CAUSALITY, INPUT PRICE VARIABILITY, AND STRUCTURAL CHANGES IN THE U.S. LIVESTOCK-MEAT INDUSTRY

by

M. Akhtar Khan and Glenn A. Helmers


2 Graduate Assistant, University of Nebraska, and Professor, University of Nebraska respectively.
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Abstract

The causality relationships between corn price variability and livestock prices and quantity variabilities were estimated. Relatively weakly causal relationships were observed for 1982-93 compared to 1970-81 period implying that corn price volatility may have been one of the predominant factors which triggered structural changes in the industry. Beef was found more susceptible to corn price shocks compared to pork.
Introduction

The United States livestock-meat economy has been subject to structural changes in the last twenty years. While the swine industry has experienced these changes in terms of a reduction in the number of hog producers with concurrent changes in control over the production process, the cattle/beef industry has observed structural changes in the form of increased concentration in the beef packing industry. It has also been suggested that the poultry sector (broilers) has already gone through gradual structural changes, particularly on the production side wherein it is a competitive constant returns-to-scale industry facing elastic factor supplies (Thurman).

Potential risk gains from vertical integration and/or coordination have been advocated by many economists (Jensen, Featherstone, and Sherrick, for example). A comprehensive review of literature on this phenomena reveals that the major advantages of integrated production and marketing are: a) increased efficiency, b) reduced uncertainty of input and output prices and a consequent reduction in income variability, and c) reduction in operational costs. The livestock-meat industry has gone through gradual structural changes to capture the potential benefits of integrated production and marketing.

The aforementioned changes in market organization and technology have transformed the U.S. livestock-meat economy into a complex national network of physical movements of livestock and meat, and uncertain developments in the vertical coordination system. These changes, including geographical dispersion and reorganized market set-up, seem to be centered on the production sector. However, the forces affecting the production sector variability results from various impacts of input supply, one of which is corn. Corn has been observed to have a higher price variability since the entrance of the U.S. in the international grain markets in early 1970s. In order to support this argument, standard deviation estimates have been
calculated for monthly prices of corn and livestock/meat for 1960-69 (Period I), 1970-81 (Period II), and 1982-93 (Period III). Results are presented in Table 1. These estimates for livestock/meat show that the least amount of price variation occurred for 1960-69, highest for 1970-81, and an intermediate degree of variation for 1982-93. Further, the estimates for corn exhibit a negligible price variation for Period I (0.094), highest for Period II (0.68), and still high (0.55) for Period III but slightly less so compared to Period II.

Given these statistics and the susceptibility and sensitivity of the livestock sector to external shocks, it is often suggested that input price volatility seems to be one of the predominant forces responsible for reshaping the U.S. livestock economy. Of predominant interest here is to empirically test the hypothesis which postulates that in response to risk originating from corn supply shocks, structural change in production and processing of livestock has evolved. In order to test this hypothesis, a time series model of input and output price variation will be estimated for two periods: Period II, representing 1970-81 and Period III, representing 1982-93. Highly significant causality relationships are expected between corn price variability and pork and beef price variability for Period II. Relatively weaker significant causal relationships are expected for Period III because the amplitude of changes are expected to be less.

The specific objective of this study is to examine the impact of corn price volatility on livestock-meat price variability allowing for structural changes in the production and processing of livestock to mitigate risk. All factors which might be influencing changes in variables were removed except one (a corn price change).

**Review of Structure-Risk Related Studies**

Several studies have been conducted regarding the analysis and implications of structural changes as related to vertical integration and/or vertical coordination in agriculture in
Jensen et al. demonstrated the financial risk and uncertainty reduction potential attributed to vertically integrated agricultural processes, specifically in the context of perishability, the nature of product in relation to the nature of its production process, and the discrete nature of production processes for agricultural commodities. The authors, while discussing possible gains and losses accruing from integration, advocated that vertical integration could: a) reduce risk and uncertainty barriers of the factor market and permits transfer of resources between segments, b) lessen capital rationing and thus encourage the adoption of the cost reducing new technology, c) increase returns by lowering storage costs, and d) reduce costs by eliminating the need for the numerous insurance schemes.

