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An Empirical Investigation of Live-Hog Demand

Joe Parcell, James Mintert, and Ron Plain

An inverse live-hog demand model was estimated to analyze whether there has been a recent increase in the magnitude of live-hog, own-quantity demand flexibility. Estimating the impact of processing capacity-utilization rate changes on live-hog prices was a second objective of this research. Results indicate that live hog prices have become more responsive to changes in hog slaughter, slaughter weight, cold storage stocks, and changes in the processing capacity-utilization rate. Finally, model results indicate that the sharp increase in processing capacity-utilization rates, the increase in average dressed weight, and the increase in hog slaughter all had a negative effect on the live-hog prices.

Key Words: Capacity utilization, live hog demand, structural change

JEL Classifications: Q11, Q12, Q13, D40

During the fourth quarter of 1998, nominal live-hog prices in the Iowa–Southern Minnesota market averaged $19.67/cwt., the lowest quarterly price average since the early 1970s, according to the Livestock Marketing Information Center. The decline in prices was even more dramatic as cash prices briefly dipped below $10/cwt. during December 1998 (Figure 1). The dramatic price decline led to large equity losses for U.S. pork producers. In response during the summer of 1999, the National Pork Producers Council (NPPC) proposed an "Action Plan," which requested government intervention in the form of pork purchases and a subsidy to launch a new pork processing plant (NPPC, July 21, 1999). Although the autumn of 1998's large price decline was attributed primarily to a large increase in domestic hog slaughter and pork production (U.S. Department of Agriculture [USDA], *Livestock, Dairy, and Poultry Update*), two factors separated it from previous hog market price declines. First, it was larger than expected on the basis of historical hog market supply and demand relationships. Second, the price decline was more severe at the live-hog market level than at the wholesale level. The objectives of this research were to determine the impact of hog slaughter capacity-utilization on live-hog prices and to determine whether the live-hog, own-quantity price flexibility has changed.

The magnitude of the live-hog price decline relative to the production increase (Figure 1) led to speculation that live-hog demand has become more inelastic. In the most recent study that focused on farm-level demand, Wohlgenant concluded the own-quantity, farm-level hog price flexibility was −2.07. During the fourth quarter of 1998, pork production rose 9.9% above that of the fourth quarter of 1997. Applying Wohlgenant's re-

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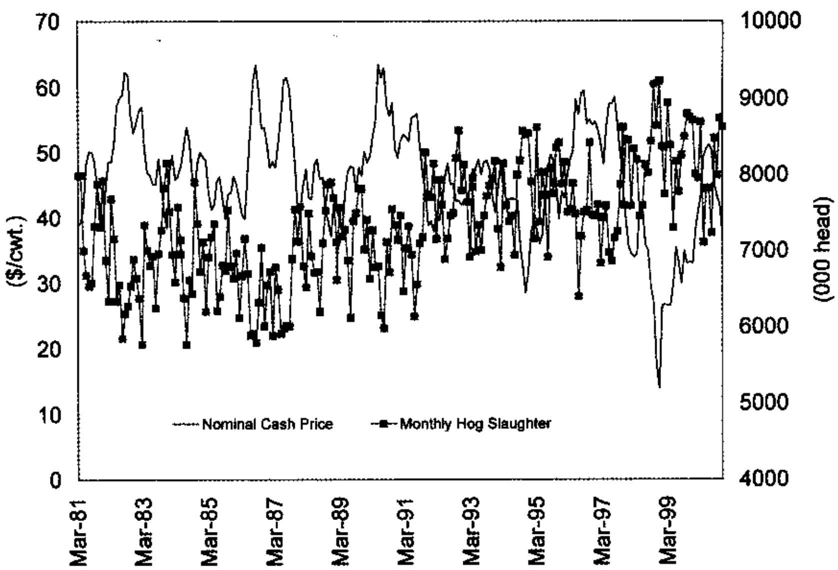

Figure 1. Monthly Average Nominal Iowa–Southern Minnesota Barrow and Gilt Live-Hog Price and Monthly Total Hog Slaughter (March 1981–December 2000)

sults to 1998 data implies that a 20%–21% live-hog price decline was expected. Instead, Iowa and Southern Minnesota live-hog prices actually declined 55%. Although competing meat supplies, such as chicken and beef, also increased during this timeframe, the meat supply increases were not large enough to explain the large farm-level price decline. On the basis of nonparametric analysis, Plain and Grimes concluded that the own-quantity, farm-level hog price flexibility changed from −2 before fall 1998 to −5 during the fall of 1998. However, this conclusion has not been substantiated with rigorous parametric research.

Several possible explanations for the shift in hog-price flexibility have been postulated. The U.S. pork industry has undergone considerable structural change over the past two decades. Real processor margins have declined substantially (USDA, *Livestock Slaughter*), and pork processing capacity-utilization levels have increased (NPPC 2000). In response to tighter pork-processing margins and the shift in capacity-utilization levels, packers may have become more price-responsive to changes in slaughter hog supplies, i.e., more willing to pay higher prices when plants are operating below capacity and more inclined to pay sharply lower prices when operating above normal capacity. Hog-marketing contract usage has also increased considerably, especially during the 1990s. Fewer than 10% of hogs marketed in 1980 were sold under some type of marketing agreement (Grimes). Surveys by Lawrence, Hayenga, and Grimes and by Grimes and Meyer in 1997 and 2000, respectively, indicated that the percentage of hogs sold under some type of marketing agreement increased from 56% in 1997 to nearly 75% in 2000.[1]

The live-hog prices fell 55% below the 1997 fourth-quarter average, but the USDA's estimate of the pork cutout (wholesale) value declined by only 32%. Although it is not unusual for wholesale and live market price changes to differ, the large discrepancy between the live and wholesale pork price changes was surprising. As a result, industry participants began to examine hog slaughter capacity to determine whether a lack of processing capacity might have been responsible for the difference in price response at the wholesale pork and live-hog market levels.

