An Empirical Investigation of Live Hog Demand

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An inverse live hog demand model was estimated to analyze claims that the live hog own quantity demand flexibility's magnitude has increased in recent years. A second objective of this research was to estimate the impact changes in processing capacity utilization rates have on live hog prices. Results indicate that in recent years live hog prices have become more responsive to changes in hog slaughter, slaughter weight, and cold storage stocks. Additionally, changes in processing capacity utilization rates, at times, also have a relatively large impact on live hog prices. Finally, when the large live hog price decline that occurred during the fall of 1998 is examined, model results indicate that the sharp increase in processor's capacity utilization rates, an increase in average dressed weight, and the increase in hog slaughter all had a large negative effect on live hog prices.

Keywords: Live Hog Demand, Structural Change, Capacity Utilization,

An Empirical Investigation of Live Hog Demand

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 (LMIC). The decline in daily 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 on the part of U.S. pork producers. In turn, the National Pork Producers Council (NPPC) proposed an "Action Plan" during summer 1999 which requested government intervention in the form of pork purchases and a subsidy to launch a new pork processing plant (National Pork Producers Council). Although fall 1998s large price decline was attributed primarily to a large increase in domestic hog slaughter and pork production (U.S. Department of Agriculture), two factors separated it from previous hog market price declines. First, it was larger than expected based upon historical hog market supply and demand relationships and, second, the price decline was much more severe at the live hog market level than at the wholesale level. The objectives of this research are 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 led to speculation that live hog demand has become more inelastic (Figure 1). In the most recent study that focused on farm level demand, Wohlgenant (1989) concluded the own-quantity farm-level hog price flexibility was negative 2.07. During the fourth quarter of 1998, pork production rose 9.9 percent above the fourth quarter of 1997. Applying Wohlgenant's results to 1998 data implies that a 20 to 21 percent live hog price decline was expected. Instead, Iowa- Southern Minnesota live hog prices actually declined 55 percent. Although competing meat supplies such as chicken and beef also increased during this time frame, the meat supply increases were not large enough to explain the large farm level price decline. Based upon non-parametric analysis, Plain and Grimes concluded that the own-quantity farm-level hog price flexibility changed from negative 2 prior to fall 1998 to negative 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 last two decades. Real processor margins have declined substantially over this period (USDA, ERS) and pork processing capacity utilization levels have increased (National Pork Producers Council). 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. Also, hog marketing contract usage has increased considerably, especially in the 1990s. Less than 10% of hogs marketed in 1980 were sold under some type of marketing agreement (Grimes). Surveys by Grimes and Lawrence and Grimes and Meyer in 1997 and 2000 indicated that the percentage of hogs marketed under some type of marketing agreement increased from 56% in 1997 to nearly 75% in 2000. The rise in hog contracting could be important. When packers are committed to purchasing a large proportion of their hogs under contract, it could, at times, result in more variable prices being paid for the remaining hogs sold in the open market.

At the same time live hog prices fell 55 percent below 1997s fourth quarter average, USDA's estimate of the pork cutout (wholesale) value declined just 32 percent. Although it's 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 appreciably in recent years. Reduced profitability in the pork processing sector led to many pork plant closures while other firms expanded to take advantage of economies of size.[1] For example, during 1997 pork plants in Council Bluffs, Iowa, Worthington, Indiana, and Moultrie, Georgia closed and IBP switched from a double 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 summer 1998 Thorn Apple Valley opted to close its Michigan slaughter facility which also reduced the industry's slaughter capacity, just before hog supplies increased sharply in fall 1998 (Luby). Data from NPPC indicate that estimated normal industry slaughter capacity between February 1998 and February 1999 declined from 417 thousand head per day to 381 thousand head per day. But, federally inspected hog slaughter data from November and December of 1998 indicates daily hog slaughter volume reached a peak of 415,548 thousand head per day, suggesting 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.

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[1]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.

If the hog price flexibility has increased (measured in absolute value), as hypothesized, it has important risk management implications for hog producers, processors, and retailers. Moreover, policy makers would also benefit from an improved understanding of hog price responsiveness 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 whether or not to expand slaughter and processing capacity. As a result, there is a need for improved measurement of the impacts that specific factors, such as pork production and pork plant capacity utilization, have on live hog prices. The results of this study can be used by swine industry decision makers and policy makers to make better decisions regarding the future of the swine industry.

Previous Research

Most previous studies analyzing 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 (1970) estimated an inverse live hog demand model. They specified a model where live hog price was hypothesized to be a function of hog production, cattle production, cold storage stocks lagged one 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 a one million pound increase in average daily production decreased live hog price by $0.769/cwt. and a one million pound increase in cold storage stocks, lagged one 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 because a low live hog price, which is highly correlated with the wholesale price, could induce storage speculation in anticipation of future higher prices. As a result, they estimated the effect a change in pork cold storage stocks had on live hog prices separately and found a one 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 last fifteen years that focused on farm level demand. He estimated the farm level flexibility for pork by regressing farm level pork quantity, an index of marketing costs and a retail demand shifter on farm level price and concluded that the own quantity farm level hog price flexibility was negative 2.07. However, Wohlgenant's study only included data through 1985. Given the structural change in the swine industry, an updated analysis of live hog demanded is warranted.

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 had processing capacity not been limiting, the fall 1998 average live hog price would have been \$3.84/cwt. to \$5.76/cwt. higher than the actual market price. Spivey, Saline, 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, Saline, and Anderson used three different proxies for a processing capacity constraint variable. The three different proxies were 1) a 0 or 1 binary variable when weekend slaughter exceeded 160,000 head for three consecutive weekends; 2) weekend slaughter; and 3) the ratio of weekend slaughter to slaughter during a 5-day work week.

