An Empirical Analysis of the Demand for Wholesale Pork Primals: Seasonality and Structural Change

by:

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A set of inverse wholesale pork primal demand models were estimated to estimate wholesale pork primal own-quantity flexibility's, to determine seasonal price fluctuations, and to examine whether the flexibility's have changed in absolute magnitude over time. Results of this analysis indicate that there is the own-quantity flexibility for some primals differences by season with in the year. Additionally, it was determined that the own-quantity flexibility increased in magnitude (absolute value) over time for some of the primal cuts evaluated here. However, for Hams and Boston Butt the own-flexibility was either unchanged or increased over the period analyzed. Increased cold storage stocks for these primals may have been used to offset the price decline of 1998.

Keywords: Wholesale Pork Primals, Structural Change, Seasonality

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The agricultural industry is rapidly changing from an industry driven by producers to an industry organized around meeting end user demand and processor demands. Organizational change in the agricultural industry has been no more apparent than in the hog industry over the past ten years. As evidence, between 1994 and 2000 the level of vertical coordination in the hog industry increased from 6.4% to 24% (Grimes and Meyer). The growth in vertical coordination can be partially attributed to firms beyond the farmgate in the marketing chain sourcing animals of known quality to meet specific end use needs and processing cost savings. Additionally, there is considerable interest by swine producers to organize processing cooperatives to add value to hogs beyond the farmgate. As more emphasis is placed on capturing value along the pork marketing chain, there are greater pricing challenges to the swine industry. The pork wholesale market is one level in the pork marketing chain where considerable price risk exists. For instance, over the past ten years the wholesale nominal price of Pork Loin ranged between \$75/cwt. and \$145/cwt. with a coefficient of variation of 0.12, and the wholesale nominal price of Pork Belly ranged between \$25/cwt. and \$65/cwt. with a coefficient of variation of 0.32. However, no previous analysis has analyzed factors affecting wholesale pork primal price variability. The objective of this research is to determine factors affecting wholesale pork primal prices, examine whether the own-quantity flexibility changes within the year, and determine whether own-quantity flexibility has changed over time for the pork wholesale primals Loin, Rib, Butt, Ham, Belly, and Picnic.[1]

[1] These wholesale primals account for over 55% of live weight carcass.

During Fall 1998, farm level hog prices dropped to near fifty-year lows. However, even though the live hog price declined 69% during the six months leading up to January 1999 the aggregate wholesale price declined only 32% and the aggregate retail price declined only 2% (LMIC). This relatively small reduction in wholesale and retail price prompted pork producers to place blame on processors and retailers for the low farm prices. Some economists openly stated that they believed the elasticity of demand for retail pork products had become more inelastic over time (Plain and Grimes). Statements regarding the change in the wholesale and retail demand elasticity over time were not based on empirical analysis; yet, the implications of these statements are important. For one, a more inelastic demand for pork products implies specializing pork at the retail level has less impact on quantity demanded today than in the past. For this analysis, the focus is on wholesale pork primal prices because wholesale prices are not subject to mark-downs, i.e., USDA reported retail prices do not include mark-downs, as in the retail sector. Also, the demand for wholesale pork primals is determined by the derived demand for retail products. No previous study has empirically analyzed changes in the demand for individual pork primals over time; therefore, an empirical analysis is needed to collaborate or refute previous claims and analyze whether the change in price from a one percent change in quantity changes within the year.

As the structure of the pork industry undergoes change and pork continues to compete for meat market share, understanding price linkages further up the marketing chain are important. The changing structure of the pork industry may have caused a change in the pricing method of pork primals. For instance, Parcell, Mintert, and Plain found that the own-quantity live hog demand flexibility was eight times larger in 1998 than observed historically. In addition, they found that processor utilization to capacity was a driving force in brining about this change. Could have similar structural change occurred at the wholesale level?

Consumers are becoming progressively more discriminating in making their purchasing patters as the economy thrives and living healthy becomes a high priority. For instance, the high protein – low carbohydrate diet has increased in popularity over the previous. One suggestion for this diet is the consumption of bacon. Thus, demand for bacon may have changed due to consumer attitudes regarding red meat. Also, processors are continually developing new products to meet end user demand. Understanding the seasonal demand for specific products would be of use in developing marketing strategies for the new products.

No previous research has explicitly analyzed the demand for wholesale pork primals, and some swine industry persons have claimed that the percentage change in price from a corresponding one percent change in quantity demanded within the marketing chain has increased in absolute value over time. To substantiate these claims, the factors affecting wholesale primal cut prices and tests of structural change in own-cut flexibility need to be analyzed. As the pork industry faces further significant restructuring, most recently the merger between Murphy Family Farms and Smithfield, many questions need to be answered about the effectiveness of current programs and strategies that were based on a different industry structure and consumers. Additionally, the National Pork Producer Council has prioritized the development of producer owned hog processing cooperatives as way for producers to add value and bypass the traditional processing firms. Examining factors affecting wholesale pork primal prices, examining whether the flexibility varies across season, and determining to what extent the elasticity of demand for pork has changed over time will help swine industry persons make better management and marketing decisions.

