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

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A set of inverse wholesale pork primal demand models are estimated to determine the own-quantity flexibility, to ascertain seasonal price fluctuations, and to examine whether the flexibilities change in absolute magnitude over time. Results indicate that the own-quantity flexibility varied within the year. Also, it is determined that the own-quantity flexibility increased in magnitude (absolute value) over time for some of the primal cuts evaluated. However, for Hams the price flexibility became positive after early 1998. An increase in cold storage stocks of Hams may have led to the positive own-quantity flexibility and cold storage stocks may have been used to offset the potential Ham 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 needs. Organizational change in the agricultural industry is no more apparent than in the hog industry over the past ten years. Between 1994 and 2000, the level of vertical coordination in the hog industry increased from 6% to 24% (Grimes and Meyer). Processors are expanding into the branded and case-ready pork market. 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 pricing decisions are crucial. 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 changed over time for the pork Loin, Rib, Butt, Ham, Belly, and Picnic wholesale primals.[1]

No previous study analyzes factors affecting wholesale pork primal price variability.[2] Yet, the pork industry is showing considerably more interest in the wholesale to farm and wholesale to retail part of the market chain. Why? Decisions such as cold storage capacity, strategic seasonal marketing contracts with producers and retailers, and the development of specialized product markets are of great importance in pricing, controlling costs,

[1] These wholesale primals account for over 55% of the live weight carcass.
[2] As a measure of this variability, 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 variation of 0.32.

and strategic planning. Three pork industry indicators of interest in the wholesale pork market include the announcement by Excel to change over an 8,000 head per day slaughter facility to a further processing facility, Smithfield Foods and IBP purchasing existing further processing facilities for cut specific and brand name products, and the National Pork Producer Council placing priority on the development of producer owned hog processing cooperatives as a way for producers to add value and bypass traditional processing firms.

Some economists openly state that the elasticity of demand for retail pork products has became more inelastic over time (Plain and Grimes).[3] Statements regarding a change in the wholesale demand elasticity over time were not based on empirical analysis; yet, the implications of these statements are important. For one, if the demand for pork products has became more inelastic over time, then discount specials on pork at the retail level has less of an impact on quantity demanded today than in the past. Are these claims applicable to the wholesale pork primals market? It has been well documented, e.g., Goodwin and Holt, and Schroeder and Mintert, that the flow of price information tends to be unidirectional up the marketing chain in the meat industry. Thus, changes at the retail demand level may or may not be appropriate for extension to the wholesale pork market. Examining factors affecting wholesale pork primal prices and determining the extent demand elasticity for pork changed over time will help swine industry persons make better management and marketing decisions.

[3] For instance, the high protein – low carbohydrate diet increased in popularity over the previous years. One suggestion for this diet is the consumption of bacon. Thus, demand for bacon possibly changed due to consumer attitudes regarding red meat.

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 relatively was no cross-flexibility effect from changes in the level of other beef; the marketing cost index was positive generally; and they found mixed results for cross-flexibility estimates of pork and chicken. Also, they found seasonal variation among 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 monthly data between 1988 and 1998 in a Seemingly Unrelated Regression (SUR) framework. They found seasonal differences associated with different broiler and turkey primals, and they found the own-quantity flexibility to among 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 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 wholesale prices and quarter intercept variables. They estimated that an elasticity of demand for Choice beef was –0.425 and Select beef was–0.858. Additionally, their system results indicated an aggregate wholesale pork elasticity of demand of –0.58. The quantity demanded of Choice and Select beef increased over time and by season. They found that the own- and cross-price elasticities varied between periods within the year and that the Select beef own-price elasticity nearly doubled the Choice beef own-price elasticity. During the second and third quarter, both the Choice and Select own-price elasticity was inelastic. Intuitively, these periods correspond with the time of year when beef is in greatest demand, i.e., summer grilling season. 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 production, 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. Since this research focuses on the wholesale level, the empirical analysis only 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) $Q_w^d = 3D_w^{\,i}(P_w, P_r, C_w)$ (wholesale demand)

(2) Q_w^s, predetermined (wholesale supply)

(3) $Q_r^d = D_r(P_r, Z)$ (retail demand)

(4) $Q_r^s = 3S_r^i(P_r, P_w, C_r)$ (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, P_r 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) are 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 totally differentiated, expressed in elasticity form, and the equations are solved for $d\ln P_r$ and $d\ln P_w$, respectively. This yields the following equations:

(8a) $d\ln P_r = E_{rz} \bullet d\ln Z + E_{rc} \bullet d\ln C_r + E_{rw} \bullet d\ln Q_w$

(8b) $d\ln P_w = E_{wz} \bullet d\ln Z + E_{wc} \bullet d\ln C_w + E_{ww} \bullet d\ln Q_w$

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: $\Theta^D{}_{ww}$ is the elasticity of wholesale-level demand with respect to wholesale price [–], $\Theta^D{}_{rz}$ is the elasticity of retail level demand with respect to the retail demand shifter [+], $\Theta^S{}_{rc}$ is the elasticity of retail supply with respect to retail marketing cost [?], $\Theta^S{}_{rw}$ is the elasticity of retail supply with respect to wholesale price [–, assuming the wholesale product is a normal good], $\Theta^D{}_{wc}$ is the elasticity of wholesale demand with respect to wholesale marketing cost [?], $\Theta^D{}_{wr}$ is the elasticity of wholesale demand with respect to retail price [+], $\Theta^S{}_{rr}$ is the elasticity of retail supply with respect to retail price [+], and $\Theta^D{}_{rr}$ 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). Given that 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} cannot 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 the 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 is chosen so that parameter estimates are flexibilities.[4] Models are specified in first-differences because the price series are 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):

$$\Delta \ln P_{jt} = E_{jz} \bullet \Delta \ln Z_t + E_{jc} \bullet \Delta \ln C_t + E_{jQ} \bullet \Delta \ln Q_{jt} + 3_k\, E_{jk} \bullet QUART_k + E_{jDUM} \bullet DUM + E_j + \Omega_{jt}$$

[4] A Box-Cox transformation procedure is used to evaluate the choice of the logarithmic functional form. For all but Pork Loin, the Log-Likelihood function for the logarithmic functional form, specified by a $\lambda = 0$, is less than 3% greater than for the value of λ found to minimize the Log-Likelihood function. For Pork Loin, a linear functional form is preferred, however, the percentage difference in the Likelihood function is 5%. A full summary of the Box-Cox test statistics between alternative choices of λ is available upon request.

Variable definitions and summary statistics of data used to estimate equation (10) are listed in table 1. The data section following this section describes the data in more detail. 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 random disturbance term. The dummy variable for the change in price quote is set equal to 1 for January 1998 and 0 otherwise.

For the retail demand shifter, Wohlgenant suggests 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 Wohlgenant, the retail demand shifter specified for this study is of the form:

(10) $$\Delta lnZ_t = 3_l \, e_{jl} \bullet \Delta lnP_{rlt} + e_{jy} \bullet \Delta lnY_t + \Delta lnPOP_t ,$$

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 is made to the model specified in equation (10). An interaction term between the own-quantity variable and the quarterly shift variable is 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) $\Delta \ln P_{jt} = E_{jz} \bullet \Delta \ln Z_t + E_{jc} \bullet \Delta \ln C_t + 3_k\ E_{jkQ} \bullet \Delta \ln Q_{jt} \bullet QUART_k + 3_k\ E_{jk} \bullet QUART_k + E_{jDUM} \bullet DUM + E_w + \Omega_{jt}$,

where variable definitions for equation (12) are the same as above.

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, and Dorfman and Foster provide an extensive explanation of the FLS estimator. FLS detects parameter instability that may indicate possible structural change in the analyzed variable. Tests for structural change, e.g., CUSUM, Chow, and Recursive residual tests, provide researchers an indication of where to partition the data. These methods, however, do not show the rate at which structural change occurs, the length of occurrence when there is a temporary structural change, and partitioning the data can cause degrees of freedom problems when using a small sample size.

Graphically depicting how the wholesale own-quantity flexibility changes over time can be useful in assessing structural change and the FLS estimator allows for such a graphical representation. The graphical representation makes inferences regarding potential structural changes that may cause the own-quantity flexibility estimate to change over time or temporarily.

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

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

where P_t is the wholesale price at time t ($t = 1, \ldots, T$), $Q_{pork,t}$ is the demand for wholesale pork at time t, and ε_t is a random disturbance term. The coefficient on wholesale pork demand (β_t) is a T x 1 vector of a time varying parameter estimate. The FLS estimator minimizes the loss function from equation 13 as:

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

where λ is a value between zero and one [λ ϵ (0,1)] , and D is a K x 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 D is specified as a positive semideifinite diagonal unit matrix with diagonal elements $d_{ii} = 1$.[5,6] Given the specification of equation (14), a large λ penalizes parameter variability and small λ allows for greater parameter variability. Time varying coefficients are obtained by estimating equation (10) for different λ values by employing the FLS command in Shazam 8.0.