The pork-processing sector has changed

[1] We do not implicitly measure the impact of this shift in procurement method because of data limitations.

appreciably in recent years. Reduced profitability in the pork-processing sector led to many pork plant closures, whereas other firms expanded to take advantage of economies of size.[2] Anderson et al. found that firm exits in the beef packing industry were primarily attributable to plant-level factors, and market-level factors attributed little to firm exits. We expected similar plant-level economic forces to motivate exit and efficiency in the pork-packing sector.

During 1997, pork plants in Council Bluffs, Iowa; Worthington, Indiana; and Moultrie, Georgia closed and IBP switched from a double shift to a single shift in its Columbus Junction, Iowa, plant. Collectively, these plant closures and operational changes reduced hog processing capacity by 23,400 hogs per day (Luby). Moreover, during the summer of 1998 and before hog supplies increased sharply during fall 1998, Thorn Apple Valley closed its Michigan slaughter facility, further reducing the industry's slaughter capacity (Luby). Data from NPPC indicated that estimated normal industry slaughter capacity between February 1998 and February 1999 declined from 417,000 head per day to 381,000 head per day. However, federally inspected hog slaughter data from November and December of 1998 indicated that the daily hog slaughter volume reached a peak of 415,548 head per day, suggesting that the industry exceeded its normal daily slaughter capacity by either increasing the number of hours worked or increasing weekend slaughter levels. Thus, it appears that a shortfall of processing capacity during fall 1998 might have contributed to the live-hog price decline as processors reduced their bids for hogs while plants were operating above normal capacity levels.

If the hog price flexibility (measured in absolute value) has increased as hypothesized, this has important implications for hog producers, processors, and retailers. Moreover, policy-makers would also benefit from an improved understanding of how hog price responds to supply changes. If processing capacity-utilization has a significant impact on live-hog prices, hog producers and processors would benefit from an improved understanding of this relationship as they make future production plans and consider expanding slaughter and processing capacity. As a result, improved measurement of the effects that specific factors, such as pork production and pork-plant capacity-utilization, have on live-hog price is needed.

Previous Research

Most previous studies that have analyzed factors affecting demand for livestock commodities focused on structural changes in retail demand with an emphasis on shifts in consumer preferences (McGuirk et al.; Moschini and Meilke; Tomek). However, a few studies evaluated farm-level demand for hogs. Hayenga and Hacklander estimated an inverse live-hog demand model. They specified a model in which the live-hog price was hypothesized to be a function of these parameters: hog production, cattle production, cold storage stocks lagged 1 month, the change in cold storage stocks between the current month and previous month, per capita income, and seasonal shift variables. Results from the empirical model estimated by Hayenga and Hacklander indicated that a 1 million–pound increase in average daily production decreased live-hog price by $0.769/cwt., and a 1 million–pound increase in cold storage stocks, lagged 1 month, decreased live-hog price by $0.023/cwt. Hayenga and Hacklander hypothesized that the month-to-month change in cold storage might be endogenous. That is, a low live-hog price (highly correlated with the wholesale price) induced storage speculation in anticipation of future higher prices. As a result, they estimated a change in pork cold storage stocks separately and found that a 1-dollar increase in live-hog price was associated with a month-to-month cold storage stock decline of 2.29 million pounds.

Wohlgenant published one of the few studies in the past 20 years that was focused on

[2] Expansion may not necessarily be through capital investment. Expansion could occur through the addition of an extra work shift to the plant schedule or faster chain speeds.

farm-level demand. Using data over the 1956–1983 period, he estimated the farm-level flexibility for pork by regressing farm-level pork quantity, which is an index of marketing costs and a retail-demand shifter on farm-level price. He concluded that the own-quantity, farm-level hog price flexibility was −2.07. However, Wohlgenant's study only included data through 1983. Given the structural change in the swine industry, an updated analysis of live-hog demanded is warranted.

Recent research by Brown and Spivey, Salin, and Anderson investigated the impact of processing capacity on live-hog price. Analyzing weekly data from 1991 through 1999 and using Saturday slaughter as a proxy for processing capacity constraints, Brown concluded that the fall 1998 average live-hog price would have been $3.84/cwt.–$5.76/cwt. higher than the actual market price if processing capacity had not been limiting. Spivey, Salin, and Anderson estimated live-hog demand and pork cutout demand models using weekly data from 1990 through 1999 to investigate the impact of slaughter capacity on price. Their models specified live-hog price and weekly cutout value as a function of weekly slaughter and a capacity measurement variable. Spivey, Salin, and Anderson used three different proxies for a processing capacity constraint variable. The three different proxies were a 0 or 1 binary variable when weekend slaughter exceeded 160,000 head for three consecutive weekends, weekend slaughter, and the ratio of weekend slaughter to slaughter during a 5-day workweek. Referring to the model using the ratio of weekend slaughter to slaughter during a 5-day workweek, their results indicated that a 1-percentage-point increase in Saturday hog slaughter decreased live-hog price by $11.63/cwt. and increased the wholesale cutout value by $10.58/cwt.