Previous Research

Capps et al. empirically analyzed factors affecting changes in monthly wholesale beef primal prices for the 1980 to 1990 period. Capps et al. regressed the wholesale price of primal cut j on lagged own-price; per capita own-quantity for cut j; per capita quantity of beef other than cut j, pork, and poultry; a marketing cost index; and monthly dummy variables. Capps et al. found the own-quantity flexibility to differ between primals; there was relatively no cross-flexibility effect from changes in the level of other beef; the marketing cost index was generally positive; and they found mixed results for cross-flexibility estimates of pork and chicken. Also, they found considerable seasonal variation between different beef primals.

Parcell and Pierce analyzed the demand for broiler and turkey wholesale primals. Assuming fixed proportions between the farm level and wholesale level, they estimated inverse demand models using Seemingly Unrelated Regression (SUR) using monthly data between 1988 and 1998. Parcell and Pierce concluded there were considerable differences in the seasonality associated with different broiler and turkey primals and the own-quantity flexibility differed between primals.

Hahn and Green empirically tested the assumption of fixed proportions in demand studies for meats between the wholesale and retail level. To empirically test this hypothesis they estimated inverse aggregate wholesale beef, pork, and chicken demand models. They specified the price of the wholesale product as a function of own retail price, a double-differenced own wholesale price, pork quantity, beef quantity, chicken quantity, CPI effect, and wage effect. Hahn and Green estimated an aggregate own-quantity flexibility for pork of -0.0621; a positive and negative cross-price elasticity for beef and chicken, respectively; neither CPI or wage effect was statistically significant; and they failed to reject the hypothesis of fixed proportions between the wholesale and retail levels.

Lusk et al. estimated wholesale models for Choice and Select beef. They specified the demand models as wholesale quantity of Choice or Select beef as a function of the own wholesale prices, wholesale prices of competing meats, quarterly intercept shift variables and a time trend variable. Lusk et al. also estimated models with interaction terms between the wholesale prices and quarter intercept variables. In doing so they determined how own- and cross-elasticity estimates change throughout the year, and they estimated how the cross-price demand elasticities between Choice and Select beef change throughout the year. Lusk et. al. found that the quantity demanded of Choice and Select beef had increased over time; they found a seasonal component to wholesale quantity demanded; and they found that the own- and cross-price elasticities varied between periods within the year and that the Select beef own-price elasticity was nearly double the Choice beef own-price elasticity. For Choice and Select beef they estimated that the own-price elasticity was the largest, in absolute value, during the first quarter of the year. During the second and third quarter both the Choice and Select own-price elasticity was inelastic. They estimated the cross-price elasticities between Choice and Select beef to be 0.192 for Choice and 0.280 for Select.

Conceptual Model

Wohlgenant analyzed farm and retail level demand for various commodities, including hogs and pork. He used a retail shift index to account for changes in the demand for substitutes and income at the consumer level. Wohlgenant also used per capita consumption and a marketing cost index to explain variation in farm and retail level hog and pork prices. The conceptual model used for this study is based on the Wohlgenant model with the elimination of the farm level and addition of the wholesale level for pork only. Because this research focuses on the wholesale level, the empirical analysis is carried out on only the wholesale level, however, the retail sector is included in the structural model to motivate the specification of the wholesale empirical model. The structural model used for this analysis is of the form:

(1)	$Q_w^d = \sum D_w^{\,i}(P_w, P_r, C_w)$	(wholesale demand)
(2)	Q_w^s, predetermined	(wholesale supply)
(3)	$Q_r^d = D_r(P_r, Z)$	(retail demand)
(4)	$Q_r^s = \sum S_r^i(P_r, P_w, C_r)$	(retail supply)
(5)	$Q_w^d = Q_w^s = Q_w$	(wholesale marketing clearing)
(6)	$Q_r^d = Q_r^s = Q_r$	(retail marketing clearing)

where Q_w^d is the quantity of the wholesale product demanded, P_w is the wholesale level price, Pr is the retail level price, C_w is the cost of marketing wholesale products, Q_w^s is the predetermined supply of the wholesale product, Q_r^d is the quantity demanded at the retail level, Z is an exogenous retail demand shifter, Q_r^s is the quantity of the retail product supplied, and C_r is the cost of marketing retail products.

Equations (5) and (6) are the market clearing conditions. Using these identities the structural system outlined in equations (1) through (6) can be rewritten as a two-equation system:

(7a) $Q_w - \sum D_w^i(P_w, P_r, C_w) = 0,$

(7b) $\sum S_r^i(P_r, P_w, C_r) - D_r(P_r, Z) = 0,$

Following Wohlgenant, equations (7a) and (7b) are total differentiated, expressed in elasticity form, and equations are solved for $dlnP_r$ and $dlnP_w$, respectively. This yields the following equations:

(8a) $dlnP_r = E_{rz} \bullet dlnZ + E_{rc} \bullet dlnC + E_{rw} \bullet dlnQ_w$

(8b) $dlnP_w = E_{wz} \bullet dlnZ + E_{wc} \bullet dlnC + E_{ww} \bullet dlnQ_w$

where,

(9a) $E_{rz} = -\Theta^d_{ww}\Theta^d_{rz}/K,$

(9b) $E_{rc} = (\Theta^d_{ww}\Theta^s_{rc} - \Theta^s_{rw}\Theta^d_{wc}) / K,$

(9c) $E_{rw} = \Theta^s_{rw}/K,$

(9d) $E_{wz} = -\Theta^d_{wr}\Theta^d_{rz}/K,$

(9e) $E_{wc} = [\Theta^d_{wr}\Theta^s_{rc} - (\Theta^s_{rr} - \Theta^d_{rr})\Theta^d_{wc}] / K,$

