Sources of Economic Variability in Cattle Feeding

by

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Previous researchers have identified factors that contribute to variability of profits and feeding cost of gain in cattle feeding. Efforts have been made to identify the relative importance of specific factors in order to assist cattle feeders in managing economic risks. The results of this research suggest that these relationships are not stable over time, and are highly unpredictable. This implies that risk management strategies for cattle feeders may be more difficult to identify and implement than previously thought.

Introduction

Between 1981 and 1994, monthly average net returns to finishing yearling steers in Kansas feedlots ranged from a loss of $120 per head to a profit of $178 per head (Jones). Over the same time period, the feeding cost of gain ranged from a low of $38.40 per cwt. to a high of $67.40 per cwt. Previous studies have quantified risks associated with feeding cattle on a continuous basis over time (Schroeder et al.; Trapp and Cleveland), or have quantified the feeding cost of gain risks over time (Albright, Schroeder, and Langemeier). Specifically, these studies have determined the contribution of cattle price, feed price, and animal performance variables to cattle finishing return and cost of gain variability. However, during any given time period return or cost variability may be more heavily influenced by particular factors than at other times. For example, during times of turbulent or harsh weather cattle performance may be a highly important risk determinant, whereas, during other times fed cattle price variability may be the most important. The relative contributions of various factors may also change over time due to technological advances in the cattle feeding process. In order to manage the risk associated with profit and cost of gain fluctuations, cattle feeders may need to focus attention on different determinants at different time periods. Identifying which factors are most influential during different time periods is essential to managing economic risks in cattle feeding.

This study employs a large sample of individual pen-level feedlot close-out data encompassing a recent 15 year time period to study the dynamics of profitability and cost of gain. The objectives of this study are to: 1) update previous research that examined the relative contributions of various factors to cattle feeding profitability and cost of gain, and; 2) to test for structural change in these relationships over time.

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Previous research

Several previous studies have examined either factors that affect cattle feeding profitability or factors that affect feeding cost of gain. Swanson and West examined Illinois Farm Bureau Farm Management Service records from 1955 through 1960 and found that feeder to fed cattle price margins explained 38% and feed cost per pound of gain explained 44% of profit variability over time. More recently, Trapp and Cleveland used individual pen closeout data from May 1986 through April 1987 to simulate cattle feeding returns. Market price risk (both fed cattle and feeder cattle) explained the majority of profit volatility (65.5%), while only 22.05% of profit volatility was attributable to production risk. Weimar and Hallam examined risks and returns associated with three types of custom cattle feeding contracts and concluded that the interrelationship among feed costs, feeder prices, slaughter prices, and performance affected the relative riskiness of the various types of contracts. They did not, however, identify the impact of these various factors on cattle feeding net returns.

Using monthly average steer pen closeout data from cattle placed on feed between January 1980 and December 1989, Langemeier, Schroeder, and Mintert concluded that fed cattle sale price, feeder cattle purchase price, and corn price were important determinants of cattle feeding profit variance. They also determined that the placement weight of the cattle significantly affected the relative importance of the performance and cost factors on profits. Schroeder et al. utilized pen-level data from over 6500 pens of cattle place on feed between January 1980 and May 1991 to study the determinants of cattle feeding profitability. In addition to the factors identified by Langemeier, Schroeder, and Mintert, the interest rate, feed conversions, and average daily gains were also important contributors to profitability.

Albright, Schroeder, and Langemeier examined factors that contribute to cattle feeding cost of gain variability. Using a large sample of individual pen close-out data, the authors concluded that variations in corn prices, feed conversions, and average daily gains were important determinants of feeding cost of gain variability.

None of these previous studies determined whether the relative importance of the various factors contributing to variability in feeding cost of gain and profitability have remained constant over time. Given the magnitude of the changes observed in the cattle feeding industry from 1980 through 1995, it is possible that the relative importance of factors contributing to both profitability and to cost of gain may have changed over time. The observed variability of various factors changes over time, and may contribute to the relative importance of those factors from a risk management perspective. For example, between 1980 and 1994 the yearly standard deviation of prices received for fed cattle represented in our data set ranged from $2.14 to$ 4.57 per cwt., and yearly feeder cattle price standard deviation ranged from $1.98 to $5.81 per cwt. Over the same time period yearly corn price standard deviation ranged from a low of $0.03 per bu. to a high of $0.37 per bu.

In addition, over the past 15 years many technological advancements have been implemented in the cattle feeding business that may affect the relationships among various factors that contribute to variability in profits and cost of gain. For example, in the early 1980's feed efficiencies and growth rates likely improved as cattle feeders adopted new combinations of growth hormone implants and knowledge and use of reimplanting schedules increased (Loy, Harpster, and Cash; Rumsey, Hammond, and McMurtry). Since the mid 1980's several new implants and implant combinations have been implemented in cattle feeding (Perry, Fox, and Beermann; Dalke et al.), which could have induced a change in the profitability and cost of gain determinants. Furthermore, new feeding techniques and feed processing technologies have been implemented in the industry over the past 15 years (Hicks et al.).

Data and Methods

Individual feedlot pen close-out data for steers placed on feed in two large western Kansas feedyards from January 1980 through December 1994 are used for the analysis. This large data set, encompassing over 9,400 pens and nearly 1,400,000 head of cattle, is a significant extension of the data used in previous studies (Albright, Schroeder, and Langemeier; Schroeder et al.). The time frame involved captures a period of hypothesized significant change in the industry, and encompasses periods of both relatively high and low input and output prices. Means and standard deviations of all variables for the entire 15 year time period are provided in Table 1.

Table 1. Means And Standard Deviations Of Variables Used In The Analysis For Pens Of Steers Placed On Feed Between January 1980 And December 1994.