Referring to the model using the ratio of weekend slaughter to slaughter during a 5-day work week, their results indicated that a one 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.

This research improves on these studies by analyzing a longer time period (1980 to 2000) and adding other explanatory variables to the live hog price demand model that are hypothesized to impact live hog price. 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. Building on Tomek's basic outline of a farm-level derived demand model and previous research by Brown; Spivey, Saline, and Anderson; and Wohlgenant, an inverse farm-level demand model for pork is specified in this study. The regression model is estimated using monthly data from 1981 to 2000. Variables are chosen so 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:

(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, 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 to December 2000). The dependent variable is the monthly average of the daily Iowa – Southern Minnesota Barrow & Gilt prices reported by USDA's Agricultural Marketing Service.

Pork production is decomposed 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. Dressed weight is included with monthly slaughter to capture the impact of changes in pork supplies 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 employed to estimate processors' capacity utilization. Studies by Barkley and Schroeder; and Ward, Koontz, Schroeder, and Barkley used proprietary cattle processing data to construct a capacity utilization variable. They employed the twelve-month lag of the ratio of cattle marketed during a period to plant capacity. However, no direct monthly measures of the pork industry's processing capacity are available over the entire study period which precludes use of this capacity measure. Schroeder and Mintert examined the effect of capacity utilization on pork margins using the ratio of the current month’s slaughter to the maximum monthly slaughter during the previous twelve months. Other studies specified capacity utilization as an "overflow" variable using Saturday slaughter as a proxy for overflow (e.g., Brown; Spivey, Saline, and Anderson). Generally, a typical hog processing plant operates two eight-hour kill shifts daily (Monday-Friday) followed by an eight-hour clean-up shift each day. Thus, to expand plant capacity a weekend "overflow" slaughter schedule is often employed.

Brown used a binary variable set equal to one when Saturday slaughter exceeded 160,000 head during three consecutive weeks. Similarly, Spivey, Saline, and Anderson used three separate variable specifications of Saturday slaughter as a proxy for utilization to capacity.

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.[2] 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.

In this study the processing capacity utilization ratio variable is defined as 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 to identify periods when facilities were both over and under-utilized.

Meatpacking plants minimize costs when operating at capacity (Ward). When slaughter is below capacity inputs are not used optimally resulting in higher costs per unit of output, and when slaughter is above normal capacity higher costs are also incurred resulting from things such as paying plant labor overtime wage rates. Thus, the relationship between the capacity utilization variable and live hog price is expected to be non-linear. However, specifying this variable appropriately is difficult because the pork processing industry has undergone considerable change over the study period. To account for possible changes in the impact of processing capacity utilization and hog slaughter on live hog prices over time, a Flexible Least Squares (FLS) estimator is used to determine the change in magnitude of the coefficient. The Flexible Least Squares estimator is discussed in more detail at the end of this section.

[2] IBP ended the Tuesday through Saturday work week during the middle of 1995 likely because labor costs of operating an irregular weekly schedule exceeded the costs of carrying hogs over the weekend (Grimes).

Wohlgenant found that an increase in processing and marketing costs (measured by an index of food marketing costs) caused live animal price to decline. This occurs because, in the short run, 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 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.[3] 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 increase.

The ratio of current month cold storage stocks to the one month lagged cold storage stocks was included in the inverse live hog demand model to determine the impact of cold storage stock movement on hog price. An increase in cold storage stocks indicates 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.

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[3]Following from Wohlgenant, a slight variation, i.e., the model in the current study was not specified in logarithmic form, of his notational form of the retail shift index ($Z_{pork,t}$) is used for the current study is:

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

where $e_{pork,j}$ 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, $e_{pork,y}$ is the income elasticity of pork, Y_t is per capita disposable income, and POP_t is population.

Seasonal dummy variables are specified as 0 or 1 binary variables where January is the default month. Seasonal dummy variables were included in the model to account for seasonality in hog production and consumer purchasing. The impact of the seasonal binary variable on price is expected to vary by month.

Evaluating a Change in Live Hog Demand

Model stability, i.e., parameter stability, is of interest when estimating models where there has been considerable structural change in the industry being investigated. For the current study, a change in live hog demand is analyzed and tested using parametric analysis. Model stability tests have typically been conducted using the CUSUM, CUSUM squared, or Log Ratio test statistics. However, these test statistics do not directly address the issue of a change in model parameters' magnitude, unless the data-set is partitioned and models re-estimated. To capture potential changes in the hog slaughter and hog weight price flexibilities, model stability is tested using the FLS estimator introduced by Tesfatsion and Veitch. FLS is used to graphically depict how the hog slaughter, hog weight, and processing capacity utilization price flexibility estimates change over time. This graphical representation is useful for making inferences that match a change in demand to a structural change.