(9f) $E_{ww} = (\Theta^s_{rr} - \Theta^d_{rr}) / K,$

(9g) $K = -(-\Theta^s_{rr} - \Theta^d_{rr})\Theta^d_{ww} + \Theta^s_{rw}\Theta^d_{wr},$

Variables used in equations (9a) through (9g) [with expected sign in bracket] are Θ^d_{ww} is the elasticity of wholesale-level demand with respect to wholesale price [–], Θ^d_{rz} is the elasticity of retail level demand with respect to the retail demand shifter [+], Θ^s_{rc} is the elasticity of retail supply with respect to marketing cost [?], Θ^s_{rw} is the elasticity of retail supply with respect to wholesale price [–, assuming the wholesale product is a normal good], Θ^d_{wc} is the elasticity of wholesale demand with respect to marketing cost [?], Θ^d_{wr} is the elasticity of wholesale demand with respect to retail price [+], Θ^{s}_{rr} is the elasticity of retail supply with respect to retail price [+], and Θ^{d}_{rr} is the elasticity of retail demand with respect to retail price [–].

Using the signs assigned to the elasticities listed in equations (9a) through (9g), it is possible to sign the parameters of equations (8a) and (8b). Because K is negative, E_{rz} is negative, E_{rw} is positive, E_{wz} is positive, E_{ww} is negative, and E_{rc} and E_{wc} can't be assigned signs because the signs of Θ^{s}_{rc} and Θ^{d}_{wc} are ambiguous.

Empirical Model

Regression models are estimated for each wholesale pork primal price j using monthly data over the 1989 to 1999 period. The wholesale price of primal price is specified as a function of own quantity; an index of marketing costs and a retail demand shift index, as defined in Wohlgenant; a dummy variable indicating a price specification change; and seasonal intercept shift variables. Models are specified as first differences of the natural logarithm of the variable. The logarithmic functional form was chosen so that parameter estimates are elasticities. First-differences were used because the price series were tested for the presence of a unit root using the Augmented Dickey-Fuller unit root test statistic. The results section lists the Dickey-Fuller unit root test statistics. The first-difference logarithmic inverse demand model for wholesale pork primal price *j* (*j* = Boston Butt, Picnic, Ham, Loin, Belly, Rib):

$$\text{(10)} \quad \Delta \ln P_{jt} = E_{jz} \bullet \Delta \ln Z_t + E_{jc} \bullet \Delta \ln C_t + E_{jQ} \bullet \Delta \ln Q_{jt} + \textstyle\sum_k E_{jk} \bullet QUART_k + E_{jDUM} \bullet DUM + E_j + \Omega_{jt}$$

Variable definitions and summary statistics of data used to estimate equation (10) are listed in Table 1. Simply, equation (10) states that variability in monthly wholesale pork primal price is a function of a retail demand shift index (Z), a marketing cost index (C), own-quantity of primal cut *j* (Q), a 0 or 1 binary seasonal variable (QUART), a 0 or 1 binary variable to represent the change in price quote effective January 1998 (DUM), and a constant (E). Ω_{wit} is a vector of *iid* ~ N(0,1) random errors. The dummy variable for the change in price quote was set equal to 1 for January 1998 and 0 otherwise.

For the retail demand shifter, Wohlgenant suggested totally differentiating the retail demand for the *j*th primal and allowing the retail demand shift variable to equal the residual of the left hand side ($dlnQ_j$) less the own-price elasticity multiplied by the differentiated logarithm of the own-price ($e_{jj} \bullet dlnP_j$). Thus, following from Wohlgenant the retail demand shifter specified for this study is of the form:

$$(11) \qquad \Delta lnZ_t = \sum_l e_{jl} \bullet \Delta lnP_{rlt} + e_{jy} \bullet \Delta lnY_t + \Delta lnPOP_t \,,$$

where e_{jl} is the cross-price elasticity of competing meat *l*, e_{jy} is the income elasticity of meat j (pork here), P_{rlt} is the retail price (r) of meat l and time t, Y_t is per capita income at time t, and POP_t is the resident population at time t.

To determine whether the own-quantity flexibility varies seasonally a slight modification was made to the model specified in equation (10). An interaction term between own-quantity variable and the quarterly shift variable was constructed. This allows for the estimation of quarterly own-quantity flexibility estimates for each wholesale primal cut *j*. The specification of this model is:

$$(12) \quad \Delta lnP_{jt} = E_{jz} \bullet \Delta lnZ_t + E_{jc} \bullet \Delta lnC_t + \sum_k E_{jkQ} \bullet \Delta lnQ_{jt} \bullet QUART_k + \sum_k E_{jk} \bullet QUART_k + E_{jDUM} \bullet DUM + E_w + \Omega_{jt}$$

The data used and variables definitions for equation (12) are the same as for data and variable definitions for equation (10).

Evaluating a Change in Wholesale Primal Demand

The test of model stability, i.e., parameter stability, used for this analysis is the Flexible Least Squares (FLS) estimator. Tesfatsion and Veitch provide an extension explanation of the FLS estimator. The FLS estimator is briefly explained here. FLS is used to graphically depict how the wholesale own-quantity flexibility changes over time. The graphical representation can be used to make inferences regarding potential structural changes that may have caused the own-quantity flexibility estimate to change over time.