Featherstone and Sherrick discussed the incentives for the firms to enter into vertically coordinated relationships. The most important were: a) to increase efficiency, b) to gain market advantage, c) to reduce uncertainty, and d) to obtain or reduce the cost of financing. Producers engaged in vertical arrangement to assure the supply of products with particular characteristics. The authors also examined the financing of vertically coordinated production systems.

Barry, Sonka and Lajili highlighted the importance of new developments in vertical coordination within the context of the U.S. agriculture sector. The authors emphasized that the new developments in vertical coordination were significantly changing the organization and management environment of U.S. agriculture and highlighted the important linkages between vertical coordination and financial structure. The study evaluated the concurrent evolution of the vertical organization of agricultural firms and recent theoretical developments for evaluating these changes, including the relationships to financial structures.

Carlton conducted a study concerning vertical integration in competitive markets under
uncertainty. After having presented the theory of a single competitive market under uncertainty, the author examined the effects of the transmission of uncertainty between different markets. The analysis showed that vertical integration could be regarded as a means of transferring risk from one sector of the economy to another. Azzam and Wellman investigated packer integration into hog production and likely impacts of increased vertical control on hog prices and quantities. The findings of the report indicated that increased packer integration in the hog industry was likely to increase overall pork production, reduce prices to the consumer, and lower the price of hogs to the independent producer.

Thurman addressed the issues related to the structural changes and demand stability in the poultry industry. The study concluded that the demand for poultry meat shifted outward in the early 1970s. At the same time, the demand relationship between poultry and pork changed from substitution to independence. It was also concluded that poultry price was predetermined for demand in annual U.S. data, while quantity was not, which implied several structural changes in the industry. Finally, the results were consistent with a competitive, constant returns-to-scale industry facing elastic factor supplies.

**Model Specification and Procedures**

The method used for econometric estimation to characterize the dynamic relationships between corn price volatility and livestock prices and quantities variability was vector autoregression (VAR). VAR analysis enables one to analyze the system from two aspects. First, Granger’s test evaluates the statistical significance (causality) of lagged variables in a VAR system. Under this procedure, inferences are drawn about which variables are significant causal determinants of other variables based upon the explanatory power within the sample. The second phase of VAR involves generating impulse response functions to evaluate the dynamic paths of adjustment of variables in the system. Alternatively, the impulse response
functions simulates over time the effect of a shock in one series on itself and in the other series of a system.

Since the treatment of the technical aspects of VAR econometrics is given elsewhere (e.g. Bessler, 1984a), only a basic outline of the empirical model is provided here.

A VAR system for \( n \) variables can be defined as:

\[
Y_t = \sum_{k=1}^{k} \begin{bmatrix} b_{11}(k) & \ldots & b_{1n}(k) \\
\vdots & \ddots & \vdots \\
\vdots & & \vdots \\
b_{ni}(k) & \ldots & b_{mn}(k) \end{bmatrix} y_{t-k} + E_t
\]

where

\( t \) = time (\( t=1, \ldots, T \)),
\( Y_t \) = an \( nx1 \) vector of economic variables,
\( k \) = the lag order of the system,
\( b_{ij}(k) \) = the parameters to be estimated, and
\( E_t \) = a vector of random errors (innovations)

Keeping in mind the biological nature of crop and livestock production and based on previous studies wherein a similar data set has been used (e.g., VanTassell and Bessler), a lag of seven months for the farm level, nine months for the wholesale level, and twelve months for the retail level were used to investigate the effect of a one percent (one standard deviation) shock in the price of corn on other variables. Moreover, the model was estimated using several other lag lengths, but the aforementioned lag lengths gave the most significant results. Finally, the VAR model was estimated using the program RATS (Doan and Litterman).