	Placement Weight					
	600-699 lb.		700-799 lb.		800-899 lb.	
Variable	Mean	S.D.[a]	Mean	S.D.	Mean	S.D.
Net Returns ($/head)	22.78	58.42	19.96	58.25	19.34	58.54
Feeding Cost of Gain ($/lb.)	49.79	7.11	49.73	7.07	51.24	7.70
Fed Cattle Price ($/cwt.)	69.19	6.96	68.91	6.91	69.25	6.81
Feeder Cattle Price ($/cwt.)	75.13	10.64	73.54	10.38	72.51	10.30
Corn Price ($/Bu.)	2.59	0.45	2.51	0.44	2.46	0.43
Hay Price ($/ton.)	71.31	16.26	71.04	17.03	71.54	17.82
Interest Rate (%)	12.88	2.50	12.46	2.32	12.09	2.25
As Fed Conversion (feed/lb.)	8.31	0.95	8.37	0.97	8.68	1.09
Average Daily Gain (lb./day)	3.05	0.38	3.20	0.37	3.26	0.40
N (No. of Observations)	2181		4851		2395	

[a] Standard Deviation of the variable over the 15 year time period.

In order to test for structural changes in cattle feeding over the 15 year time period of the data, we specify and estimate both a profit equation and a feeding cost of gain equation. Based on the findings of Langemeier, Schroeder, and Mintert, models are estimated separately for each of three different placement weight categories of feedlot steers; 600-699 lbs, 700-799 lbs, and 800-899 lbs. Following Schroeder et al., the profit equation is specified as:

(1) $\text{NET RETURN}_i = f(\text{FEDP}_i, \text{FEEDERP}_i, \text{CORNP}_i, \text{INT}_i, \text{CONV}_i, \text{ADG}_i)$

where; NET RETURN is the net return to the cattle owner from feeding pen i ($ per head), FEDP is the fed steer selling price f.o.b. the feedyard ($/cwt.), FEEDERP is the feeder cattle purchase price ($/cwt.), CORNP is the average corn price during the feeding period, INT is the Kansas City Federal Reserve Bank interest rate for cattle feeding loans during the placement month (%), CONV is the as-fed feed conversion of the cattle in the pen (lbs. of feed per lb. of gain), and ADG is the average daily gain of the cattle during the feeding period (lbs. per day).

Net returns are defined as total revenue received when the fed cattle are sold, minus the total cost of the feeder cattle, minus the cost of feeding the cattle (feed, processing, medication, yard charges, etc.), minus interest on the feeder animal and other costs. In most instances the fed steer selling price is available from the individual close-outs. However, in some cases, this information is not provided. For observations where fed steer selling price is missing, the weekly average western Kansas fed cattle price is used. Similarly, for many observations the actual feeder cattle purchase price is not available. The average Dodge City Kansas feeder cattle price of the appropriate weight category and placement week is used in these cases. Corn prices are obtained from Kansas Agricultural Statistics, and interest rates are obtained from the Kansas City Federal Reserve Bank.

Changes in feed grain and hay prices directly affect feeding costs, however animal performance can also have considerable influence on feeding cost of gain. Similar to Albright, Schroeder, and Langemeier the feeding cost of gain equation is specified as:

(2) $\text{COST-OF-GAIN}_i = f(\text{CORNP}_i, \text{HAYP}_i, \text{CONV}_i, \text{ADG}_i)$

where; COST-OF-GAIN is the cost of gain ($ per cwt.) for pen i , including the components of feed cost, veterinary cost, processing cost, yardage, and miscellaneous, HAYP is the average Western Kansas alfalfa hay price for the feeding period, and CONV and ADG are as defined previously.

The long time-series nature of the data is used to test whether the coefficients on factors influencing cattle feeding profitability and cost of gain have changed over time, and to determine the relative contributions of various factors to variability in profits and cost of gain during different time periods. Using ordinary least squares regression, equations 1 and 2 are first estimated with data encompassing the entire 15 year time period for each weight category. The models are then re-estimated using information from each possible subset of years, hypothesizing that a structural change occurred between the early time period and later time period. The smallest data set to be used for either the early period or the late period is arbitrarily chosen to be three years. Therefore structural change is only tested for the years between 1982 and 1991. The statistical test proposed by Chow is used to determine when a structural change in the relationships between various factors and both profitability and feeding cost of gain most likely occurred for each of the placement weight groups.

Coefficients of separate determination (Burt and Finley) are calculated from the estimation of both equation 1 and equation 2 for each placement weight category. These measures allocate the total variability of the dependent variable that is explained by the regressors in the model into individual explanatory contributions. In the current framework, the coefficients of separate determination provide a relative comparison of the contribution of volatility in various factors to economic risks in cattle feeding, either profits or costs. Coefficients of separate determination for each explanatory variable (C_j) are defined as:

$$C_j = \sum_{k=1}^{n} B_j B_k r_{jk}$$

where B is the regression coefficient times the ratio of the standard deviation of the independent variable to the standard deviation of the dependent variable (Ezekiel and Fox), r is the simple correlation coefficient, and n is the number of explanatory variables (not counting the intercept) in the regression. The sum of the coefficients for a particular regression equation equals the R^2 goodness of fit measure and one minus the sum of these coefficients equals the unexplained variation. It is the change in the relative magnitudes of the various coefficients of separate determination over time that is of particular interest in this study.

Results

The explanatory variables were statistically significant, and the coefficients had the expected signs for each equation and time period specification. In the profit model increases in fed cattle prices consistently resulted in increased net returns, whereas increases in feeder cattle purchase prices resulted in decreased net returns. Increases in both corn prices and interest rates consistently had a negative influence on net returns. Higher (poorer) feed conversions negatively influenced profits, while higher (better) average daily gains positively influenced profits. Increasing both corn prices and hay prices consistently resulted in higher feeding cost of gain, as did higher feed conversions and lower average daily gains.

The values of the F-statistic resulting from the Chow tests for structural change from each model are reported in Table 2. The values are all statistically significant at the .05 level, based on a critical value of 2.01 in the profit model and 2.21 in the cost of gain model. This result provides strong evidence to suggest that the relative effects of various factors on cattle feeding profitability and cost of gain are not constant over time. In addition, the erratic nature of the Chow test results makes it difficult to achieve our original objective of identifying specific periods of structural change.

Table 2. F - Statistic Values Resulting From The Chow Test For Structural Change In The Cattle Feeding Profit And Cost of Gain Models.