The FLS estimator is described briefly here. Assume a simple aggregate inverse wholesale pork demand model:

$$P_t = \beta_t Q_{pork} + \varepsilon_t , \tag{13}$$

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

$$\sum_{t=1}^{T} (P_t - \beta_t Q_{pork,t}) + \lambda \sum_{t=1}^{T} (\beta_{t+1} - \beta_t) \text{ D } (\beta_{t+1} - \beta_t) . \tag{14}$$

where λ is a constant greater than zero, and D is a K x K matrix selected 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). Time varying coefficients are obtained from by estimating equation (10) for different λ values by employing the FLS command in Shazam 8.0.

Data

Averages and standard deviations of data used in the estimation of inverse wholesale pork primal demand models are listed in table 1. All series are monthly data from February 1989 through December 1999. The monthly wholesale primal prices for Pork Loin, Pork Rib, Boston Butt, Ham, Pork Belly, and Boneless Picnic were obtained from LMIC.

Average daily per capita pork consumption for the different meat types was calculated as pork production adjusted for pork imports, exports, and the between month change in cold storage stocks for the specific wholesale pork primal. Production, import, and export data were obtained from LMIC. Individual pork primal cold storage stocks data was obtained from USDA *Cold Storage* reports. For Pork Rib, cold storage values were not kept during the entire time period. Thus, constant proportions were assumed between pork production and the quantity of Pork Rib in the wholesale marketplace. Average daily pork consumption between the six different wholesale primals only varies by the difference in beginning and ending cold storage stocks within the month.

Previous research has either assumed fixed proportions between the farm and wholesale level (Lusk et al. and Parcell and Pierce) or suggested fixed proportions as a result of estimated models (Capps et al.). Previous research analyzing the fixed proportions hypothesis between levels in the meat marketing chain are mixed, e.g., Hahn and Green; Wohlgenant, Wohlgenant and Haidacher. The current study uses a combination of the fixed proportion assumption (aggregate pork production) and variable proportion assumption (change in cold storage stocks for individual pork primals) to formulate a daily per capita own-quantity demand variable.

The food marketing cost index was obtained from various issues of *Agricultural Outlook*. The retail shift index was computed using national monthly average retail prices for pork chicken, ground beef, and steak (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.

Price and index data used for this analysis are nominal values. Following research by Peterson and Tomek that suggested deflating may cause autocorrelation and introduce a deterministic trend in the error vector, nominal values were used so to not introduce noise into the model.

Results

Each wholesale primal price, after being transformed by the natural logarithm operator, was tested for stationarity using the augmented Dickey-Fuller test for the presence of a unit root, and the lag order was determined by minimizing the Akaike Information Criteria. The Dickey-Fuller test statistic was –1.61 for Pork Loin, -1.89 for Boston Butt, -1.55 for Pork Rib, -1.05 for Ham, -2.01 for Pork Belly, -2.82 for Boneless Picnic, and the 10% critical value was -2.57. Therefore, the null-hypothesis of a unit root could not be rejected for five of the six price series. Data were first differenced, and the first differenced price series were found to be stationary for all of the primal price series. The number of observations used in the estimation was 131. Because wholesalers and retailers trade in all wholesale primals, exogenous shocks may have a similar impact across the wholesale pork primal prices. A Breusch-Pagan test statistic (Table 2) was computed to test for a diagonal covariance matrix. The null-hypothesis of a diagonal covariance matrix was rejected. Thus, models were estimated using Seemingly Unrelated Regression (SUR) estimator to improve estimation efficiency (Greene). Durbin-Watson test statistics for the presence of autocorrelation, an inherent problem with time series data, are listed at the bottom of Table (2). The size of the Durbin -Watson test statistic, for each model, suggests autocorrelation is not a concern.

Model results of the equation estimated following the model described in equation (10) are listed in Table 2. The explanatory variables explained between 86% and 98% of the variation in the different wholesale pork primal prices over the February 1989 to December 1999 period. P-values are listed to indicate the significance level of the estimated coefficients. Because the model was estimated in first-differences of the natural logarithm of the data, coefficients are flexbilities.

The own-quantity flexibility was statistically significant and of the expected sign for four of the six wholesale primal cuts evaluated here. Pork Loin and Boston Butt had a own-quantity flexibility estimates of around –0.49, and Pork Belly and Boneless Picnic had own-quantity flexibility estimates of around –0.25. This result is consistent with the difference between relatively higher quality cuts, i.e., Pork Rib, and low quality cuts, i.e., Pork Belly, found for other wholesale cuts of other meats (Capps et. al.; Lusk et. al.; Parcell and Pierce). Neither the Pork

Rib or Ham own-quantity flexibility was statistically significant. It can be concluded that there is not a wholesale price response associated with a change in the quantity demanded for these products. The size of the own-quantity flexibility for the different primals was significantly different than the aggregate own-quantity flexibility estimated by Hahn and Green, -0.06. This suggests that it may be important to analyze wholesale pork primal prices separately because aggregation estimation results are not representative of estimation results obtained for individual primal cuts.