A five variable system of equations consisting of monthly prices and quantities for two
periods: Period II (1970-81) and Period III (1982-93) for commercial steer slaughter (QB),
commercial barrow and gilt slaughter (QP), price of beef (PB), price of pork (PP) and price of
corn (PC) was used. The model was estimated using three different price levels: 1) choice
steer slaughter price (Omaha, 1000-1100 lbs) (BPF), 2) barrow and gilt price (Minnesota, 230-
250 lbs) (PPF), both to represent farm level prices; 3) choice beef wholesale boxed cut-out
prices (550-700 lbs) (PBW); 4) pork carcass cut-out prices (PPW), both to represent wholesale
prices; 5) choice retail beef price (PBR); and 6) retail pork price (PPR), both to represent retail
prices. The analysis was based on real prices expressed in terms of dollars per pound for beef
and pork and dollars per bushel for corn. The nominal price series were converted to real
prices using the consumer price index. All data series were obtained from publications of
United States Department Of Agriculture.

In order to test the hypothesis that increased corn price variation may have been one of
the significant cause which have triggered structural changes in the livestock industry, the
construction/generation of a variable indicative of the price quantity variability is extremely
important. Freebairn in his study regarding the supply and inventory response functions for the
cattle and sheep sector in New South Wales used a range of current price, last year's price, and
the price two years previous to generate a new variable. This variable was used in a
simultaneous system of equations and was assumed to represent producers’ information about
the anticipated variability of future prices. This can be written in notational form as follows:

\[ \text{Var}(P_i) = \text{VPi} = (P_i, P_{i-1}, P_{i-2}) \]

The above representation to account for variation in the time series is referred to as an
absolute but crude measure of variability. A moving variance estimate, also referred to as a
relative measure, has been suggested as an appropriate and relatively better measure of
variation in time series data. For the purpose of this study, therefore, the aforementioned
variables were converted to a moving variance estimate to generate a new set of variables. These variables would take into account the price variation trend for two periods, namely Period II and Period III. Again, the model was estimated for three different levels (the farm, wholesale, and retail) and impulse response functions were generated to observe the dynamic path of these variable for an extended period of time.

**Results and Discussion**

The results from vector autoregression analysis are presented in Table 2. The results are found to conform to the descriptive statistics given in Table 1 and Figure 2. The statistical significance of the estimates reveals strong causality relationships between corn price variability (PVCRN) and variation in prices (PVB and PVP) and quantities (QVB and QVP) of beef and pork, respectively, with a relatively higher level of significance for beef compared to pork for Period II. This implies a greater susceptibility of beef prices and quantities to corn price variability relative to pork prices and quantities. The reason for this phenomena may be attributed to the movement of hog production towards large-scale confined units in the 1970s in some of the major hog producing areas of the U.S. The estimates are non-significant for the wholesale sector for Period II, except for beef quantities, which suggests the notion of inflexibility of wholesale prices relative to the prices in both the farm and retail sectors.

The VAR estimates clearly exhibit weakly significant causal relationships between corn price variability and beef and pork price variabilities for Period III. Further, though the relationships are generally relatively weak for Period III, the statistical significance is still higher for beef than for pork. The relatively weak causal relationships seen in Period III could be supported by the increasingly large scale contract production of hogs. When compared to the poultry sector, the pork industry behaves similarly in terms of the sensitivity of prices and quantities towards corn price shocks. Further, as the hog industry is not as geographically
dispersed as the beef industry, it fulfills the qualifications of a fully integrated industry.

Impulse response functions have been generated from the model and are graphed in Figures 1 and 2. By observing the dynamic movement of variables across 36 months, three inferences can be made. First, the variability of responses is certainly higher for Period II compared to Period III. In comparing periods, allowance must be made for differences between Figures 1 and 2 in terms of the vertical axis. Second, the duration of the impact of a corn price variability shock on the other four variables was longer in Period II than for Period III. Third, in terms of the differences between the dynamic behavior of quantities and prices of pork and beef, it can be seen that pork revealed less variability than beef. We may conclude that beef, in general, is more susceptible to corn price variability shocks relative to pork. Strong causality relationships among the aforementioned variables for Period II compared to Period III indicate that unexpected movements in corn prices may have been one of the predominant factors which triggered structural changes in the livestock-meat industry of the U.S.