Our research improves on these studies by analyzing a longer time period (1980–2000) and adding other explanatory variables, which are hypothesized to affect live-hog price, to the live-hog price demand model. The omission of these factors in previous research may have produced biased parameter estimates due to model misspecification.

Empirical Model

Tomek noted that changes in farm-level derived demand for agricultural commodities are a function of changes in retail-level demand, marketing, and processing costs, i.e., derived demand. An inverse farm-level demand model for pork is specified in this study. This model was built on Tomek's basic outline of a farm-level derived demand model and previous research by Brown, Wohlgenant, and Spivey, Salin, and Anderson. The regression model is estimated using monthly data from 1981 to 2000. Variables are chosen so that the model captures the impact of changes in processing capacity relative to industry size using a proxy variable designed to measure processing capacity-utilization. The empirical model to be estimated is as follows:

(1) Iowa − Southern Minnesota Barrow & Gilt Cash Price$_t$
= f(monthly hog slaughter$_t$,
average dressed weight$_t$,
processing capacity − utilization ratio$_t$,
index of processing and marketing costs$_t$,
retail demand shift index$_t$,
cold storage stocks$_t$,
price specification change$_t$,
seasonality$_t$).

Variable definitions and the expected impact on live-hog price from a unit increase in the relevant explanatory variables are listed in Table 1. The subscript t refers to month (t = March 1981–December 2000). The dependent variable is the monthly average of the daily Iowa–Southern Minnesota Barrow & Gilt prices reported by the USDA's Agricultural Marketing Service.

Pork production is divided into head slaughtered and dressed weight. Monthly slaughter is included in the model to capture packer demand for hogs, which is partly based on the availability of shackle space. The average dressed weight is included with monthly

Table 1. Description of Variables Used in Live-Hog Inverse Demand Model Specified in Equation (1) and Expected Impact on Live-Hog Price

Variable	Description	Expected Impact on Live-Hog Price
Iowa–Southern Minnesota Barrow & Gilt Cash Price$_t$	Average price received by hog producers for a 48% lean animal in Iowa–Southern Minnesota cash market in month t	
Monthly Slaughter$_t$	Monthly nonholiday slaughter in month t, converted to a 30-day month	(−)
Average Dressed Weight$_t$	Average live-hog dressed weight in month t	(−)
Processing Utilization : Capacity Ratio$_t$	Ratio of current month (t) nonholiday average daily slaughter to maximum month average daily slaughter during the same quarter in the previous year	(?)
Index of Processing Costs$_t$	Simple average of cost of 500 KWH of electricity and wage rate for packing plant employees in month t	(−)
Retail Demand Shift Index$_t$	Summation of cross-elasticities of demand multiplied by the retail price of competing good, plus the income elasticity of pork multiplied by the sum of per capita income, plus population, in month t	(+)
Cold Storage Stocks$_t$	Ratio of pork cold storage stocks reported at the end of the month in month t to pork cold storage stocks in month $t - 1$	(−)
Price Specification Change$_t$	A 0 or 1 binary variable set equal to one following the April 1999 Iowa–S. Minnesota cash price specification change	(?)
Seasonality$_t$	Separate 0 or 1 binary variables for month t (default = December)	(?)

slaughter, to capture the impact of changes in pork demand on live-hog prices. All other factors being equal, increases in monthly slaughter and average dressed weight are both expected to lead to lower live-hog prices.

Several methods have been used to estimate processors' capacity-utilization. Barkley and Schroeder used proprietary cattle-processing data to construct a capacity-utilization variable. They used the 12-month lag of the ratio of cattle marketed during a period to plant capacity. However, no direct monthly measurements of the pork industry's processing capacity are available over the entire study period, so the use of this capacity measure was precluded. Schroeder and Mintert examined the effect of capacity-utilization on pork margins using the ratio of current-month slaughter to the maximum-month slaughter during the previous 12 months. Other studies specified capacity-utilization as an "overflow" variable, using Saturday slaughter as a proxy for overflow (e.g., Brown; Spivey, Salin, and Anderson). Generally, a typical hog processing plant operates two 8-hour kill shifts daily (Monday–Friday), followed by an 8-hour cleanup shift each day. Thus, to expand plant capacity, a weekend "overflow" slaughter schedule is often used.

Brown used a binary variable set equal to one when Saturday slaughter exceeded 160,000 head during three consecutive weeks. Spivey, Salin, and Anderson used three separate variable specifications of Saturday slaughter as a proxy for capacity-utilization. However, there is a fundamental problem with such a methodology. Beginning in the early 1980s and ending in the middle 1990s, IBP implemented a Tuesday-through-Saturday processing week to reduce the costs of carrying hogs over the weekend.[3] As a result, IBP's overflow day was Monday, not Saturday. Thus, using Saturday slaughter as a proxy for processor capacity-utilization may be flawed.

For the current analysis, the processing capacity-utilization variable is the ratio of average daily slaughter in the current month to maximum average daily slaughter during the same quarter in the previous year. This capacity-utilization variable specification was chosen to account for the seasonality in pork production and simultaneously capture periods when facilities were over- and underused.