A one percent increase in the marketing cost index did not have a statistically significant impact on any of the wholesale pork primal prices. Hahn and Green also did not find the marketing cost index to be statistically significant in explaining the variability of the aggregate wholesale primal price. Visually observing of the data indicates that there was little variability in the food marketing cost index over the period of study.

The retail demand shift variable was statistically significant for three of the six equations. Furthermore, the sign on the coefficient, when statistically significant, was of the expected sign. The retail shift index was the largest in magnitude for Pork Rib and Ham, which suggests Pork Rib and Ham are more responsive to exogenous changes at the retail level than from a change in own-quantity demanded at the wholesale level. Wohlgenant provided a methodology for separating the effects of the retail shift index components. Because the primary focus of this study is on determining seasonal variability and changes over time in the own-quantity flexibility, decomposing the retail shift index coefficient was not done.

The dummy variable for the change in specification of the USDA wholesale primal price was not statistically significant for any of the wholesale pork primal price equations. Even though there was a noticeable change in the price level for each pork primal price, transforming the price data using natural logarithms and first differences likely reduced the impact of the price quote specification change in the multivariate analysis.

For the quarterly intercept shift variables, statistical significance and magnitude of the effect varied by wholesale primal cut. Relative to the first quarter, the price for four of the six pork primals was statistically lower during the fourth quarter. This is consistent with the exogenous increase in pork production associated with the seasonal production of pork.

Seasonal Variation in Own-Flexibilities

Model results for the estimation of equation (12) are listed in Table 3. Equation (12) was specified so that the own-quantity flexibility varied between quarters of the year. The results presented in Table 3 only differ from results presented in Table 2 by the inclusion of the own-quantity and seasonal shift interaction terms. The models were estimated jointly using the SUR estimator. The Durbin-Watson test statistics indicated that residual autocorrelation is not a concern. The explanatory variables chosen explained between 86% and 98% of the variability in the wholesale pork primal prices over the period evaluated.

For Pork Loin, Boston Butt, and Boneless Picnic that seasonal varying own-quantity flexibility estimates were generally statistically different from zero. Additionally, a *t*-statistic was computed between the own-quantity flexibility, for the respective primal, reported in Table 2 and for each of the statistically significant seasonal varying own-quantity flexibilities reported in Table 3. For each of the statistically significant own-quantity flexibilities reported in Table 3 the calculated *t*-statistic rejected the null-hypothesis that the parameter estimates were equal. Thus, it can be concluded that the own-quantity flexibility for some wholesale pork primals varies within the year. This result is consistent with the findings of Lusk et al. for the case of Choice and Select beef.

The results of the seasonal own-quantity flexibility estimates presented here are consistent with the seasonal build up of cold storage stocks. However, it appears that the seasonal change in cold storage stocks is not sufficient to remove the change in price responsiveness to a percentage change in quantity.

Time Path of Wholesale Primal Flexibilities

Flexible Least Squares was used to develop a graphical representation of the time path of the different pork primal own-quantity flexibilities over time. The FLS estimator was used to estimate the model specified in equation (10). Summary statistics of the flexible least squares estimator for the own-quantity flexibility coefficients are reported in Table 3 for chosen delta values of 0.001, 0.1 and 1. As delta becomes larger, the Flexible Least Squares estimator approaches the OLS estimator and the standard errors on the coefficient decrease in value rapidly.

The time paths of the own-quantity flexibility estimates for Boston Butt, Boneless Picnic, Pork Belly, Ham, and Pork Loin, at λ=0.001, are graphed in Figure 3. The weighting coefficient, λ=0.001, was chosen to give the model the most flexibility. The parameter estimates by themselves are of little value. The value of the FLS estimator is observing the change in magnitude of the coefficients over the period of study. As can be observed from Figure 3, the own-quantity flexibility remained fairly constant, for all cuts, until 1997. Following the beginning of 1997, the wholesale primal flexibilities, other than Pork Belly and Ham, became significantly more flexible (increased in absolute value), particularly during 1998. For Boston

Butt, the own-quantity flexibility was observed to be five times greater in absolute value than historically observed. Alternatively, the own-quantity flexibility for Pork Belly and Ham was relatively unchanged, to an increase, over the entire period. One assessment of why the wholesale Pork Belly and Ham own-quantity flexibility was unchanged was that cold storage stocks of Pork Belly and Ham increased so that a change in price was not needed to offset the greater quantity of pork moving through the wholesale marketplace. Figure 4 is used to graphically depict the time path of the Ham own-quantity flexibility and cold storage stocks.

Conclusions

Inverse wholesale pork primal demand models, for Pork Loin, Boston Butt, Pork Rib, Ham, Pork Belly, and Boneless Picnic, were estimated to empirically analyze whether there is a seasonal component of the wholesale own-quantity flexibility and to determine whether the own-quantity flexibility has increased in magnitude (absolute value). The period of evaluation was 1989 through 1999. No previous research has explicitly analyzed factors affecting variability in wholesale pork primal prices. Results indicate that the own-quantity flexibility varies by wholesale primal; there is seasonal variation in the own-quantity flexibility of Pork Loin, Boston Butt, and Boneless Picnic; and the own-quantity flexibility for Pork Loin, Boston But, and Boneless Picnic has increased in magnitude (absolute value) over time.