Year Tested For Structural Change	F - Statistic Values					
	Profit Model			Cost-Of-Gain Model		
	Placement Weight			Placement Weight		
	6-7 cwt.	7-8 cwt.	8-9 cwt.	6-7 cwt.	7-8 cwt.	8-9 cwt.
82-83	42.26	47.36	15.28	65.27	107.82	47.87
83-84	34.64	34.52	13.07	48.89	92.05	32.65
84-85	35.64	28.65	10.98	48.79	82.74	31.72
85-86	37.36	31.67	13.52	26.91	50.15	30.93
86-87	34.03	34.48	17.97	23.36	51.98	37.63
87-88	30.52	35.33	21.52	25.08	70.99	74.67
88-89	22.60	27.58	19.26	42.58	132.62	116.88
89-90	23.26	17.54	15.92	37.93	110.59	102.87
90-91	18.19	13.10	22.23	34.59	114.02	70.39
91-92	15.70	11.04	18.26	24.19	85.33	53.82

For 600-699 lb. steer placements the value of the F-statistic ranged from 15.7 to 42.26, with the largest value occurring when testing for structural change between 1982 and 1983. For 700-799 lb. steer placements, the value ranged from 11.04 to 47.36, and again the largest value occurred when testing for structural change between 1982 and 1983. When testing for structural change in the determinants of profit for 800-899 lb. steer placements, the value of the F-statistic ranged from 10.98 to 22.23, with the largest value occurring when testing for change between 1990 and 1991. Similar results were found when testing for structural change in the feeding cost of gain equation. Findings varied, depending upon the placement weight category being tested. For 600-699 lb. placements the value of the F-statistic ranged from 23.36 to 65.27, with the largest F value occurring when testing for structural change early in the period between 1982 and 1983. For 700-799 lb. placements, calculated values ranged between 51.98 and 132.62, and the largest F value occurred when testing for change between 1988 and 1989. Finally, for the heaviest placements the value of the F-statistic ranged from 30.93 to 116.88 and the highest F value occurred when testing for change between 1988 and 1989.

In an effort to better understand the structural change test results, equations 1 and 2 were estimated for each placement year. Then coefficients of separate determination were calculated for each year of the data set for both the profit model and the cost of gain model. The resulting values are reported in Tables 3 and 4.

Table 3. Coefficients Of Separate Determination By Year For The Profit Model (Equation 1).

	600-700 lb. Placements						700-800 lb. Placements						800-900 lb. Placements					
Year	C1[a]	C2	C3	C4	C5	C6	C1	C2	C3	C4	C5	C6	C1	C2	C3	C4	C5	C6
80	52.6	6.1	17.5	5.9	3.7	9.7	53.2	13.7	17.9	2.9	6.7	3.6	45.5	12.8	22.0	4.5	12.9	0.7
81	56.0	22.2	5.9	-0.2	3.3	2.0	59.8	23.4	1.1	2.4	2.9	4.0	57.6	27.5	-2.2	5.0	3.6	4.9
82	70.7	12.1	-1.2	1.1	5.0	7.7	73.7	15.6	-1.0	1.5	3.6	4.4	74.6	19.3	-2.5	0.5	2.5	3.2
83	66.1	40.9	3.3	-3.4	-6.1	-3.6	70.0	37.2	3.4	-4.8	-6.6	-1.5	63.1	37.9	2.4	-1.4	-2.8	-0.6
84	49.6	18.3	-3.5	-0.1	19.7	10.4	51.1	21.3	1.2	-2.9	16.1	9.4	26.9	49.3	-0.9	-1.3	15.3	7.7
85	59.4	22.2	17.8	-1.6	0.9	-0.5	59.6	27.0	8.9	0.2	1.3	0.7	66.7	23.7	3.8	1.4	2.0	1.6
86	82.7	4.1	10.8	5.0	-3.1	-1.5	58.4	25.8	8.0	2.5	0.4	1.1	55.6	31.8	1.9	1.8	1.4	3.6
87	28.3	44.2	-1.0	-0.2	12.7	11.9	30.7	53.4	0.8	-0.2	6.1	4.4	36.2	49.8	-0.3	0.0	1.9	8.4
88	53.5	16.2	5.9	-1.2	8.1	6.0	56.8	28.0	0.7	-2.5	3.9	5.3	62.9	19.9	1.2	-4.2	6.6	9.4
89	54.0	15.4	2.1	7.0	2.7	4.5	63.8	13.6	2.4	-0.7	2.1	4.9	77.4	-7.6	1.6	0.5	0.3	13.8
90	0.6	28.8	7.6	-1.5	27.0	18.5	0.0	41.4	1.4	-1.0	21.6	20.7	21.1	29.4	3.8	-0.2	5.0	29.5
91	48.7	34.1	7.3	0.0	3.7	1.9	57.7	26.3	4.0	2.1	1.8	3.1	46.9	36.4	2.0	5.3	3.2	3.4
92	27.0	10.9	0.5	-2.2	29.7	20.1	-8.2	24.0	-1.4	1.0	35.6	29.3	-3.3	31.6	5.4	6.8	28.5	31.7
93	50.7	1.0	2.4	17.4	10.0	13.1	42.1	11.5	5.3	14.0	10.6	5.9	45.9	13.7	15.9	1.1	9.0	2.6
94	53.1	30.1	13.9	-0.7	0.4	0.1	49.9	26.6	18.4	-4.7	1.3	4.2	48.0	31.0	13.2	-3.4	3.0	2.8
Avg.	50.2	20.4	6.0	1.7	7.8	6.7	47.9	25.9	4.7	0.7	7.2	6.6	48.3	27.1	4.5	1.1	6.2	8.2

[a] C1 through C6 are the coefficients of separate determination for Fed Cattle Price, Feeder Cattle Price, Corn Price, Interest Rate, Feed Conversion, and Average Daily Gain respectively.

Table 4. Coefficients Of Separate Determination By Year For The Cost Of Gain Model (Equation 2).