To illustrate use of the FLS estimator consider a simplified inverse live hog demand model of the form:

$$P_t = \beta_t Q_{pork,t} + \varepsilon_t , \qquad (2)$$

where P_t is the live hog price at time t (t = 1, . . ., T), $Q_{pork,t}$ is the quantity demanded of live hogs at time t, and γ_t is an *iid* ~ N(0,1) random error vector. The coefficient on live hog demand ($\exists_t$) is a 1 x T vector of a time varying parameter estimate. The FLS estimator minimizes the loss function from equation 2 as:

(3) $$\sum_{t=1}^{T}(P_t - \beta_t Q_{pork,t})^2 + \lambda\sum_{t=1}^{T}(\beta_{t+1} - \beta_t)' D\ (\beta_{t+1} - \beta_t)\,.$$

where 8 is a chosen constant greater than zero, and D is a K x K fixed matrix chosen to account for the difference in scaling between regressors. The first term is the sum of squared errors. The second term is the sum of squared parameter variations over time. The matrix D is specified as a diagonal matrix with diagonal elements $d_{ii} = \sum_{t=1}^{T} x_{ti}^{2} / T$ (Tesfatsion and Veitch, and Lutkepohl).

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 & 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 & Gilt price changed from a 48% lean hog to a 52% lean hog. Therefore, for the April 1999 to December 2000 period an Iowa-Southern Minnesota barrow and gilt price was estimated 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 LMIC. Aggregated monthly head slaughter was converted to a 30-day month to account for the difference in slaughter days between months. The capacity utilization ratio ranged from 80 to 116 percent over the period and averaged 97 percent. Average slaughter weight is the average dressed hog weight which was collected from various issues of *Livestock Slaughter* (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). Pork cold storage stocks data was obtained from *Cold Storage* reports (USDA).

The retail shift index was computed using national monthly average retail prices for chicken and beef (LMIC). Monthly annualized U.S. population and monthly annualized U.S. disposable income were obtained from the St. Louis Federal Reserve Bank web site. Per capita income was computed by dividing U.S. disposable income by U.S. population.

Results

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.

First-differenced Ordinary Least Squares (OLS) model results are reported in table 3. The model explained 56 percent of the variation in the Iowa-Southern Minnesota live hog cash price over the March 1981 to December 2000 period. P-values are listed to indicate the significance level of the estimated coefficients. Monthly slaughter, average dressed weight, processing capacity utilization, cold storage stocks, and several seasonal binary variables had a significant impact on live hog prices. Price 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 the average live hog slaughter price flexibility was –0.288. At first glance, this value appears to be significantly smaller than reported by other researchers. However, in this study pork production was decomposed into head slaughtered and carcass weight. Thus, the impact of both hog slaughter and dressed weight need to be examined to identify the estimated impact of a change in pork production on hog price.

As expected, increases in dressed weights also had a negative and statistically significant impact on price. A one-pound increase in dressed weight led to a $1.02/cwt. decline in live hog price. The dressed weight flexibility indicates a one percent increase in average dressed weight was associated with a 2.90 percent decline in live hog price. So, model results suggest that changes in hog dressed weights have a larger impact on live hog prices than changes in hog slaughter.

The capacity utilization variable also had a negative sign and was statistically significant. A one-percentage point increase in the capacity utilization ratio is associated with a live hog price decline of $0.28/cwt. The capacity utilization flexibility, calculated at the mean, was –0.42.

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 one-percentage point increase in the pork cold storage stock ratio was associated with a live hog cash price decline of $0.11/cwt. The cold storage flexibility, computed at the mean, was –0.175.

The processing cost variable did not have a statistically significant impact on live hog price. Changes in the processing cost index occurred slowly over the period of this study, indicating that the index captured long-run cost changes in the industry. Thus, the processing cost index likely did not capture short-run changes in processor costs associated with changes in capacity utilization. Instead, these short-run cost changes were more likely captured by the processing capacity utilization variable. Consequently, these results indicate that long-run changes in processor costs had no significant impact on live hog prices, but they do not necessarily indicate that short-run variation in processor costs had no impact on hog prices.

Finally, the coefficient on the retail demand shift index was positive and statistically significant.[4] This result was not as expected, and it is difficult to explain this result. Using annual data Wohlgenant found that a one-percentage point increase in the demand shift index increased the farm level pork price by two percent. Differences between the current study and Wohlgenant’s study include the use the monthly data, a different time period, and a more appropriately specified model.

[4] To interpret the retail demand shift index coefficient, it must be decomposed following Wohlgenant's procedures. The retail demand shift variable was included primarily for proper model specification. A more complete interpretation of this variable is omitted because the focus of this study does not directly pertain to the decomposition of this coefficient into cross-price and income effects.

Time Path of Live Hog Flexibility

Flexible Least Squares was used to develop a graphical representation of the time path of the live hog price flexibility estimate over time. Individual FLS parameter estimates are of little value. The real value of the FLS estimator is that it provides an opportunity to observe the change in magnitude of the coefficients over the study period 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. Figure 2 indicates the plot of the residual series' for the OLS and the FLS estimator. Clearly, the FLS estimator provides a more accurate in-sample forecast than OLS. This is important because it is difficult to appropriately specify the live hog demand model to capture the structural change and due to limited observations over a short time period.

The time paths of the own flexibility and carcass weight flexibility estimates, for 8=0.001, are graphed in Figures 3 and 4, respectively. As can be observed from Figure 3, the hog slaughter flexibility varied substantially over the February 1981 to January 1994 period. In late 1998 the hog slaughter flexibility increased (in absolute value) significantly. The pork carcass weight flexibility time path increased in absolute value from the early to the late 1990s and the variability of the flexibility also increased. Based solely on the slaughter own-flexibility it would be difficult to assert that the live hog demand flexibility has increased in absolute value over time. However, when combined with the carcass weight impact it is clear that the hog production flexibility has increased in magnitude and most of this increase can be attributed to hog weights. 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 fall 1994 (Figure 5). The FLS estimator indicates the magnitude of the capacity utilization parameter increased 400% in the fall of 1998. Also, since 1994 the capacity utilization flexibility has become more variable. The period 1994 through December 2000 has seen considerable entry, exit, and closing of processing facilities by hog processors, leading to great price responsiveness. This trend may suggest further information is required to assess the impact of capacity utilization on live hog prices.