For Pork Loin, Boston Butt, and Boneless Picnic the estimated first quarter own-quantity flexibility was greater than twice the magnitude of the estimated own-quantity flexibility when not accounting for seasonal fluctuations. During other periods within the year the difference in magnitude was less. The own-quantity flexibility for Boston Butt was found to have increased in magnitude by about 5 times during the past two years, -0.30 to around –1.50. However, the own-quantity flexibility of Pork Belly and Ham was either unchanged or increased over the period of study. One reason for this may be the relatively longer period that Pork Bellies and Ham can remain in cold storage, thus, allowing cold storage stocks to change to off-set large price fluctuations.

Results of this study are important for two specific reasons. First, the disaggregated own-quantity flexibilities estimated in this study are significantly different than aggregate wholesale own-quantity flexibilities estimated in previous research. Second, the results of this study suggest there is seasonal variability in the magnitude of a wholesale primal price response from a corresponding one percent change in quantity demanded. This result is important because it provides processors with information on pricing strategies; it helps operating processors, and those planned to enter the processing business, make better quarterly cash flow and income projections; and it suggests that future research analyzing structural change and market power may want to evaluate separate periods within the year. Lastly, this study used parametric analysis to validate claims that the own-quantity flexibility at the wholesale level has increased in magnitude over time. However, the change in own-quantity flexibility magnitude was not necessarily apparent or consistent across wholesale pork primals.

As with all studies, this study has limitations. First, separability among the wholesale pork primals was assumed due to data limitations common with analysis of this type. Secondly, a proxy variable was computed as an own-quantity for different pork primals. Numerous researchers have tested the assumption of fixed proportions; however, Hahn and Green note that most tests are indirect. Future research could empirically test the fixed proportion hypothesis by using cold storage stocks of individual pork primals as a proxy for own-quantity versus pork production at the farm level.

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Table 1. Description of Variables and Summary Statistics of Data used in Estimation of Variability in Monthly Wholesale Pork Primal Price (February 1989 to December 1999).

Variable	Description	Expected Impact on Pork Primal	Avg	S.D.
j	Pork Primal Cut *j*, where *j*= Pork Loin, Boston Butt, Pork Rib, Ham, Pork Belly, Boneless Picnic			
t	Month *t* between February 1989 and December 1999, *t* = 1, . . ., 132			
P_{jt}	Wholesale price of pork primal cut *j* in month *t*.			
	Pork Loin ($/cwt.)			
	Pork Rib ($/cwt.)		$106.62	$12.39
	Boston Butt ($/cwt.)		$111.49	$15.20
	Ham ($/cwt.)		$68.99	$12.57
	Pork Belly ($/cwt.)		$65.92	$12.45
	Boneless Picnic ($/cwt.)		$49.10	$15.89
			$62.62	$8.83
Q_{jt}	Average daily per capita pork consumption, adjusted for pork imports, exports, and primal *j* change in cold storage stocks, in month *t* (lbs.)	(−)		
	Pork Loin (lbs/per capita/day)		0.179	0.074
	Pork Rib (lbs/per capita/day)		0.176	0.074
	Boston Butt (lbs/per capita/day)		0.182	0.013
	Ham (lbs/per capita/day)		0.173	0.080
	Pork Belly (lbs/per capita/day)		0.174	0.086
	Boneless Picnic (lbs/per capita/day)		0.180	0.073
C_t	Food marketing cost index (energy cost index) (1992=100) in month *t*	(?)	187.85	24.02
Z_t	Retail demand shifter. 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*.	(+)	21.25	0.07
DUM_t	A 0 or 1 binary variable indicating a change in the specification of the wholesale price quote for the different primal cuts, =1 for January 1998, 0 o.w.	(?)		
$QUART_{kt}$	Separate 0 or 1 binary variables for quarter *k* (*k* = 1, 2, 3, 4; *default* = Q_1)	(?)		

Table 2. Estimation Results of Determinants of Wholesale Poultry Cut Prices Estimated Following Equation 12 (Dependent Variable is Wholesale Cut Price).

	Wholes Pork Primal Equation					
	Pork Loin	Boston Butt	Pork Rib	Ham	Pork Belly	Boneless Picnic
Own Cut Flexibility	-0.489**	-0.490***	0.029	0.053	-0.270*	-0.244***
	(<0.01)	(<0.01)	(0.71)	(0.68)	(0.08)	(<0.01)
Index of Marketing Costs	0.534	0.678	-0.449	-0.121	-0.353	0.097
	(0.20)	(0.24)	(0.20)	(0.84)	(0.62)	(0.75)
Retail Shift Index	0.054	0.005	0.322***	0.231*	0.219	0.149**
	(0.56)	(0.97)	(<0.01)	(0.09)	(0.17)	(0.03)
Specification Dummy	0.062	0.097	0.005	0.128	-0.069	0.007
	(0.40)	(0.34)	(0.94)	(0.23)	(0.58)	(0.89)
Q2	-0.008	0.080***	-0.003	0.014	0.006	0.018
	(0.67)	(0.01)	(0.86)	(0.63)	(0.87)	(0.22)
Q3	-0.025	-0.047*	-0.138***	0.059**	-0.038	-0.014
	(0.18)	(0.07)	(<0.01)	(0.03)	(0.23)	(0.30)
Q4	-0.058***	-0.002	-0.622***	0.019	-0.063*	-0.029*
	(0.01)	(0.93)	(<0.01)	(0.54)	(0.07)	(0.05)
Constant	0.023*	-0.008	0.513***	-0.025	0.031	0.007
	(0.08)	(0.66)	(<0.01)	(0.20)	(0.17)	(0.50)
R-squared	0.97	0.93	0.98	0.92	0.86	0.98
Durbin-Watson	2.78	2.81	2.48	2.18	2.15	2.28
No. of observations[b]	131	131	131	131	131	131
Breusch-Pagan test statistic for a diagonal covariance matrix			709.28	42 D.F.		