Meatpacking plants minimize costs when they are operating at capacity (Ward). When slaughter is below capacity, inputs are not used optimally, and when slaughter is above capacity, additional costs are incurred in paying overtime labor. The impact on live-hog price from changes in the level of capacity-utilization is left to be determined empirically. However, appropriately specifying this variable is difficult, because the pork processing industry has undergone considerable change over the period of the study. To account for the differences in the impact of processing capacity-utilization on live-hog price over time and for varied levels of slaughter, a flexible least-squares (FLS) estimator is used to determine the change in magnitude of the coefficient. The FLS estimator is discussed in more detail at the end of this section.

Wohlgenant found that an increase in processing and marketing costs (measured by an index of food-marketing costs) caused the live-animal price to decline. This occurs because, in the short run, the hog supply is very inelastic. Therefore, short-run increases in marketing costs are passed on to hog sellers via live-hog price reductions. As a result, live-hog prices are expected to decline when the marketing cost index increases.

A retail-demand shift index is included in the inverse live-hog demand model, because the demand for live-hogs is derived from consumer demand for retail pork. Following the method of Wohlgenant, the retail-demand shift index is the summation of cross-elasticities of demand for retail good *j*, with respect to pork, multiplied by the retail price of good *j*, plus the pork income elasticity multiplied by the sum of per capita income and population.[4] Cross-price and income elasticities were taken from McGuirk et al. An increase in the retail-demand shift index is expected to increase farm-level demand, leading to live-hog price increases.

The ratio of current-month cold storage stocks to the 1-month-lagged cold storage stocks was included in the inverse live-hog demand model to determine the impact of cold storage constraints on price. An increase in cold storage stocks indicates that current period production is larger than consumption. The ratio was used to account for changes in cold storage stocks between months. Schroeder and Mintert found that an increase in cold storage stocks increased pork-processing margins. Therefore, an increase in cold storage stocks is expected to lead to a live-hog price decline.

To account for the change in the Iowa–Southern Minnesota live-hog price specification, the price specification change variable is a binary variable that is set equal to 1 for April 1999 forward. Seasonal dummy variables are specified as 0 or 1 binary variables where Jan-

[3] IBP ended the Tuesday through Saturday workweek during the middle of 1995 likely because labor costs of operating an irregular weekly schedule exceeded the costs of carrying hogs over the weekend.

[4] The retail shift index ($Z_{\text{pork},t}$) used for the current study is specified as (Wohlgenant):

$$\Delta Z_{\text{pork},t} = \exp\left[\sum_{j \neq i} e_{\text{pork},j} \Delta\log(P_{jt}) + e_{\text{pork},y} \Delta\log(Y_t) + \Delta\log POP_t\right],$$

where $e_{\text{pork},j}$ is the cross-price elasticity of meat type j with respect to pork, P_{jt} is the price of meat type j at time t, $e_{\text{pork},y}$ is the income elasticity of pork, Y_t is per capita disposable income, and POP_t is population.

Table 2. Summary Statistics of Variables used in Estimating the Live-Hog Inverse Demand Model Specified in Equation (1) (Monthly data between March 1981 to December 2000)[a]

Variable	Avg.	Std. Dev.	Min	Max
Nominal Iowa–Southern Minnesota Barrow & Gilt Cash Price ($/cwt.)	45.98	8.21	13.92	63.44
Average Monthly Nonholiday Slaughter (000 head)	8,451.70	835.51	6,503.70	10,380
Average Monthly Dressed Weight (lbs.)	181.37	6.569	169	197
Processing Capacity-Utilization Ratio	97.24	6.75	80.33	115.89
Index of Processing Costs	35.55	3.89	28.71	43.05
Retail Demand Shift and Marketing Index	1.18	0.53	0.20	3.74
Cold Storage Stocks (million lbs.)	333.95	86.89	175.06	595.23
Cold Storage Index	100.45	8.85	78.11	131.79

[a] The number of observations used to compute summary statistics was 238.

uary is the default month. The impact of the seasonal binary variable on price is expected to vary by month.

Evaluating a Change in Live-Hog Demand

Model stability, or parameter stability, is of interest when estimating models for industries that have undergone considerable structural change. For the current study, a change in live-hog demand is analyzed and tested using parametric analysis. To capture potential changes in the coefficients, model stability is examined here using the FLS estimator introduced by Tesfatsion and Veitch and applied by Dorfman and Foster; Lutkepohl; Parcell; and Poray, Foster, and Dorfman. The FLS estimator is used to arrive at time-varying parameter estimates by minimizing the sum of squared residual measurement and residual dynamic errors (Tesfatsion and Veitch). We used FLS to graphically depict how coefficients change in magnitude over time, i.e., to observe the evolution of structural change.

