothesize that futures price and the use of the steer contract to cross hedge heifers may be responsible for this edge. Perhaps the same omitted variable accounts for the two bidirected edges found in Nebraska.

In the Texas DAG, three edges run from heifers to steers (h45→s45, h56→s56, and h67→s67). In the Nebraska work only the first of these heifers to steers edges is found, (h45→s45). There are two reverse flows from steers to heifers found in Nebraska results (s78→h78 and s78→h67). These are not present in the Texas outcome.

Generally, this same result, that slaughter animals account for the majority of their own price uncertainty, is found in both Nebraska and Texas. Bessler and Davis (2004) find slaughter steers and heifers account for in excess of 80% of the variability at the same three time horizons (0, 1, and 12 months ahead).

In Nebraska two relatively light weight feeder animals, 400–500 lb steers and 500–600 lb heifers, account for 44% of the price uncertainty in all feeder cattle prices. This result only partially agrees with results found in Bessler and Davis (2004), where they find the heavier heifers, 600–700 lb and 700–800 lb, account for the preponderance of the uncertainty in Texas feeder cattle prices.

There are several explanations for the difference between the Nebraska and Texas study results. First, these two states have very different types of cattle, *bos taurus* verses *bos indicus*, with unique physical growth and reproductive characteristics. Second, the climate, land use, and production methods are quite different. About 78–80% of Texas beef cattle producers have 50 cows or less compared with Nebraska's 56–57% (Table 8). These roles are reversed for their feedlot producers as illustrated by the 2003 statistics (Table 9), where about 91% of Texas feedlots had 1000 or more animals, while more than 84% of Nebraska's feedlots had less than 1000 animals. The Texas grazing period is longer in length and leads to a wide variety of calving periods. Over the time period of this work the majority of Nebraska beef cattle were born in the spring with a portion of those calves being directly placed into the feedlot just after weaning. Further, Texas plays a relatively larger role in U.S. calf production (~13% in the 2001 calf crop) compared with Nebraska (~5% of the 2001 calf crop) (Shields and Mathews, 2003). The disparity in calf production and fattening systems in the two states give credibility to the different results. It is apparent that while both these states are top ranked in beef cattle production, they have evolved very different production systems and most likely pricing patterns.

Discussion

We observe that both studies have very similar time series properties, in both cointegration and stationarity. Each state has a different gender/class that is weakly exogenous: Nebraska indicates the light steer class and Texas indicates the medium heifer class. The mapping of the innovations into DAGs exhibits some similarities, especially with respect to the fat cattle classes and initial flow of information from fat classes through the two heaviest heifer groups. In total the DAGs have 8 edges in common, 5 of these edges are identically directed and 3 are altered in direction or have a missing direction. The Nebraska DAG adds 5 new edges and drops 4 of the original edges drawn on the Texas figure. The innovation accounting results

Table 8. Operations with 50 or Less Cows, by State

Year	1993	1995	1997	1999	2001	2003
Nebraska						
Number	13,200	13,000	12,800	12,700	12,200	11,800
Percent	57.39%	56.52%	55.65%	55.22%	55.45%	56.19%
Texas						
Number	130,000	134,000	133,000	135,000	133,000	132,000
Percent	80.00%	78.36%	78.20%	78.52%	78.20%	78.79%

Data from the National Agricultural Statistics Service (NASS, 2006) website.

Table 9. Feedlot Operations by Size and State for 1993 and 2003

Head of Cattle Per Feedlot	<1000	1000–1999	2000–3999	4000–7999	8000–15999	16000–31999	>32000
				Nebraska			
1993							
Numbers	5,050	270	173	123	54	24	6
(Percent)	(88.60)	(4.74)	(3.04)	(2.16)	(0.95)	(0.42)	(0.11)
2003							
Numbers	4,140	525	192	0	0	35	8
(Percent)	(4.49)	(10.71)	(3.92)	(0.00)	(0.00)	(0.71)	(0.16)
				Texas			
1993							
Numbers	0	6	11	18	35	29	38
(Percent)	(0.00)	(4.38)	(8.03)	(13.14)	(25.55)	(21.17)	(27.74)
2003							
Numbers	0	12	40	0	0	33	49
(Percent)	(0.00)	(8.96)	(29.85)	(0.00)	(0.00)	(24.63)	(36.57)

Data from the National Agricultural Statistics Service (NASS, 2006) website.

using the forecast error variance decomposition indicates some similarities such as the effect of the fat cattle price innovations on themselves. But definite differences are evident, such as the three Nebraska calf classes, 400–500 lb heifers, 500–600 lb steers, and 700–800 lb steers, which accounted for a large portion of the price variation in the feeder cattle markets. However, in the Texas results most of the variation in feeder prices comes from the two heaviest heifer classes. The impulse responses, as with the other results, reflect these similarities and differences.

A strict interpretation of the notion of replication in scientific discourse would suggest that the results on Nebraska cattle prices do not replicate the Texas cattle price study completed by Bessler and Davis (2004). Information arising in the pricing of steer classes in Nebraska appears to play a more important role in price discovery than did similar classifications in Texas. This result leads us to look for differences between the two states that might account for the disparity. Looking at the institutional constructs, production practices, and transportation of animals within and between the two feeding and breeding regions, differences are apparent. Our results tend to support the tentative hypothesis that within the state of Nebraska feeding of animals plays a relatively larger role in the discovery of price. This conclusion is of course subject to further testing and research, which may also help us in understanding our partial success in the extension of the Bessler and Davis (2004) results to Nebraska.