Figure 6 graphically depicts the time path of the cold storage coefficient over the period March 1981 to December 2000. Other than one small deviation in the fall of 1998, the pork cold storage flexibility has oscillated around zero. It may be that the pork carcass weight 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's useful to examine the impact several factors such as increases in average daily non-holiday hog slaughter, dressed weights, pork processors capacity utilization and pork cold storage stocks had on live hog prices during fall 1998. To quantify these impacts, tables 4 and 5 were constructed to provide a simulation using the OLS coefficients and FLS coefficients estimated for the fourth quarter of 1998. The impact of a change in one of the explanatory variables on the 1998 live hog price was computed relative to the average, the third quarter of 1998, and the fourth quarter of 1997. These periods were used to help explain impacts associated with changes in variables within year, across year, and over the entire time period.

Because of possible structural changes, computing impacts relative to an average over a long time period may not accurately reflect the impact on live hog price.

The reported average nominal 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 (USDA). Using the OLS parameter estimates the impact on live hog price varied, depending on the base period used to compute the impact. Slaughter weight had the largest impact followed by hog slaughter, capacity utilization, and cold storage. The total impact from these four variables was $17.45/cwt. when compared to the average, $9.64/cwt. when compared to third quarter 1998, and $5.25/cwt. when compared to the fourth quarter of 1997. These values are substantially different than the actual price differences observed during 1998s fourth quarter.

Using the FLS coefficients (Table 5) the impact varied based on the base period used to compute price changes and the ranking of the variables changed. Hog slaughter had the largest impact followed by slaughter weight, capacity utilization and cold storage. The estimated hog slaughter impact was nearly six times larger in the simulation when the FLS, instead of the OLS, coefficients were used. Moreover, the capacity utilization impact was approximately twice as large in the FLS vs. the OLS simulation. The estimated impact of changes in cold storage stocks on live hog prices was smaller in the FLS simulation vs. the OLS simulation. The total impact from these four variables was $37.02/cwt. when compared to the average, $17.87/cwt. when compared to third quarter 1998, and $13.40/cwt. when compared to the fourth quarter of 1997. Results from the FLS simulation for fourth quarter 1998 appear to be overstated when compared to the long-term period, but were actually smaller than actual price changes observed from fall 1997 to fall 1998.

Both simulations indicate that number of head slaughtered and slaughter weight played a significant role in the low prices observed during the fall of 1998. Capacity utilization was also a factor, however, it did not play as large a role in the fall 1998 price decline as slaughter and slaughter weight.

Conclusions

Using monthly data from 1981 through 2000, two inverse live hog demand models, employing two alternative econometric techniques, were estimated to investigate claims that the live hog own-quantity price flexibility has increased in magnitude (absolute value) and whether processing capacity utilization affects live hog prices. Several conclusions can be drawn based upon these results. First, when employed in a late 1990s simulation, estimates from the Flexible Least Squares model better explain observed price changes than estimates from the OLS model, which implies that structural change did occur and price flexibilities have changed over time. Second, results indicate live hog demand has become more inelastic with respect to dressed hog weight and hog slaughter since the mid-1990s. As a result, modest changes in hog slaughter and dressed weights lead to relatively larger changes in hog prices than just a decade ago. Third, this study demonstrates conclusively that high capacity utilization in the pork processing sector contributed to increased live hog price variability. Results reveal that when processing plants are operated at high capacity utilization rates it has a negative effect on prices paid for live hogs compared to periods when capacity utilization rates are low. Moreover, since early 1994 the capacity utilization price flexibility has increased in both magnitude and variability. This impact was especially noticeable in the fall of 1998 when slaughter increased to unprecedented levels during November and December.

Processing capacity may again become a critical issue in the future. Figure 7 is used to illustrate the change over time in processor capacity utilization. Since the early 1980s capacity utilization has trended toward 100%. There has been considerable change regarding the operation of most pork processing facilities over the last 20 years. During the 1980s packers typically operated an 8-hour single-shift 5-day week, where packers could increase capacity 50% by moving to a 10-hour day and processing animals on Saturday. However, packers have shifted away from the traditional slaughter week to capture economies of size and lower their costs. As a result, most pork packing facilities now operate two processing shifts per day and a third shift is used for cleanup. Thus, most packing facilities can only increase capacity by increasing weekend operations. This reduction in processors capacity flexibility likely explains why capacity utilization rates now have a larger and more variable effect on live hog prices than prior to the mid-1990s. For instance, the Marshall, Missouri, Excel plant recently announced plans to discontinue hog slaughter by August 1, 2001. What impact will 8,000 head capacity have on hog prices immediately and during the fourth quarter when capacity is typically exhausted.

The impact of changing structure and operational techniques in the meat processing sector on prices received by livestock producers is likely to be of considerable interest in the future. As a result, some consideration should be given to development of an alternative data series which provides a more accurate measure of the industry's capacity utilization. And, given that the structure of the beef processing sector has also been changing, future research could focus on factors affecting live cattle prices with particular attention paid to the impact of changing structure in the processing sector.