Here is a brief description of the FLS estimator. Assume a simplified inverse farm-level demand model like the following:

$$(2)\quad P_t = \beta Q_t + \varepsilon_t$$

where P_t is the price at time t ($t = 1, \ldots, T$), Q_t is demand at time t, and ε_t is a random disturbance term. By allowing the coefficient ε to vary over time, the FLS estimator minimizes the loss function derived from Equation (2), which can be specified as

$$(3)\quad \sum_{t=1}^{T} (P_t - \beta_t Q_t)^2 + \lambda \sum_{t=1}^{T-1} (\beta_{t+1} - \beta_t)' \mathbf{D}(\beta_{t+1} - \beta_t),$$

where β_t is a $T \times 1$ vector of time-varying parameter estimates, λ is a value between 0 and 1 ($\lambda \in [0, 1]$), and $\mathbf{D}$ is a $K \times K$ weighting matrix. The first term is the sum of squared errors. The second term is the sum of squared parameter variations over time. The matrix $\mathbf{D}$ is specified as a positive definite diagonal unit matrix with diagonal elements d_{ij}.[5] Given the specification of Equation (3), a large λ penalizes parameter variability and small λ allows for greater parameter variability.

Data

Summary statistics of data used in the estimation of the inverse live-hog demand model are listed in Table 2. All data series are monthly from March 1981 through December 2000. The monthly live-hog price paid to producers is the Iowa–Southern Minnesota barrow and

[5] Poray, Foster, and Dorfman specify the weighting matrix such that the diagonal elements associated with the seasonal shift variables do not allow for time-varying parameter estimates. They note that these variables potentially pick up all of the variation.

gilt price. Monthly values were calculated by averaging daily prices reported by the USDA. Beginning in April 1999, the price quote for the Iowa–Southern Minnesota barrow and gilt price changed from a 48% lean hog to a 52% lean hog. As a result, an Iowa–Southern Minnesota barrow and gilt price was estimated for the period April 1999 to December 2000 using a lagged Iowa–Southern Minnesota price and the USDA terminal market price during the current month. The average cash price was $45.98/cwt., with a range of $13.92/cwt. to $63.44/cwt. The price series was deflated by the consumer price index, with 2000 as the base year (Bureau of Labor Statistics).

Monthly slaughter was computed using daily federally inspected hog slaughter collected from Livestock Marketing Information Center. Aggregated monthly head slaughter was converted to a 30-day holiday-adjusted month to account for the difference in slaughter days between months. The capacity-utilization ratio ranged from 80% to 116% over the period and averaged 97%. The average slaughter weight is the average dressed hog weight, and slaughter weight data were collected from various issues of *Livestock Slaughter* (USDA). Pork cold-storage stocks data were obtained from *Cold Storage Reports* (USDA). The processing and marketing cost index was computed as the simple average of the cost of 500 KWH of electricity and average wages paid to packing plant employees (Bureau of Labor Statistics). The retail-shift index was computed using national monthly average retail prices for chicken and beef (Livestock Marketing Information Center). Monthly-annualized U.S. population and monthly-annualized U.S. disposable income were obtained from the Federal Reserve Bank of St. Louis web site (Federal Reserve Economic Data). Per capita income was computed by dividing U.S. disposable income by U.S. population.

Results

Statistical tests were computed and models were estimated using *SHAZAM* version 9.0 software. The dependent variable used in the estimation of Equation (1) was tested for stationarity using the augmented Dickey-Fuller stationarity test, and the lag order was determined by minimizing the Akaike Information Criteria. The Dickey-Fuller test statistic was −2.14, and the 10% critical value was −2.57. Therefore, the null hypothesis of a unit root could not be rejected. Data were first-differenced, and the first-differenced price series was found to be stationary. The number of observations used for estimation was 238.

Model results are reported in Table 3. The model explained 78% of the variation in the Iowa–Southern Minnesota live-hog cash price over the period March 1981 to December 2000. Monthly slaughter, average dressed weight, processing capacity-utilization, the retail-shift demand index, cold storage stocks, and several seasonal binary variables had a significant impact on live-hog prices. Flexibilities for the statistically significant variables were computed at mean values for the respective variables.

An increase in monthly slaughter led to a live-hog price decline. Results indicate that the average live-hog slaughter price flexibility was −0.33. This value is significantly less than has been previously reported. However, pork production for this study was decomposed into head slaughter and carcass weight.

As expected, increases in dressed weights had a negative and statistically significant impact on price. A 1-pound increase in dressed weight led to a $1.10/cwt. decline in live-hog price. The dressed-weight flexibility indicates the 1% increase in average dressed weight was associated with a 3.10% decline in live-hog price.

The capacity-utilization variable had a negative sign and was statistically significant. A 1–percentage point increase in the capacity-utilization ratio decreases live-hog price by $0.20/cwt. The capacity-utilization flexibility calculated at the mean was −0.31.

Increases in cold-storage stocks had a significant, negative impact on live-hog prices. The cold storage stock variable was the ratio of the current month's pork cold-storage stocks to the previous month's pork cold-storage stocks. A 1–percentage point increase in

Table 3. Estimation Results of First Difference Live-Hog Inverse Demand Model (Dependent Variable is the Iowa–S. Minnesota Live-Hog Barrow & Gilt Cash Price, $/cwt.)