	600-700 lb. Placements				700-800 lb. Placements				800-900 lb. Placements			
Year	C1[a]	C2	C3	C4	C1	C2	C3	C4	C1	C2	C3	C4
80	10.8	16.5	65.1	1.4	45.3	8.0	35.4	5.0	84.5	-10.1	20.8	-0.4
81	20.4	2.8	17.5	10.6	23.4	-2.2	32.2	13.0	18.9	0.9	15.3	29.6
82	3.9	16.1	47.6	16.6	0.3	21.1	34.9	23.9	12.3	1.5	63.1	7.6
83	-2.8	10.3	61.1	15.0	-12.9	17.2	85.5	-1.7	-10.0	8.0	88.6	5.6
84	3.0	4.8	48.9	24.1	-2.1	2.4	68.2	16.8	0.1	4.1	56.7	21.7
85	13.8	-2.2	43.6	18.5	6.6	1.0	40.8	24.6	12.1	-0.5	41.8	26.4
86	45.4	-0.3	38.1	7.3	39.4	-1.0	32.0	14.5	41.2	1.0	20.5	23.3
87	6.3	1.2	65.5	19.4	5.8	1.6	74.2	12.5	1.4	2.8	63.4	22.1
88	16.4	22.6	29.8	23.1	12.0	33.4	28.3	18.0	7.7	31.8	29.8	20.9
89	-7.0	2.4	55.5	29.7	-2.2	0.0	46.4	34.9	0.2	-0.8	43.2	38.8
90	-1.4	-4.9	50.4	44.4	-1.7	-4.0	76.4	17.7	-0.8	-2.6	95.4	4.0
91	0.1	2.7	55.0	31.0	0.0	4.7	65.2	19.0	0.1	1.0	86.6	7.4
92	-13.9	-4.3	89.2	24.3	-9.0	-5.9	103.7	9.0	-5.2	-4.6	101.5	7.1
93	35.6	7.6	34.6	15.7	39.0	-0.6	46.2	11.6	26.7	4.3	49.5	7.0
94	9.1	0.3	65.8	9.6	15.1	0.3	32.5	34.3	13.9	0.9	55.5	9.3
Avg.	9.3	5.0	51.2	19.4	10.6	5.1	53.5	16.9	13.5	2.5	55.4	15.4

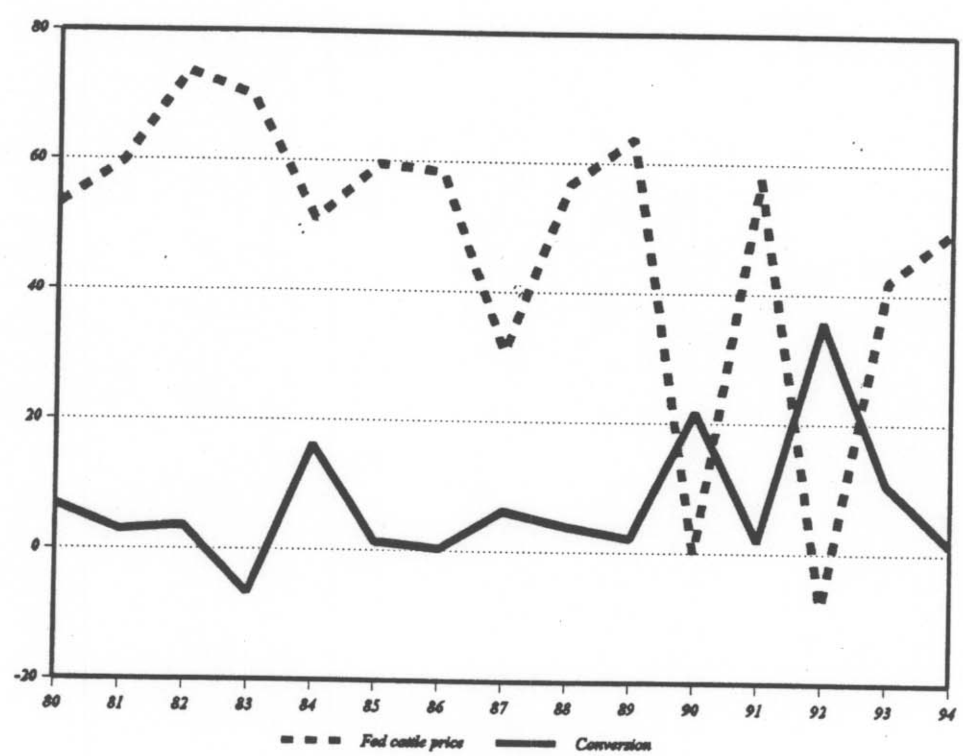
[a] C1 through C4 are the coefficients of separate determination for Corn Price, Hay Price, Feed Conversion, and Average Daily Gain respectively.

Calculation of the coefficients of separate determination by individual years helps to explain the erratic nature of the Chow test results. When estimating both models, the relative contribution of each factor changes dramatically year by year. For example, fed cattle price changes explain anywhere from 0 to 82% of the variability in profits from feeding 600 to 700 pound feeder cattle, depending on the year. Feed conversion volatility explains anywhere from -6.1 to 30% of profit variability when feeding 600 to 700 pound feeder cattle, and from -6.6 to nearly 36% of profit variability from 700 to 800 pound placements. Similar large changes are observed in all coefficients of separate determination for both models and all placement weight categories.

Negative coefficients of separate determination are difficult to interpret, however negative values for specific factors do indicate that those factors are playing a very minor role in explaining profit or cost of gain variability in a given year, and the effect is likely interacting with other variables in the model. The pattern of changes in the relative contribution of the various factors between years is somewhat similar across placement weights. This result indicates that whatever exogenous factors are causing the changes in the relative importance of various factors in the models are having a similar affect on all three placement weight categories.

An illustration of the erratic nature of the coefficients of separate determination is provided in Figure 1. The relative contributions of fed cattle price and feed conversion volatility to profit variation is plotted over time for the 700 to 800 pound feeder placement weight category.

Figure 1. Coefficients Of Separate Determination Of Fed Cattle Price And Conversion From Estimation Of The Profit Model (Equation 1) For 700 to 800 Lb. Placements By Year.



dynamic context in order to understand the structural changes since complete integration of the industry. Understanding the economic dynamics of the changes that have taken place in the broiler industry can help us arrive at some useful policy implications.