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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 non-holiday slaughter during month *t*, converted to a 30-day month.	(-)
Average dressed weight_t	Average live hog dressed weight during month *t*	(-)
Processing utilization to capacity ratio_t	Ratio of current month (*t*) non-holiday average daily slaughter to maximum month average daily slaughter during the same quarter in the previous year.	(-)
Index of marketing costs_t	Simple average of fcost of 500 KWH of electricity and wage rate for packing plant employees during 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.	(+)
Cold storage stocks_t	Ratio of Pork cold storage stocks reported at the end of the month during month *t* to Pork cold storage stocks in month *t*-1.	(-)
Seasonality_t	Separate 0 or 1 binary variables for month (*default* = December)	(?)

Table 2. Summary Statistics of Variables used in Estimation of Live Hog Inverse Demand Model Specified in Equation 1 (Monthly data between March 1981 to December 2000).

Variable	Avg.	S.D.	Min	Max
Nominal Iowa - Southern Minnesota barrow & gilt cash price ($/cwt.)	45.98	8.21	13.92	63.44
Slaughter during month *t* (000 head)	8451.70	835.51	6503.70	10380
Average monthly dressed weight during month *t* (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 index	1.18	0.534	0.195	3.735
Cold storage stocks (million pounds)	333.95	86.89	175.06	595.23
Cold Storage Index	100.45	8.85	78.11	131.79

Note: Number of observations used to compute summary statistics was 238.

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	p-value	Flexibility at the Mean
Average daily non-holiday slaughter (000 head)	-0.002***	0.005	-0.288
Dressed weight (lbs)	-1.021***	0.000	-2.904
Processing capacity utilization ratio (index)	-0.275***	0.001	-0.415
Cold storage stocks (index)	-0.111***	0.000	-0.175
Retail demand shift index (index)	-1.127***	0.007	-0.020
Index of processing costs (index)	1.036	0.130	n/a
Seasonal shift variables (*default* = January)			
February	-3.548***	0.002	
March	-3.309***	0.004	
April	-0.465	0.671	
May	0.685	0.549	
June	-2.739**	0.042	
July	-5.451***	0.000	
August	-2.231*	0.083	
September	-1.829	0.118	
October	-0.616	0.681	
November	-3.681***	0.005	
December	-3.301***	0.006	
Intercept	3.516***	0.000	
F-statistic	301.153***	0.000	
R – squared	0.559		
Mean of the Dependent Variable ($/cwt., 2000=100)	63.753		
No. of observations	238		
rho	0.143		

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

Table 4. Economic Impact of Fourth Quarter 1998 Live Hog Demand Factors Using Coefficients from Table 3[a]

Relative to Fourth Quarter 1998	Per Capita Own-quantity Slaughter (000)	Slaughter Weight (lbs.)	Cap./ Util. (index)	Cold storage (index)	Own-quantity impact	Slaughter Weight	Capacity/ utilization impact	Cold storage impact
	Observed Levels in Relative Period				Impact on Live Hog Price $/cwt.			
Relative to Average	8445.46	181.31	96.33	100.48	**-3.60**	**-10.57**	**-2.45**	**-0.83**
Relative to Third Quarter 1998	9344.50	185.67	102.88	96.96	**-1.64**	**-6.12**	**-0.65**	**-1.23**
Relative to Fourth Quarter 1997	9368.58	190.33	100.10	100.06	**-1.59**	**-1.36**	**-1.42**	**-0.88**
					Levels observed in Fourth Quarter 1998			
					10099.24	191.67	105.26	108

a. For example, the ($3.60)/cwt. for the own-quantity impact for "relative to the average" is computed by multiplying the own-quantity coefficient (-0.002) by the difference between the average slaughter over the entire time period (8445.46) and the average slaughter during the fourth quarter of 1998 (10,099.24)

Table 5. Economic Impact of Fourth Quarter 1998 Live Hog Demand Factors Using the Average Coefficient for the Fourth Quarter 1998 from Flexible Least Squares Estimator[a]

Relative to Fourth Quarter 1998	Per Capita Own-quantity Slaughter (000)	Slaughter Weight (lbs.)	Cap./ Util. (index)	Cold storage (index)	Own-quantity impact	Slaughter Weight	Capacity/ utilization impact	Cold storage impact
	Observed Levels in Relative Period				Impact on Live Hog Price $/cwt.			
Relative to Average	8445.46	181.31	96.33	100.48	**-19.55**	**-12.28**	**-4.81**	**-0.38**
Relative to Third Quarter 1998	9344.50	185.67	102.88	96.96	**-8.92**	**-7.11**	**-1.28**	**-0.56**
Relative to Fourth Quarter 1997	9368.58	190.33	100.10	100.06	**-8.64**	**-1.58**	**-2.78**	**-0.40**
					Levels observed in Fourth Quarter 1998			
					10099.24	191.67	105.26	108

a. See note below Table 4 for how values are computed.