Variable	Coefficient	Standard Error	Flexibility at the Mean
Average Daily Nonholiday Slaughter	−0.002***	0.001	−0.331
Dressed Weight	−1.097***	0.261	−3.122
Processing Capacity-Utilization Ratio	−0.202***	0.075	−0.307
Cold Storage Stocks	−0.102***	0.027	−0.161
Index of Processing Costs	0.024***	0.002	
Retail Demand Shift Index	−1.026***	0.427	Not of the expected sign
Price Specification Change	0.637	0.744	NA
Seasonal Shift Variables (Default = January)			
February	−2.998***	1.155	
March	−2.953***	1.162	
April	−0.405	1.094	
May	0.982	1.149	
June	−3.570**	1.309	
July	−5.467***	1.136	
August	−2.158*	1.299	
September	−1.670	1.177	
October	1.348	1.293	
November	−2.961***	1.293	
December	−2.714***	1.107	
Intercept	3.117***	0.973	
F-statistic (Variables Jointly Different from Zero)			425.480***
R^2			0.782
Mean of the Dependent Variable ($/cwt., 2000 = 100)			63.753
No. of Observations			238
ρ (Autocorrelation Coefficient)			0.066

Note: One, two, and three asterisk(s) represent coefficients significantly different from zero at the 10%, 5%, and 1% level, respectively.

the pork cold storage stock ratio was found to decrease the live-hog cash price by $0.10/cwt. The cold storage flexibility, computed at the mean, was −0.16.

The retail demand shift index was negative, which is not as expected.[6] This unexpected result may be because farm-level prices do not respond quickly to changes at the wholesale and retail level (e.g., Schroeder and Mintert). Similarly, the processing cost variable was of the incorrect sign and was statistically significant. Measuring the processing cost is difficult because processing cost changes slowly over time. Furthermore, Wohlgenant indicated that processing cost variables may not be good indicators of nonfarm input prices. The FLS parameter estimates indicate that the coefficient for this variable switched from positive during the first portion of the time period to negative and statistically significantly for the later portion of the study.

Time Path of Live-Hog Flexibility

FLS was used to develop a graphical representation of the time path of the live-hog price flexibility estimate over time. Individual FLS

[6] A more complete interpretation, i.e., decomposition of the parts, of this variable is omitted because the focus of this study does not directly pertain to the decomposition of this coefficient.

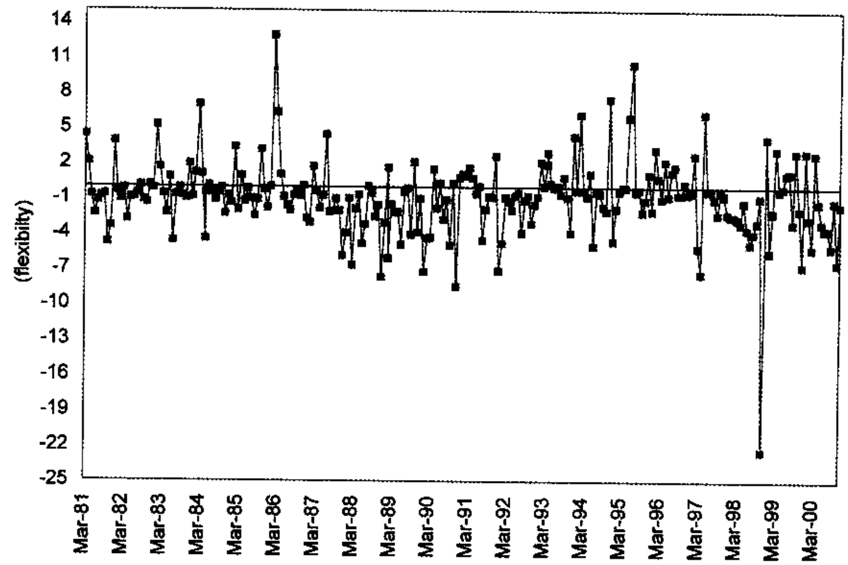

Figure 2. Time Path of the Slaughter Own-Flexibility Coefficient for $\lambda = 0.001$

parameter estimates are of little value. However, the value of the FLS estimator is in observing the change in magnitude of the coefficients during the period of study to assess the impact of structural change. The FLS estimator was used to estimate the model specified in Equation (1). A benefit of the FLS estimator is that parameter flexibility allows for outlying data points due to structural change. This is important because it is difficult to appropriately specify the live-hog demand model to capture the evolvement of structural change.

The time paths of the own flexibility and carcass weight flexibility estimates, for $\lambda = 0.001$, are graphed in Figures 2 and 3, respectively. As can be observed from either Figure 2 or 3, the own-price flexibility varied substantially over the period February 1981 to January 1994. In late 1998, the live-hog flexibility increased (in absolute value) signifi-