Data and Methodology

Data for the U.S. broiler industry were obtained from the U.S. Egg and Poultry Statistical Series, 1960-1992. Monthly time series data for total U.S. consumption (1000 lbs.), feed cost on a liveweight basis (cents/lb.), 12-city composite wholesale price (cents/lb.), total ready-to-cook (RTC) U.S. production (1000 lbs.) were chosen. The selected data series summarize the aggregate dynamic characteristics of the broiler industry. The time period for this study was limited to the years 1978 through 1992 due to the availability of the 12-city composite wholesale price data. Monthly data on the 12-city composite is available from 1978 to 1992 and it also coincides with the period after complete integration of the U.S. broiler industry. The index of poultry and eggs prices received by farmers was used to deflate the nominal feed cost and wholesale price.

Prior to model specification the data is examined for stationarity and tested for the cointegration between the levels of these variables. The unit root test based on the Augmented Dickey-Fuller (ADF) test was used to check for stationarity. The results of the ADF test revealed that all the variables had an ADF t-test statistic greater than the critical value at 0.10 level. We find no evidence that the variables are non-stationary.

The next step is to test the data sets for the presence of cointegration. The null hypothesis that there are at the most *r* co-integrating vectors in the system is tested using two likelihood ratio tests called the trace test and maximum eigenvalue test. The trace test statistic computed for various lag lengths was compared with the corresponding 90% critical value provided by Johansen and Juselius (1990). At all the lag lengths tested, the computed trace test statistic for at most no cointegrating vectors was less than the corresponding 90% critical value. We find no evidence of cointegrating vectors in the system.

Nonexistence of cointegrating vectors in the system suggests that the data are stationary. This result implies that a regular vector autoregressive (VAR) model be used for further analysis of the system.

Model Specification

We consider four structural variables for the broiler industry: total consumption of broiler meat (*C*), feed cost per pound of meat produced (*FC*), wholesale producer price per pound (*Pr*), and total broiler meat produced (*Pd*). Assume that the dynamic behavior of this vector, y_t, is governed by the following structural model :

$$By_t = Cd_t + E(1)\,y_{t-1} + u_t \tag{1}$$

where $E(1)$ = $A(L)B$,

y_t = n x 1 vector of variables observed at time t,

B, C = full rank n x n matrices of coefficients,

$A(L)$ = matrix of polynomials of order n in the lag operator L that captures the propagation mechanism of the broiler industry,

d_t = n x 1 vector of the deterministic component corresponding to y_t, and

u_t = n x 1 vector of structural disturbances.

The u_t vector is also referred to as the innovation vector or vector of shocks and is assumed to have a zero mean. The vector of disturbances is assumed to be serially uncorrelated, mutually orthogonal and has unit variance. These shocks do not have common causes and the innovations have zero cross correlation. Let Σ denote the covariance matrix of structural innovations.

Before identifying the structural model we need a representation that is suitable for estimation and depends only on the observable variables of y_t. Premultiplying both sides of (1) by B^{-1} we get the autoregressive representation for the n-vector y given by:

$$y_t = B^{-1}Cd_t + B^{-1}E(1)\,y_{t1} + B^{-1}u_t,$$

$$y_t = C^{*}d_t + F(1)^{*}y_t + v_t, \tag{2}$$

where the covariance matrix of v_t is represented by Ω. The v_t are mean zero, serially independent, one-step-ahead forecast errors. The reduced form in equation (2) summarizes the sample information about the joint process of the y_t variables. To move from the reduced form to the structural model one needs a set of identifying restrictions on B. A full description of these restrictions is discussed later in this paper. Given these restrictions one can recover the structural equations as well as the structural innovations.

Before imposing the identifying restrictions on the model a common lag length for the system needs to be chosen. The likelihood ratio test statistic developed by Tiao and Box was used to determine common order of lag length. The lag length for the BVAR was set at 9. After choosing the lag length of the VAR model, the specification issues associated with the construction of Bayesian VAR model were examined. These deal with an additional set of specification issues associated with the choice of stochastic restrictions imposed on the coefficients of the model.

Stochastic restrictions can be imposed by creating a prior distribution for each of the estimated parameters. With a monthly VAR of four variables and nine lags, the model would include at least 36 parameters per equation. If we assume a constant term for each of the variables there would be an four additional parameters per equation. We have four equations in the system. Hence, we have a total of 160 prior distributions to specify. Although these can be specified individually, it is by no means an easy task. Also, the individual specification of each parameter's prior could be subject to criticism about its specification.

Litterman (1986) developed a systematic method that alleviated the task of individual specification of each prior. He suggested using the Bayesian prior distribution on parameters of a VAR, which centers on a simple random walk process for each individual series. This is based on the assumption that the behavior of most economic variables can be approximated as a random-walk around an unknown, deterministic drift.

In this study a symmetric prior was specified, where the tightness parameters for the coefficients of variable i in equation j are the same for all i and j. Next, a grid search for choosing the appropriate values of the hyperparameters (λ, γ_1, γ_2) was conducted based on data over the period January 1978 through December 1983. In this search the value of λ ranged from 0.1 to 1.00, γ_1 ranged from 0.001 to 1.0, and γ_2 was evaluated over the values 0, 1 and 2. Out-of-sample forecasts are generated for each combination of parameter setting using the Kalman filter, as described in Doan and Litterman (1990) for the period January 1984 through December 1992. The one-step ahead forecast performance statistic as given by Theil's U-value was calculated for each combination of parameter setting. The combination parameter setting for ($\lambda = 0.3$, $\gamma_1 = 0.0$, $\gamma_2 = 0.4$) which minimizes Theil's U-value over the out-of-sample period was obtained. This combination of parameter settings was used to specify the BVAR model.

After obtaining a specified BVAR the imposition of identification restrictions was considered. A review of earlier studies indicate that identification of dynamic relationships based on the vector autoregressive (VAR) method was pioneered by Sims (1980) and extended by Bernanke (1986) and Sims (1986). Bernanke and Sims claimed that this latter method was an improvement over its predecessors such as Sims recursive method. This variant differed from the usual VAR approach in that it orthogonalized the estimated VAR residuals into the "true" underlying structural disturbances. The Bernanke and Sims method calculates the disturbances by inverting an estimated, explicitly structural model of the relationship among the contemporaneous VAR residuals. We used this method for model identification purposes.