[5] Poray, Foster, and Dorfman specify the weighting matrix such that 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. Upon estimation using the FLS estimator in this study, it is determined that the seasonal shift variables do not sufficiently capture the coefficient variability of the other variables. This is analyzed visually.
[6] A positive semi-definite D matrix ensures a minimum is obtained in the loss function.

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. LMIC provided the monthly wholesale primal prices for Pork Loin, Pork Rib, Boston Butt, Ham, Pork Belly, and Boneless Picnic. Price series are represented graphically in graphs 1, 2, and 3.

Average daily per capita pork consumption for the different meat types is calculated as pork production adjusted for pork imports, exports, and the between month change in cold storage stocks for the specific wholesale pork primal. LMIC also supplied the production, import, and export data. USDA *Cold Storage* reports provided cold storage stocks information. For Pork Rib, cold storage values were not kept during the entire time period. Thus, constant proportions are 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 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 is obtained from various issues of *Agricultural Outlook*. The retail shift index is 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 was obtained from the St. Louis Federal Reserve Bank.

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 are used so to not introduce noise into the model.[7]

Results

Each wholesale primal price, after being transformed by the natural logarithm operator, is tested for stationarity using the augmented Dickey-Fuller, and the lag order is 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 is -2.57. Therefore, the null-hypothesis of a unit root cannot be rejected for five of the six price series. Data are first differenced, and the first differenced price series are found to be stationary for all of the primal price series. The number of observations used in the estimation is 131.

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[7] One reviewer expressed concern over the use of nominal values. Peterson and Tomek suggested the use of real price data could result in inefficient standard errors. Thus, as further support for the use of nominal values, a J test was conducted between the nominal price model and a real price model. For H_1: nominal prices are appropriate, the p-values for the null-hypothesis of alpha value equal to zero were 0.165 for Pork Loin, 0.499 for Boston Butt, 0.439 for Pork Rib, 0.774 for Ham, 0.905 for Pork Belly, and 0.463 for Boneless Picnic. For H_2: real prices are appropriate, the p-values for the null-hypothesis of alpha value equal to zero were 0.167 for Pork Loin, 0.502 for Boston Butt, 0.420 for Pork Rib, 0.775 for Ham, 0.955 for Pork Belly, and 0.482 for Boneless Picnic. The results of the J test, albeit a relative weak test, indicate that either nominal or real prices could be used without loss of efficiency.

Since 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) is computed to test for a diagonal covariance matrix. The null-hypothesis of a diagonal covariance matrix is rejected. Thus, models are 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.

As previously stated, the supply of pork is assumed predetermined. To verify this assumption a test of exogeneity is carried out using the *Wald* test Statistic (Greene). The statistic is distributed chi-squared with one degree of freedom, the critical value is 3.84 at the 5% level. An instrument is computed for the per capita consumption variable by using all other exogenous variables listed in equation 11 and a lagged per capita consumption variable for the individual primal (Greene). For each of the test statistics computed, the null-hypothesis of the pork primal per-capita consumption exogenous to the model cannot be rejected. Each of the test statistic values is below one. [8]

Results of equation (10) are described in table 2. The explanatory variables explain between 86% and 98% of the variation in the different wholesale pork primal prices, as indicated by the R^2. Because the model is estimated in first-differences of the natural logarithm of the data, coefficients are flexbilities.

[8] Care is taken in the interpretation of the *Wald* test statistic for endogeneity as it is not considered a powerful test. However, the level of the test statistics computed here – below one – provides a strong argument that a more powerful test statistic will produce a similar result.

Own-quantity price flexibility of demand is statistically significant and of the expected sign for four of the six wholesale primal cuts. Pork Loin and Boston Butt have price flexibility of demand estimates around –0.49, and Pork Belly and Boneless Picnic have price flexibility of demand estimates of around –0.25. These four primals represent roughly 55% of the wholesale carcass value. This result is consistent with the difference between relatively higher valued cuts and lower valued cuts found for other meat wholesale cuts (Capps et. al.; Lusk et. al.; Parcell and Pierce). Neither the Pork Rib or Ham price flexibility of demand is statistically significant. There is not a wholesale price response associated with a change in the quantity demanded for these products. The size of the price flexibility of demand for the different primals is significantly different than the aggregate price flexibility of demand 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 does 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 the data indicates that there is little variability in the food marketing cost index over the period of study.