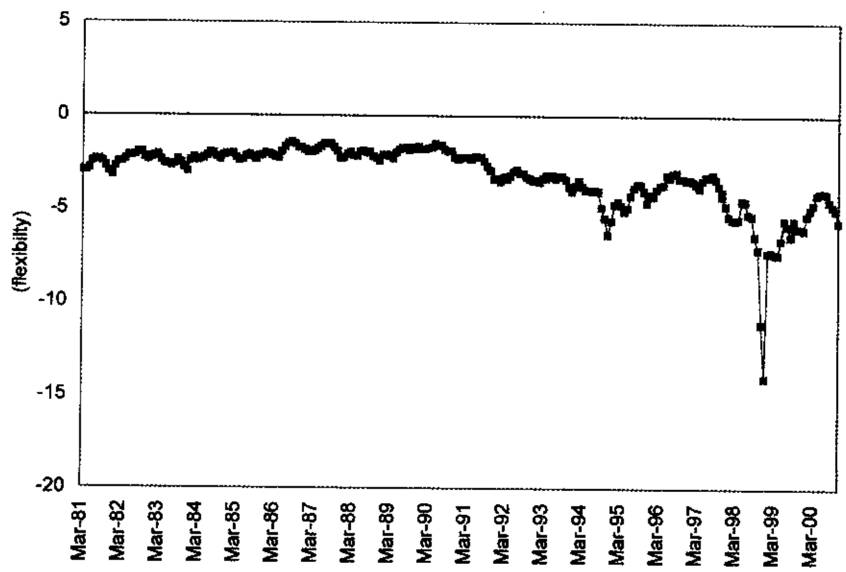

Figure 3. Time Path of the Pork Carcass Weight Coefficient for $\lambda = 0.001$

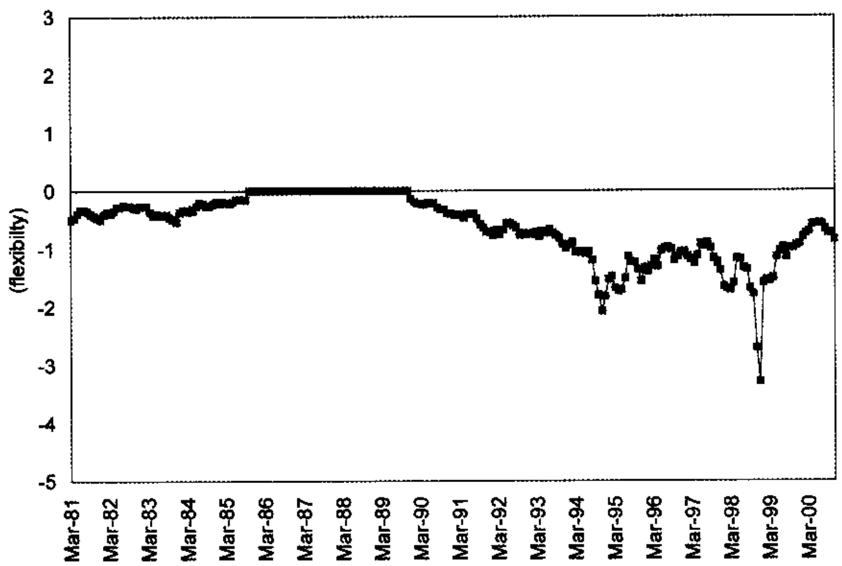

Figure 4. Time Path of the Capacity-Utilization Price Flexibility Coefficient for $\lambda = 0.001$

cantly. The pork carcass weight flexibility time path has increased in absolute value since the early 1990s, and the variability of the flexibility has increased. Solely on the basis of the slaughter own flexibility, it would be difficult to assert that the live-hog demand flexibility has increased in absolute value over time. However, combined with the impact of carcass weight, it is clear that hog production flexibility has increased in magnitude, and most of this increase can be attributed to heavier hogs. That is, shackle space has generally been sufficient, other than during the fourth quarter of 1998.

The capacity-utilization elasticity estimate increased (in absolute value) substantially beginning in the fall of 1994 (Figure 4). The FLS estimator indicates the magnitude of the capacity-utilization estimate increased 400% in the fall of 1998 and then returned to near the historical average level. Since 1994, the capacity-utilization flexibility has become more variable, which might suggest that further information is required to assess the impact of capacity to utilization on the live-hog industry.

Other than one small deviation in the fall of 1998, the time-path pork cold-storage flexibility has oscillated around zero (figure not reported). It might be that the pork carcass weight variable, in addition to the head slaughtered variable, is capturing some of the impact on hog price from varying levels of pork cold-storage stocks. That is, cold-storage stocks are dependent not only on the number of animals slaughtered but also on the total pounds of pork processed.

What Happened in 1998?

The dramatic live-hog price collapse that occurred in fall 1998 helped motivate this study. As a result, it is useful to examine the impact several factors such as increases in average daily nonholiday hog slaughter, dressed weights, pork processors' capacity-utilization, and pork cold-storage stocks had on live-hog prices during fall 1998. To quantify these effects, Table 4 was constructed to provide a simulation using the FLS coefficients estimated for the fourth quarter of 1998. Because of the changes in coefficients' magnitude over time, we felt it only appropriate to simulate for the FLS estimator results. The impact of a change in one of the explanatory variables on the 1998 live-hog price was computed relative to the fourth quarter average, the third quarter of 1998, and the fourth quarter of 1997. These periods were used to help explain differences in interpretation of the impact within the year, across years, and during the entire period.

Table 4. Economic Impact of Fourth Quarter 1998 Live-Hog Demand Factors, Using the Average Coefficient for the Fourth Quarter 1998 from the Flexible Least-Squares Estimator

	Average Daily Nonholiday Slaughter (000)	Slaughter Weight (lbs.)	Capacity-Utilization (index)	Cold Storage (index)	Average Daily Nonholiday Slaughter	Slaughter Weight	Capacity-Utilization Impact	Cold Storage Impact
	Observed Levels in Relative Period				Impact on Live-Hog Price ($/cwt.)			
Relative to Average	8,445.46	181.31	96.33	100.48	−$20.22[a]	−$11.23	−$4.17	−$0.08
Relative to Third Quarter 1998	9,344.50	185.67	102.88	96.96	−$9.23	−$6.51	−$1.11	−$0.11
Relative to Fourth Quarter 1997	9,368.58	190.33	100.10	100.06	−$8.93	−$1.45	−$2.41	−$0.08
					Levels Observed in Fourth Quarter 1998			
					10,099.24	191.67	105.26	108

[a] For example, the (−$20.22)/cwt. for the own-quantity impact for "relative to the average" was computed by multiplying the FLS own-quantity coefficient by the difference between the average slaughter over the entire time period (8,445.46) and the average slaughter during the fourth quarter of 1998 (10,099.24).