The identification restrictions specific to this study can be obtained by examining the underlying economic theory governing the U.S. broiler industry structure. Identification is limited to contemporaneous interaction between variables. This relationship is observed between the prediction errors from the BVAR, v_t in equation (2), and the structural shocks u_t in equation (1). To isolate the impact of u_t on y_t, the prediction errors from equation (3) are related to the structural innovations in equation (3), u_t by :

$$\begin{aligned} Bv_t &= u_t, \\ v_t &= B^{-1}u_t, \end{aligned} \qquad (3)$$

The structural disturbances u_t are assumed to be uncorrelated. When this assumption is admittedly strong, it allows us to specify the elements of the B matrix in a relatively unrestricted way. In order to identify the elements of the B matrix, we need to closely examine the individual and dynamic characteristics of the variables included in this model. For this purpose, we present a closer look into the mechanics of the broiler industry structure. The following section will help us understand and incorporate the behavioral relationships between the variables included in this model.

In addition to commercial consumption, the time series consumption data compiled by USDA accounts for demand from the pet food industry, military sector and inventories. A review of the quarterly issues of Livestock and Poultry: Situation and Outlook Reports from 1989 to 1994 and Stillman's (1985) work indicates that consumption figures are largely influenced by total production of broilers and the wholesale composite price. Based on this information we postulate that in equation (2), unpredictable movements in consumption of chicken, v_{Ct} are caused mainly by the unpredictable producer price changes (v_{Prt}) and unpredictable production changes (v_{Pdt}), these in turn depending on the consumption elasticity, β_C, and random shocks to aggregate consumption, u_{Ct}. Thus, the consumption equation is given by:

$$v_{Ct} = \beta_C v_{Prt} + \beta_C v_{Pdt} + \alpha_C u_{Ct}. \qquad (4)$$

Feed cost changes are mainly dependent on corn and soybean prices. The demand for these feed constituents from the broiler industry is not large enough to affect feed prices. It was assumed that unpredictable movements in feed cost, v_{FCt} will not be affected by any of the variables included in the system except for its own random shocks to aggregate feed cost, u_{FCt}. Thus the feed cost equation can be specified as :

$$v_{FCt} = \alpha_{FC} u_{FCt}. \qquad (5)$$

The wholesale composite price data published by the ERS is a weighted average price of various chicken products, such as whole birds, cutup parts and further processed products. However, the composite price does not average the prices of all the components in the total consumption variable explained earlier. Stillman identified various factors that mainly influence broiler prices. These factors include chicken consumption, prices of substitutes (such as beef and pork), disposable income, feed cost, and production.

Based on this evidence, we postulate that the unpredictable movements in wholesale price of chicken, v_{Prt} are mainly influenced by the unpredictable changes in consumption, feed cost and production (v_{Ct}, v_{FCt} and v_{Pdt}), depending on the respective elasticities, β_C, β_{FC} and β_{Pd} and by random shocks to producer price, u_{Prt}. This is represented as follows:

$$v_{Prt} = \beta_{Pr} v_{Ct} + \beta_{Pr} v_{FCt} + \beta_{Pr} v_{Pdt} + \alpha_{Pr} u_{Prt}. \qquad (6)$$

Stillman noted that the quantity of broilers produced is related to number eggs hatched to ready-to-cook weight broiler production. Broiler producers feed animals to a certain weight range. This feed conversion process is dependent upon broiler price and feed cost. Based on this evidence Stillman identified broiler production as a function of broiler hatch, broiler prices and feed costs.

This information can be incorporated into the model by assuming that unpredictable movements in broiler production, v_{Pdt}, are caused mainly by the unpredictable feed cost (v_{FCt}) and producer price changes (v_{Prt}), depending on the respective elasticities, β_{FC}, β_{Pr} and random shocks to aggregate production, u_{Pdt}. This equation is given as

$$v_{Pdt} = \beta_{Pd} v_{FCt} + \beta_{Pd} v_{Prt} + \alpha_{Pd} u_{Prt} \text{ .} \qquad (7)$$

The four structural equations contain seven non-zero elements of the matrix B and four diagonal elements of variances of the u_t elements. There are a total of eleven non-zero elements in the A and B matrices. Because there are only ten unique elements in a just-identified case, the condition leads to the specification of an overidentified model. Although overidentified models may not in general yield perfectly orthogonal estimates of the u's, Bernanke noted that such a departure from orthogonality is small. Further, he adds that "in practice one rarely enjoys the luxury of having many substantive overidentifying restrictions."

After selecting the identification restrictions, the next step was to estimate the B matrix using the maximum likelihood technique. The estimated B matrix is used to trace out the impulses response functions and forecast error variance decomposition of all the variables in the system.

Model Results and Interpretation

Impulse Response Functions

The analysis of the impulse response functions (IRF) from the structural BVAR are interpreted to clarify the structural changes in the U.S. broiler industry structure. This interpretation is related to industry events and economic theory governing the behavior of the variables included in the model. Such information can be helpful in understanding the characteristics of the IRFs with respect to the dynamic nature of the U.S. broiler industry structure.

Feed costs account for over 60 percent of liveweight production costs. While estimating the feed cost, the ERS economists assumed that 70 percent of the feed cost depends on corn price and the remaining 30 percent is influenced by soymeal prices, plus other ingredients. Feed costs are converted to a cost per ton basis, and again converted to a feed cost per pound of liveweight broiler, based on the number of pounds of feed required to produce one pound of live broiler (Christensen, 1993). The main components of feed cost are corn and soymeal prices. These input prices are influenced by factors external to broiler production (Chavas and Johnson 1982). Thus, feed cost was assumed to be exogenous while identifying the structural model in the earlier chapter. This exogeneity makes feed cost responses unresponsive when other variables in the system are shocked.

Shocks to feed costs have a significant influence on the other variables included in this system. A positive shock to feed cost leads to an increase in production costs and a decrease in net returns to broiler production. Poor net returns hamper production expansion in the following year. During 1990 an increase in feed cost was observed due to strong grain demand, tight grain stock situations and poor weather conditions. This led to lower net returns in broiler production. Broiler production in 1991 showed a slow growth rate of six percent compared to a seven percent growth in 1990. Do we observe a similar production response to a positive feed cost shock in this study?