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

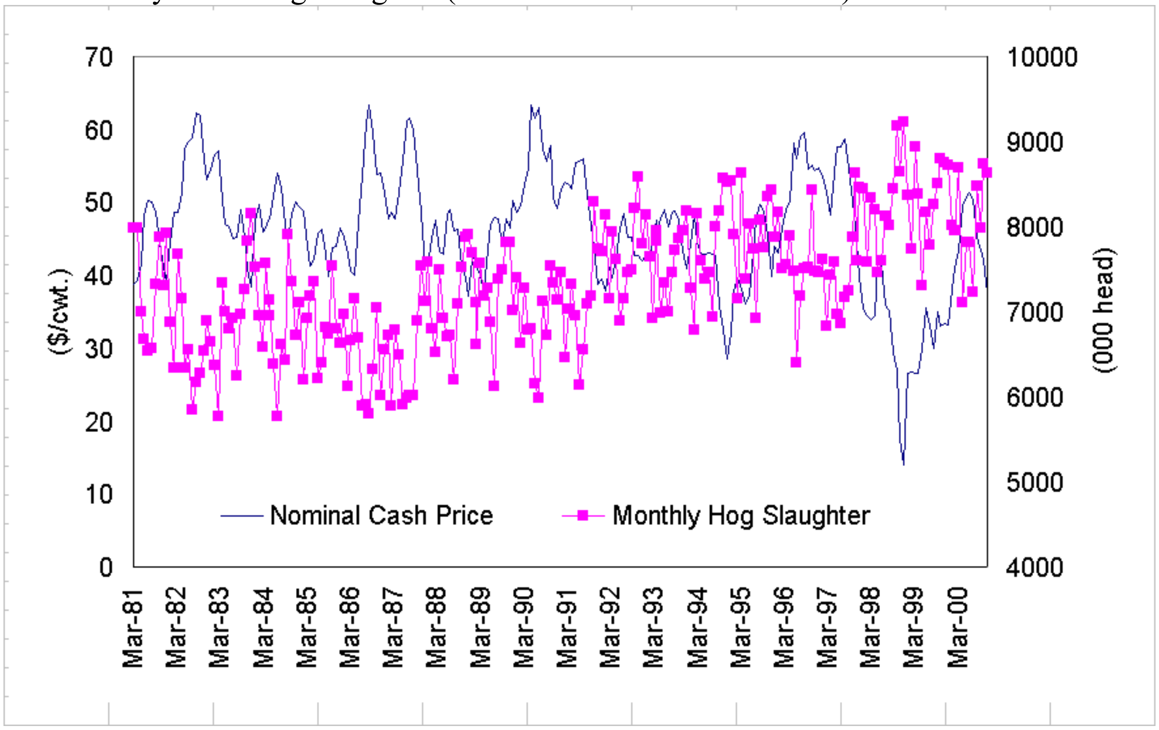

Figure 2. Plot of residuals from Live Hog Demand Model using Ordinary Least Squares and Flexible Least Squares.

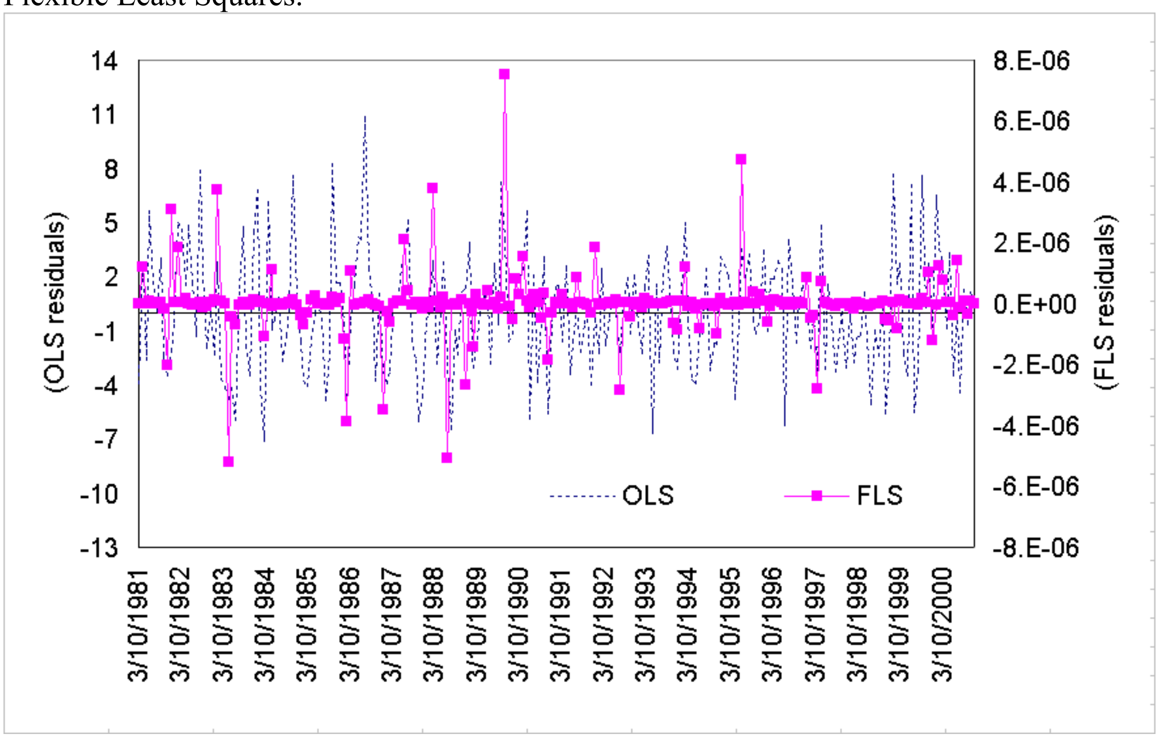

Figure 3. Time Path of the Point Slaughter Own-Flexibility Coefficient for 8=0.001, March 1981 - December 2000.