Note: Three, two, and one asterisks refer to coefficients statistically significant at the 0.01, 0.05, and 0.10 levels, respectively

[a]p-values in parenthesis under parameter estimates

[b]Observations refer to monthly observations between February 1989 and December 1999

Table 3. Estimation Results of Seasonal Wholesale Pork Primal Flexibilities Estimated from Equation 14 (Dependent Variable is Wholesale Cut Price).

	Wholes Pork Primal Equation					
	Pork Loin	Boston Butt	Pork Rib	Ham	Pork Belly	Boneless Picnic
Own Cut Flexibility						
Q1	-1.058***	-0.982***	-0.093	0.008	-0.604	-0.619***
	(<0.01)	(0.01)	(0.67)	(0.98)	(0.17)	(<0.01)
Q2	-0.434***	-0.710***	-0.125	-0.138	-0.081	-0.306***
	(0.01)	(<0.01)	(0.40)	(0.59)	(0.79)	(0.01)
Q3	-0.312**	-0.135	0.187	0.104	-0.265	-0.085
	(0.03)	(0.50)	(0.13)	(0.63)	(0.29)	(0.42)
Q4	-0.542***	-0.539*	0.052	0.282	-0.216	-0.188
	(0.01)	(0.07)	(0.28)	(0.36)	(0.55)	(0.21)
Index of Marketing	0.542	0.850	-0.326	0.098	-0.425	0.205
Costs	(0.21)	(0.15)	(0.37)	(0.88)	(0.57)	(0.51)
Retail Shift Index	0.007	-0.072	0.285***	0.179	0.208	0.095
	(0.95)	(0.60)	(<0.01)	(0.22)	(0.22)	(0.18)
Dummy	0.055	0.091	0.004	0.129	-0.074	0.002
	(0.45)	(0.37)	(0.95)	(0.23)	(0.55)	(0.97)
Q2	-0.006	0.072***	-0.009	0.005	0.014	0.015
	(0.79)	(0.01)	(0.60)	(0.88)	(0.71)	(0.32)
Q3	-0.028	-0.055**	-0.142***	0.058**	-0.38	-0.017
	(0.13)	(0.03)	(<0.01)	(0.03)	(0.23)	(0.19)
Q4	-0.056***	0.003	-0.059***	0.023	-0.060*	-0.027*
	(0.01)	(0.91)	(<0.01)	(0.44)	(0.09)	(0.07)
Constant	0.022*	-0.10	0.051***	-0.026	0.029	0.006
	(0.09)	(0.59)	(<0.01)	(0.18)	(0.19)	(0.54)
R-squared	0.97	0.93	0.98	0.92	0.86	0.98
Durbin-Watson	2.79	2.78	2.46	2.21	2.16	2.23
No. of observations[b]	131	131	131	131	131	131
Breusch-Pagan test statistic for a diagonal covariance matrix	330.30	15 D.F.				

Note: Three, two, and one asterisks refer to coefficients statistically significant at the 0.01, 0.05, and 0.10 levels, respectively

[a]p-values in parenthesis under parameter estimates

[b]Observations refer to monthly observations between February 1989 and December 1999

Table 4. Summary Statistics of Flexible Least Squares Estimate for model for the Own-quantity flexibility Estimate.

	Wholes Pork Primal Equation					
λ	Pork Loin	Boston Butt	Pork Rib	Ham	Pork Belly	Boneless Picnic
0.001	-0.454	-0.444	0.103	-0.141	-0.149	-0.238
	(0.252)[a]	(0.422)	(0.199)	(0.238)	(0.164)	(0.182)
0.1	-0.453	-0.439	0.099	-0.112	-0.151	-0.233
	(0.242)	(0.401)	(0.188)	(0.204)	(0.150)	(0.178)
1	-0.491	-0.493	0.032	0.039	-0.222	-0.238
	(0.001)	(0.002)	(0.001)	(0.003)	(0.001)	(0.001)

[a]Standard errors in parenthesis under parameter estimates

Figure 1. Monthly Average Nominal Wholesale Pork Loin and Rib Price between February 1989 and December 1999.