Figure 1 indicates that a positive feed cost shock leads to a decline in production. A one percent standard deviation shock on feed cost led to a 0.12 percent decline in the first month. After 12 months, production has decreased by 0.6 percent, with a maximum decline of -0.77 percent after 27 months. When the impulse responses are extended up to 60 months the seasonal fluctuation dies out. The dampening out of the impulse responses by the end of 30 months confirms that the data was stationary.

Higher feed costs also affect wholesale prices. During the 1983-1984 drought, feed costs rose due to tight feed supplies. This situation limited broiler production which eventually resulted in high wholesale prices. Babula *et al.* (1990) attributed such price-increasing shocks to corn production in explaining poultry prices. They studied the price transmission mechanisms linking farm corn price, farm poultry price and consumer price in two periods, from 1965-1968 and from 1973-1985.

The early period's patterns of impulse responses parallel those expected where producers are price-takers in a perfectly competitive industry. Poultry producers having faced higher feed costs, marketed birds early leading to price-depressing higher slaughter rate. During the recent period, increased corn price lead to an increase of farm poultry price. The authors noted that a change in response patterns was consistent with a change from an industry of many small, price taking producers to a vertically integrated industry where producers had the market power to pass on corn-based feed cost increases to consumers.

Since our data set ranges from 1978 to 1992, we can expect to observe a price response similar to the pattern Babula *et al.* observed in their recent period. In fact, Figure 2 shows a similar price response for a one percent standard deviation shock in feed cost. The impulse response shows an initial decline from 0.2 percent in the first month to -0.08 percent in the third month. This price behavior may be due initial lag in transmission of feed cost shock. After the initial decline, the price response picks up in the consecutive months and stabilizes after six months at 0.67 percent.

The behavior of price in response to a positive feed cost shock indicates that the increase in feed cost was followed by an eventual increase in wholesale price. This evidence suggests that the industry transmits feed cost increases to consumers through increased prices.

The next variable discussed here is the wholesale price of broilers. Bernard and Willett (1994) pointed out that sales of these broiler products occur in concentrated wholesale markets. This wholesale concentration affects market price relationships. Downward wholesale price movements are transmitted more frequently to growers than are increases. Further, they note that wholesalers share a larger portion of price increases with consumers than decreases. This research finding makes us assume that a price increasing shock may not lead to significant increase in production.

Figure 3 indicates that a slight increase in production is followed by seasonal fluctuation. A one-standard deviation price shock causes a 0.14 percent increase in production in the first month and a 0.12 percent decrease in the next month. This is followed by a series of seasonal fluctuations which dies out in the long-run indicating stationarity and temporary effect of the structural shock. This impulse response pattern indicates the tepid response of broiler production to a price increasing shock.

The final variable discussed here is total production. This represents the total quantity of ready-to-cook broiler meat produced in a given period. Besides weather, factors such as feed cost, wholesale price and net returns have a major influence on broiler production. Expanded production has a major influence on wholesale prices.

Higher than average yields of food grain production during 1988-1989 led to a decline in feed cost. Lowered feed costs and strong wholesale prices in 1988 yielded positive net returns of 8 cents per pound in the same year. Increase in net returns provided the financial support for expanded production in the following years. Broiler production rose seven percent in 1989 compared to a five percent in the previous year, reaching around 17.3 billion pounds.

This sudden increase in production depressed the 12-city composite wholesale broiler price to an average of 59 cents per pound in 1989 compared to 66.3 cents in 1988. This trend was expected to continue through 1990 due to positive indicators such as favorable feed grain prices, positive net returns in 1989 and increase in per capita consumption. This evidence suggests a negative price response to a positive production shock. Figure 4 shows an identical representation of the evidence presented above. Given a positive production shock, the wholesale price responds with a sudden decline of 35 percent in the first month. This is followed by a gradual normalization over a 12 month period and finally the fluctuation dies out in the long run.

Forecast Error Variance Decomposition

Impulse responses identify the dynamic effects of each structural shock but they are not helpful in determining the relative importance of different shocks as a source of broiler industry fluctuations. Analysis of FEV decompositions indicates the relative contribution of each structural shock. The errors from a k-step ahead forecast depend on realizations of the structural shocks over the next k quarters. Error decomposition attribute within sample error variance to alternative series. For example, the proportion of the FEV attributed to a consumption shock is a measure of the relative contribution of consumption shocks to fluctuations over the next k quarters. The sum of the proportions attributed to each structural shock is always one because the shocks are orthogonal.

Table 1 lists the FEV and the decompositions for horizons of 1, 12, 24, 36, 48 and 60 months. The decompositions divide forecast variances into proportions explained by each variable in the system. Total consumption appears to be weakly exogenous in the model, with only 53 percent of its FEV explained by its own innovations in the first month. The innovation in total production explains 39 percent of the variation, while the innovations in price explain the rest of the variation in the short-run. In the long-run, the innovation in feed cost tends to explain 19 percent of the variation in consumption. Besides consumption accounting for 55 percent of the variation, production accounted for 21 percent and price accounted for 4 percent.

Feed cost is completely exogenous in the first month. All the variation is explained by own innovation. This is true even in the long-run, at the end of 60 months it still explains 86 percent of its own innovation.

Wholesale price appears to be endogenous with 72 percent of its variation explained by innovation in production. The rest of the variation in price is explained by consumption, while price accounts for less than one percent of its variation. This result explains the price response to a production shock. The same result is observed even at longer horizons. After 60 months, production explains 55 percent of the variation and 38 percent of it is explained by consumption, while 5 percent is explained by feed cost.

Total production also appears to be driven by consumption. Innovations from the consumption shock account for 61 percent of the total variation in production at the first month. Innovations from a production shock or own innovations explain only 38 percent of the variation in production. In the long run or after 60 months, the variations in production is mostly explained by innovation in consumption (58 percent) and feed cost (23 percent). Own innovation only explain 18 percent of the variation.