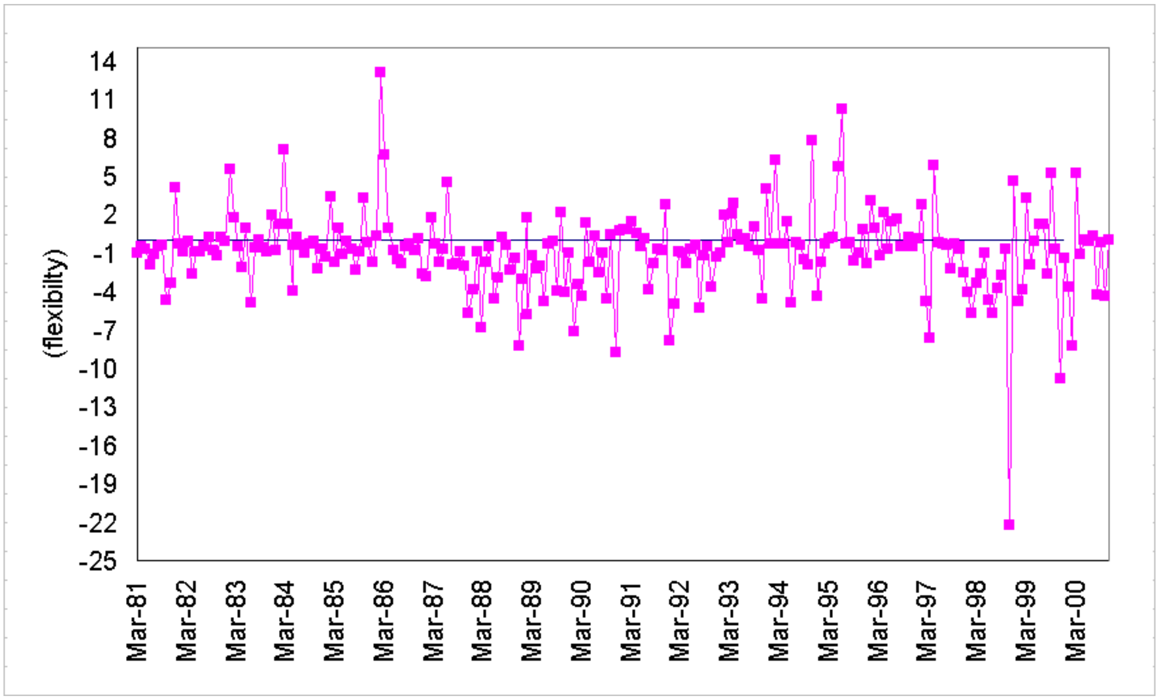

Figure 4. Time Path of the Pork Carcass Weight Coefficient for 8=0.001, March 1981 - December 2000.

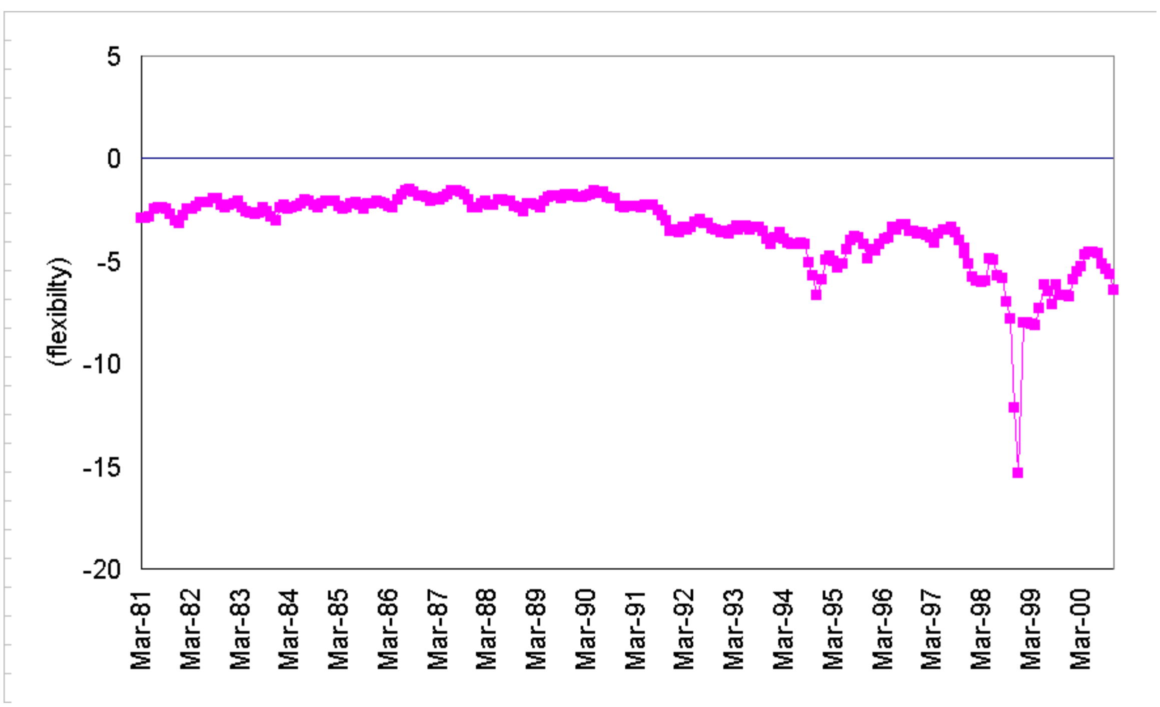

Figure 5. Time Path of the Capacity-Utilization Price Flexibility Coefficient for 8=0.001, March 1981 - December 2000.