The reported average producer prices received were $19.48/cwt. for the fourth quarter of 1998, $46.06/cwt. over the entire time period, $33.46/cwt. for the third quarter of 1998, and $43.68/cwt. for the fourth quarter of 1997. Using the FLS coefficients, the impact varied on the basis of the relative base period and the ranking of the variables. Own quantity had the largest impact, followed by slaughter weight, capacity-utilization, and cold storage. The total impact from these four variables was $35.70/cwt. compared with the average, $16.96/cwt. compared with the third quarter of 1998, and $12.87/cwt. compared with the fourth quarter of 1997. This simulation indicates the number of head slaughtered and slaughter weight played a significant role in the low prices observed during the fall of 1998. Capacity-utilization was a factor to a lesser extent; however, capacity-utilization was economically significant in analyzing the impact on live-hog price.

Implications

Using monthly data from 1981 through 2000, an inverse live-hog demand model using a pork processing capacity constraint variables was estimated to investigate claims that live-hog demand flexibility has increased in magnitude (absolute value). Results from FLS estimations indicate that the live-hog demand flexibility has increased in absolute magnitude since the mid-1990s. The processing head own flexibility might not have increased in magnitude substantially, but the pork carcass weight time path has increased substantially over that of the previous 10 years.

We found that capacity-utilization and cold-storage flexibility have changed over time to a lesser extent. However, since early 1994, the capacity-utilization variable has increased in magnitude and variability (Figure 4). In a simulation of factors leading to the 1998 price decline, it was found that the live-hog price decline capacity-utilization had an economically significant impact on price. Processing capacity may again become a critical issue during upcoming years if additional

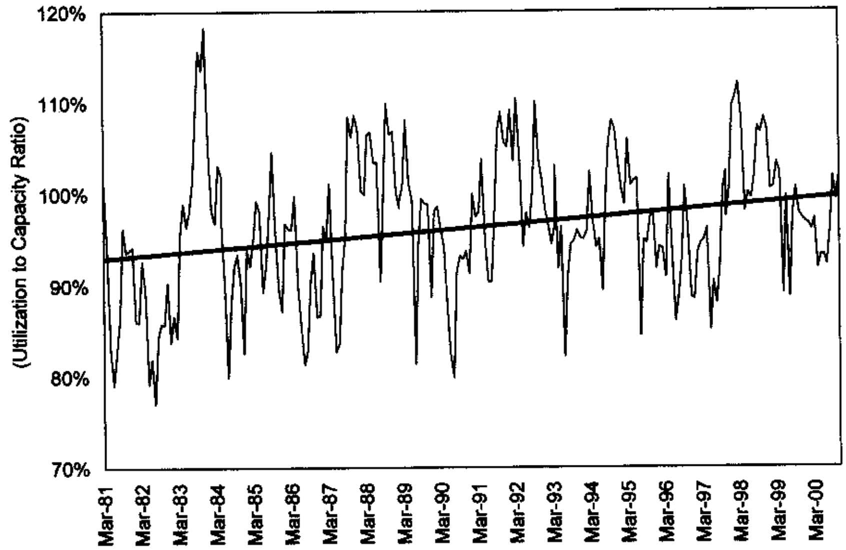

Figure 5. Processing Utilization-Capacity Ratio Specified as the Current Month's Average Daily Slaughter to Maximum Monthly Average Daily Slaughter during the same Quarter 12 Months Prior

plants close and if there is no plant entry or expansion.

Figure 5 is used to illustrate the change in processor utilization to capacity. Over time, this variable has drifted toward 100%. There has been considerable structural change in pork processing facilities over this time period. During the 1980s, packers typically operated an 8-hour, single-shift, 5-day week, which allowed packers to effectively increase capacity by 50% by moving to a 10-hour day and processing animals on Saturday. Because of economies of size, packers shifted away from the traditional slaughter week. Now, packing facilities typically operate two processing shifts, and a third shift is used for cleanup. In other words, the processing capacity of most packing facilities can only increase by operating during the weekend. Thus, the impact of a change in capacity-utilization on live-hog price might have become more variable since the mid-1990s because processors have less capacity flexibility.

Results from this study have several important implications for the pork sector. First, the study indicates that live-hog flexibility increased in absolute value during the mid- to late-1990s, but this was due more to heavier animals than more animals. As a result, modest changes in hog slaughter and head slaughtered led to relatively larger changes in hog prices than just a decade ago. Second, we found that high capacity utilization in the pork-processing sector was associated with hog prices. This was especially true in the fall of 1998, when slaughter increased to unprecedented levels during November and December.

The limitations of this study are that there is no primary level data for the processing utilization-capacity variable and that the FLS estimator is a relatively new mechanism for analyzing structural change. Future research should include a regional analysis of factors affecting live-hog price and look to incorporate a percentage of animals marketed through marketing-contracting variable. Furthermore, a similar analysis of the cattle industry could prove to be insightful, because there have been claims that the cattle industry has undergone significant structural change, but processing capacity has not been a serious constraint.

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