The scientific community generally wants model results to (broadly speaking) transfer to other "similar" cases. We want, in short, external validity (Campbell and Stanley, 1966). When we began this study, we expected to find the same outcome as reported by Bessler and Davis (2004). Failure to find such is perhaps a lesson that results don't always transfer and for good reason. Perhaps the importance of the breeding animals in Texas price discovery process is reflective of the proportional differences in market participants. Nebraska has many feedlots of small size, accounting for more than the majority of producer numbers, while Texas has more than the majority of small-size calf producers. Interestingly, the outcome of the analysis matches closely with the proportion of the market participants, leading to the plausibility that participant type may be more influential than volume in the price discovery process. It is apparent that differences in the markets do exist, and that it would be a mistake to assume price discovery

Table 10. Forecast Error Variance Decompositions on Prices for Cattle from 10 Nebraska Market Classes, Monthly Data: January 1992–May 2003; H10→S11

Horizon (months)	Percent									
	S11	H10	S78	H78	S67	H67	S56	H56	S45	H45
					(S11)					
0	4.09	95.90	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1	4.35	89.05	4.25	0.00	0.48	0.23	0.00	1.42	0.15	0.07
12	6.27	67.32	11.63	5.17	1.38	1.27	0.81	4.20	1.74	0.22
					(H10)					
0	0.00	100.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1	0.44	92.41	4.98	0.05	0.52	0.11	0.00	1.25	0.15	0.08
12	2.06	65.60	16.35	5.05	1.00	1.62	1.01	5.04	1.87	0.40
					(S78)					
0	0.00	0.00	100.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1	0.24	0.01	96.11	0.58	0.33	0.88	0.26	1.42	0.15	0.03
12	6.39	3.26	32.39	3.93	2.93	2.82	6.81	25.57	14.77	1.12
					(H78)					
0	0.00	3.87	56.86	39.27	0.00	0.00	0.00	0.00	0.00	0.00
1	0.13	1.95	73.21	21.30	0.00	3.07	0.00	0.00	0.31	0.01
12	4.03	3.72	32.83	9.53	1.83	4.23	6.92	21.88	13.57	1.44
					(S67)					
0	0.00	0.00	0.00	0.00	38.94	0.00	0.00	61.06	0.00	0.00
1	0.34	0.26	15.88	0.15	27.60	1.41	0.89	51.13	1.54	0.78
12	7.94	1.57	11.06	3.22	6.12	2.35	7.40	39.23	19.56	1.52
					(H67)					
0	0.00	1.11	63.54	11.29	0.00	24.05	0.00	0.00	0.00	0.00
1	0.20	0.61	68.68	9.43	0.08	16.85	1.64	1.46	0.79	0.26
12	4.25	1.91	25.40	6.04	1.79	6.00	9.05	26.41	17.39	1.74
					(S56)					
0	0.00	0.00	0.00	0.00	4.30	0.00	60.96	17.18	14.55	3.01
1	0.05	0.03	2.71	0.03	3.47	0.46	50.84	20.74	17.98	3.68
12	4.78	0.71	10.94	3.37	2.91	2.37	18.74	29.54	24.29	2.37
					(H56)					
0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	100.00	0.00	0.00
1	0.10	0.16	8.47	0.14	0.18	2.22	0.42	85.07	1.25	1.99
12	3.80	0.56	12.29	3.46	1.14	3.13	7.50	47.29	18.49	2.32
					(S45)					
0	0.00	0.00	0.00	0.00	11.01	0.00	0.00	44.01	37.26	7.71
1	0.15	0.25	2.94	0.01	8.34	0.81	1.74	42.17	34.37	9.22
12	4.72	0.64	8.51	2.69	3.01	2.10	7.37	40.17	27.38	3.41
					(H45)					
0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	44.34	0.00	55.66
1	0.29	0.48	3.29	0.37	0.25	2.25	1.92	47.66	4.95	38.55
12	3.38	0.43	10.15	3.25	1.09	3.12	7.75	42.08	20.52	8.24

Notes: Error variance decompositions are partitions based on observed innovations from the estimated error correction model. The entries sum to 100 (within rounding error) for any particular row. The interpretation of each row is as follows: looking ahead at the horizon given in the left hand column, the uncertainty in cattle prices for the class given in the subcategory in the far left margin (e.g. (H78)) is attributable to variation in each series labeled as the column heading in the proportions given in each cell entry. Classification symbols are given as: S11 = Slaughter Steers; H10 = Slaughter Heifers; S78 = Steers 700–800 lb; H78 = Heifers 700–800 lb; S67 = Steers 600–700 lb; H67 = Heifers 600–700 lb; S56 = Steers 500–600 lb; H56 = Heifers 500–600 lb; S45 = Steers 400–500 lb; H45 = Heifers 400–500 lb. Here we assume H10 → S11. If we reverse the arrow here, this results in changes in only the columns under headings S11 and H10, as this alternative specification merely reallocated the total attributed to S11 and H10 between the two series. For example, under the assignment of causation S11→ H10, the first two columns at horizons one and two under the S11 panel read 100.00 and 0.00 at horizon zero and 93.37 and 0.03 at horizon 1.

for beef cattle is uniformly achieved in the various regions of the United States.

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