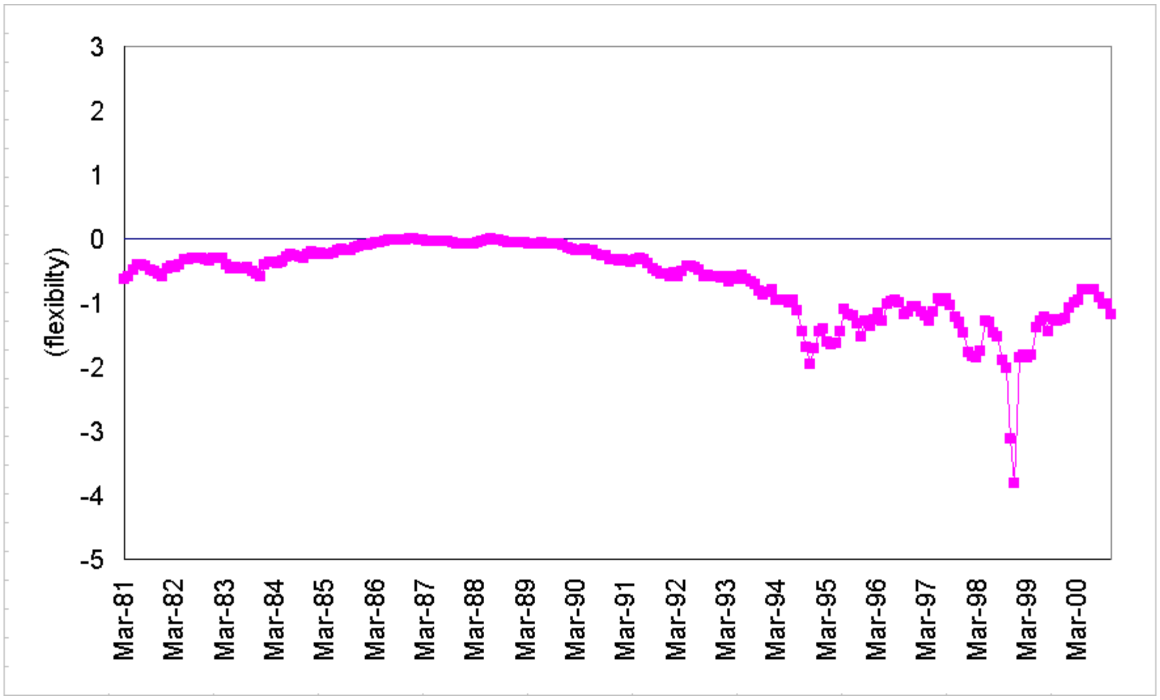

Figure 6. Time Path of the Pork Cold Storage Coefficient for 8=0.001, March 1981 - December 2000.

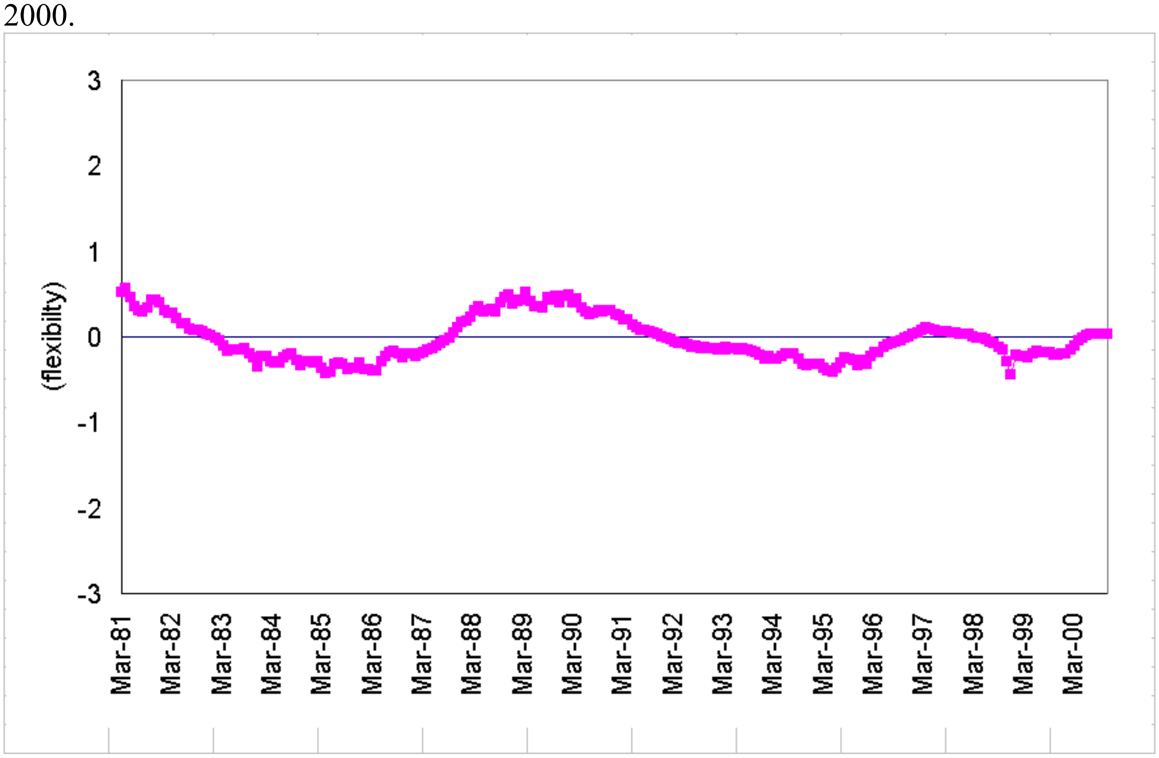

Figure 7. Processing Utilization to Capacity Specified as the Ratio of the Current Months Average Daily Slaughter to Maximum Monthly Average Daily Slaughter During the same Quarter Twelve Months Prior (March 1981- December 2000).