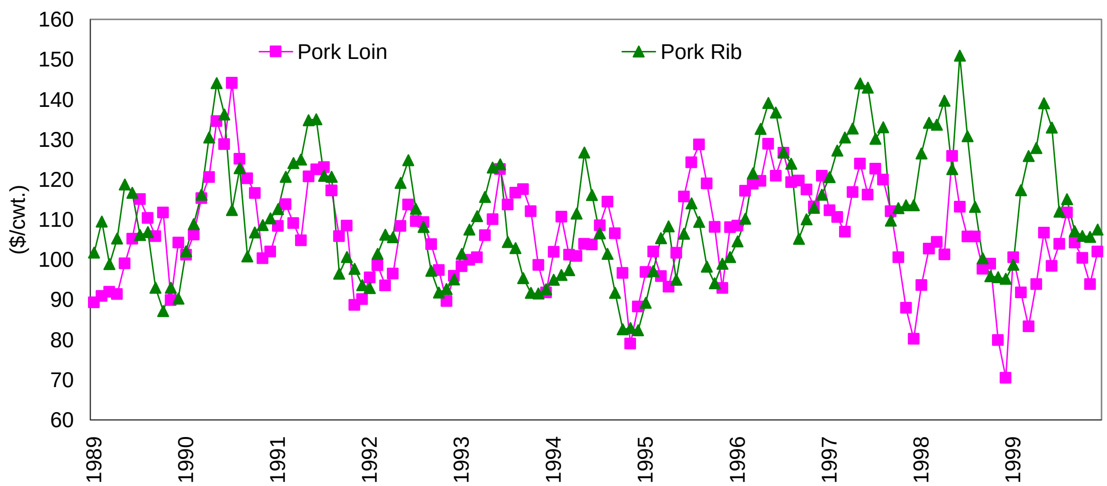

Figure 2. Monthly Average Nominal Wholesale Pork Boston Butt, Belly, Ham and Picnic Price between February 1989 and December 1999.

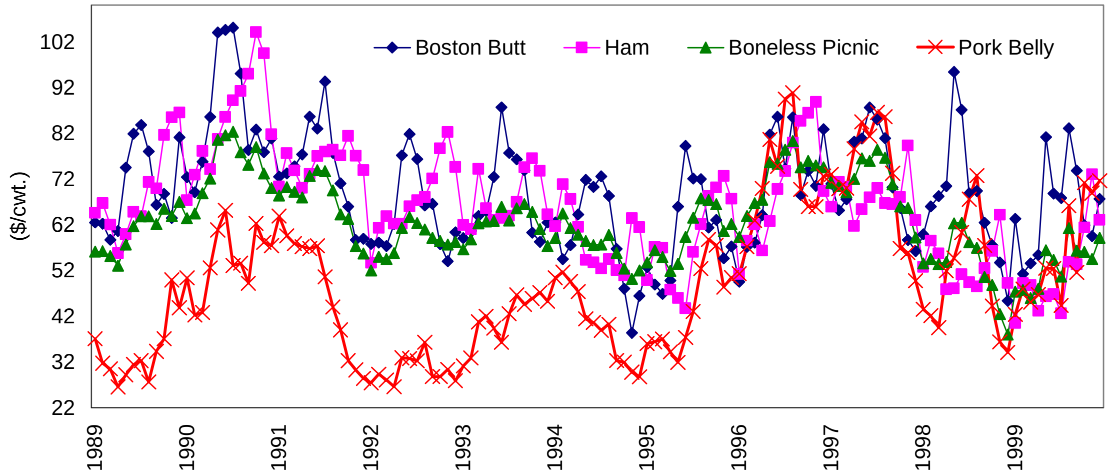

Figure 3. Monthly Time Path of Wholesale Pork Primal Flexibilities from Flexible Least Squares Estimator, λ=0.001, from February 1989 to December 1999.

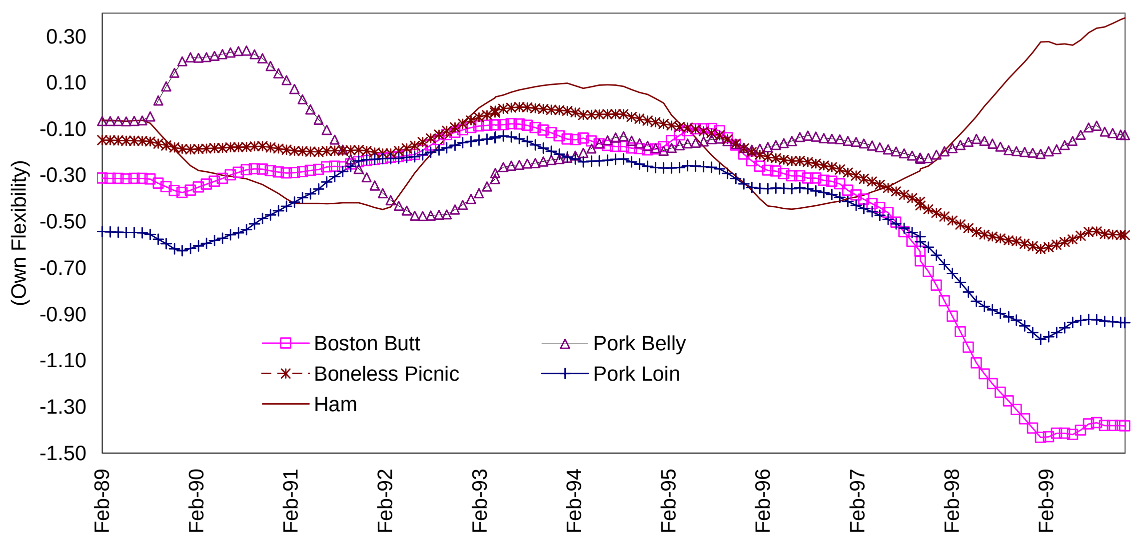

Figure 4. Own-Quantity Flexibility and Cold Storage Stock for Ham, 1989 through 1999.