Research Implications

The structure of the broiler industry was examined as a system using the structural BVAR approach. The implications of this research are presented by using individual results to explain the dynamics of the system. Industry evidence confirming the influence of higher feed cost on declines in broiler production has been highlighted in the empirical results. Improvements in the feed conversion ratio by better feed management, genetic engineering and an increase in production efficiency have helped to bring down the feed requirement per pound of broiler meat produced. Despite advances in production practices, the results in Figure 1 suggest that feed costs continue to be a critical factor influencing broiler production. However, the industry can minimize this effect on production by adopting better risk management practices at the national and farm level.

This result suggest that the influence of feed cost on production has to be minimized. A public policy of feed subsidies and feed transportation aid was suggested by Babula *et al.* However, this may benefit the poultry producers but may have adverse impacts on consumers. The industry may control feed cost increases by holding buffer stocks, developing more cost effective feed management techniques, or through breeding birds with higher feed conversion ratio.

Vertical integration of the industry has also affected the relationship between wholesale price and broiler production. Figure 3 shows that a positive shock on wholesale price resulted in a tepid production response. Changes in the broiler industry structure towards complete vertical integration may explain this effect. Use of advanced management techniques may have armed the integrators with the ability to monitor market conditions. In the event of such price increases they will be able to sell at higher prices without allowing for supply increases. Vertically integrated firms that produce, process and sell the finished products have become fewer and larger. Christensen (1988) noted that in 1984, 134 firms operating 238 federally inspected plants processed more than 4 billion birds weighing nearly 18 billion pounds. During the same year, the four largest firms operated 41 plants that slaughtered 33.7 percent of all the broiler produced.

Bernard and Willett note that such concentrations of sellers or integrators may provide opportunities for the exercise of market power. They conclude that increased concentration by integrators has resulted in asymmetric price relationships, where downward movements in the wholesale price are passed on more fully to growers than are price increases. Wholesalers pass through a larger portion of their price increases with consumers than their price decreases. Asymmetric price relationships may lead to an imbalance in the market equilibrium in favor of these large integrators.

Producers at the farm level are faced with limiting factors such as fluctuating input and product prices, the fixed biological nature of production and regulatory restrictions. Despite limitations faced by the primary producers, production has shown a positive growth for the last 13 years. The increase in production has been aided by various factors such as advances in technology, vertical integration, positive net returns over the years and support from export market in the recent years. Figure 4 shows that a production increasing shock has resulted in sharp decline of wholesale prices by 3.5 percent after first month.

The initial effect of sharp increases in production results in suppressed prices for producers and lowered net returns. Low net returns hamper production growth the over the following year. The industry can minimize this production expansion effect on wholesale price by venturing into new consumption channels for their products. Frozen foods, further processing and convenience foods are some of the areas that have helped in absorbing such production shocks.

Public policies can also be framed to reduce the impact of sudden production expansion on the wholesale price. Trading of broiler futures contracts is one such policy in this direction. This came into effect on February 7, 1991 and offers a hedging instrument for use by producers, processors, food product buyers, traders and others with interests in broiler price movements. This futures contract is for 40,000 pounds of broiler chicken and it has a provision for cash settlement. The cash settlement price is based upon the 12-city wholesale composite broiler price.

Given the commencement of the futures trading in broilers, the integrators have an alternative to limit production based on future demand. The decision on how many chicks to place for future production is in the hands of the integrator. If this decision can be based on the future contracts traded and with efficient risk management the spurts in production to profitable prices can be controlled.

Assured future supply of broiler meat creates opportunities for various enterprises that specialize in further processing of broilers. Further processing is new trend in production of broiler products that involves value added products. In 1990 approximately 60 percent of all broilers were further processed by the integrators and other processors. The top four firms account for 41 percent of this value-added production. The increased interest in further-processed products stems from processors responding to changing consumer demands and tastes, increased expanded demand for convenience foods. Another segment that has expanded in the recent years is the fast-food industry. This segment has also helped in providing a market to absorb excess broiler production.

The BVAR model used in this study can also be used to simulate impulse response functions given an increase in production costs due to emergent environment regulation. Results of such an analysis could be useful in framing feasible environmental policies. Future work should include the prices of substitute such as beef or pork in the BVAR model to assess the competitive impact on the performance of the broiler industry.

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Figure 3. Production response to a price shock

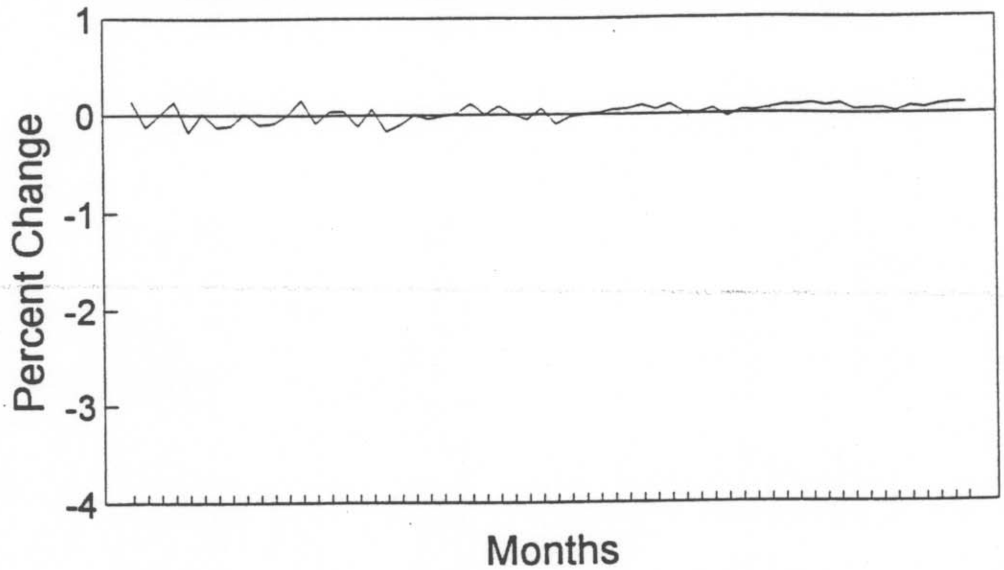

Figure 4. Price response to a production shock