Table 1. Estimated Standard Deviations for Monthly Prices of Corn and Livestock/Meat (Historical Data).

<table>
<thead>
<tr>
<th>Period</th>
<th>Retail</th>
<th>Wholesale</th>
<th>Farm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Period I (1960-69)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cattle/Beef</td>
<td>N/A</td>
<td>N/A</td>
<td>3.17</td>
</tr>
<tr>
<td>Hogs/Pork</td>
<td>N/A</td>
<td>N/A</td>
<td>3.18</td>
</tr>
<tr>
<td>Corn</td>
<td>0.094</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>Period II (1970-81)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cattle/Beef</td>
<td>34.43</td>
<td>23.56</td>
<td>16.75</td>
</tr>
<tr>
<td>Hogs/Pork</td>
<td>44.91</td>
<td>32.77</td>
<td>24.48</td>
</tr>
<tr>
<td>Corn</td>
<td>0.68</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>Period III (1982-93)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cattle/Beef</td>
<td>19.83</td>
<td>13.00</td>
<td>7.91</td>
</tr>
<tr>
<td>Hogs/Pork</td>
<td>19.70</td>
<td>14.46</td>
<td>12.13</td>
</tr>
<tr>
<td>Corn</td>
<td>0.55</td>
<td>---</td>
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</tr>
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</table>
Table 2. F-Test for the Significance of Causality of Variables.

<table>
<thead>
<tr>
<th>Direction</th>
<th>Retail Price</th>
<th>Wholesale Price</th>
<th>Farm-Level Price</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Period II (1970-81)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PVCRRN®QVB</td>
<td>1.90**</td>
<td>1.66*</td>
<td>2.59***</td>
</tr>
<tr>
<td>PVCRRN®PVB</td>
<td>1.67*</td>
<td>0.47</td>
<td>1.83**</td>
</tr>
<tr>
<td>PVCRRN®QVP</td>
<td>1.79*</td>
<td>1.68</td>
<td>1.98**</td>
</tr>
<tr>
<td>PVCRRN®PVP</td>
<td>1.78*</td>
<td>1.07</td>
<td>1.81*</td>
</tr>
<tr>
<td><strong>Period III (1982-93)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PVCRRN®QVB</td>
<td>1.22</td>
<td>1.46</td>
<td>2.005**</td>
</tr>
<tr>
<td>PVCRRN®PVB</td>
<td>1.65*</td>
<td>0.95</td>
<td>1.74*</td>
</tr>
<tr>
<td>PVCRRN®QVP</td>
<td>0.67</td>
<td>0.83</td>
<td>0.45</td>
</tr>
<tr>
<td>PVCRRN®PVP</td>
<td>1.87*</td>
<td>1.25</td>
<td>1.68*</td>
</tr>
</tbody>
</table>

Note: All variables are as defined in the text.

*** Significant at 1 percent.
** Significant at 5 percent.
* Significant at 10 percent.
Figure 1. Estimated Farm (1a), Wholesale (1b), and Retail (1c) Level Response of Variability of Quantities and Prices of Beef (QVB and PVB) and Pork (QVP and PVP) to Corn Price Variability for Period II (1970-81).
Figure 2. Estimated Farm (2a), Wholesale (2b), and Retail (2c) Level Response of Variability of Quantities and Prices of Beef (QVB and PVB) and Pork (QVP and PVP) to Corn Price Variability for Period II (1982-93).
References


Jensen, H.R. "Integration as an Adjustment to Risk and Uncertainty." Journal Paper No. 1339, Agricultural Experiment Station, Purdue University, Lafayette, Indiana.


VanTassell, L. and D.A. Bessler. "Dynamic Price Adjustments Between Commercial Purebred..."