The retail demand shift variable is statistically significant for three of the six equations. Furthermore, the sign on the coefficient, when statistically significant, is of the expected sign. The retail shift index is the largest in magnitude for the 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. Because the primary focus of this study is on determining seasonal variability and changes over time in the price flexibility of demand, the retail shift index coefficient is not decomposed.

The dummy variable for the change in specification of the USDA wholesale primal price is not statistically significant for any of the wholesale pork primal price equations. Even though there is a noticeable change in the price level for each pork primal price, transforming the price data using natural logarithms and first differences likely reduces 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 varies by wholesale primal cut. Relative to the first quarter, the price for four of the six pork primals is 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

Estimated results of equation (12) are listed in table 3. Equation (12) is specified so that the price flexibility of demand varies between quarters of the year. Results presented in table 3 only differ from table 2 by the inclusion of the price flexibility of demand and seasonal shift interaction terms. Models are estimated jointly using the SUR estimator. The Durbin-Watson test statistics indicate that residual autocorrelation is not a concern. The explanatory variables 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, seasonal varying price flexibility of demand estimates generally are statistically different from zero. Additionally, a paired *t*-statistic is computed between the price flexibility of demand 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 price flexibilities of demand reported in table 3, the calculated paired *t*-statistic rejects the null-hypothesis that the parameter estimates are equal.[9] Thus, the price flexibility of demand 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.

[9] For Pork Loin, the test statistic for test of means was 7.88, 1.83, 5.92, and 1.01 for the first, second, third, and fourth quarter, respectively. For Boneless Butt, the test statistic for test of means was 3.52, 3.02, and 0.47 for the first, second, and fourth quarter, respectively. For Boneless Picnic, the test statistic for test of means was 9.99 and 3.12 for the first and second quarter, respectively. Statistical significance follows from the t-statistic critical values.

Time Path of Wholesale Primal Flexibilities

Flexible Least Squares is used to graphically represent the time path of the different pork primal price flexibilities of demand over time. The FLS estimator estimates the model specified in equation (10). Summary statistics of the flexible least squares estimator for the own-quantity flexibility coefficients are reported in table 4 for chosen values of λ equal to 0.001, 0.1 and 1. As λ 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 price flexibility of demand estimates for Boston Butt, Boneless Picnic, Pork Belly, Ham, and Pork Loin, at λ=0.001, are graphed in figure 4. The weighting coefficient, λ=0.001, is chosen to give the model the most flexibility. As observed from figure 4, the price flexibility of demand 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 price flexibility of demand is observed to be five times greater in absolute value than historically observed. Alternatively, the price flexibility of demand for Pork Belly and Ham is relatively unchanged, or increases slightly, over the entire period. One assessment of why the wholesale Pork Belly and Ham price flexibility of demand is unchanged stems from cold storage stocks of Pork Belly and Ham. Specifically, cold storage stocks of Pork Belly and Ham increases so that a change in price is not needed to offset the greater quantity of pork moving through the wholesale marketplace. Figure 5 graphically depicts the time path of the Ham price flexibility of demand and cold storage stocks.

Given the price flexibility of demand estimates began increasing (in absolute value) in 1997, not all of the change is attributed to the large supply of hogs entering the market in 1998.

Demand factors such as advertising campaigns, change in consumer diet, case-ready and branded products possibly led to this change. Unfortunately, given the limited time period from which the structural change occurred, finding strong conclusions about the cause of the change is difficult. However, this analysis motivates the need for further analysis in the future.

Conclusions

Inverse wholesale pork primal demand models, for Pork Loin, Boston Butt, Pork Rib, Ham, Pork Belly, and Boneless Picnic, are estimated to empirically analyze whether there is a seasonal component of the wholesale price flexibility of demand and to determine whether the own-quantity flexibility increases in magnitude (absolute value). The period of evaluation is 1989 through 1999. No previous research explicitly analyzes factors affecting variability in wholesale pork primal prices. Results indicate that the price flexibility of demand varies by wholesale primal; there is seasonal variation in the own-quantity flexibility of Pork Loin, Boston Butt, and Boneless Picnic; and the price flexibility of demand for Pork Loin, Boston But, and Boneless Picnic increases in magnitude (absolute value) over time. These primals account for approximately 55% of the wholesale pork carcass. Demand factors such as advertising campaigns, change in consumer diet, case-ready and branded products may have lead to this change. Conversely, some observed change in price flexibility of demand possibly resulted from the over supply of hogs entering the market during the fourth quarter of 1998. However, the observed magnitude change in price flexibility of demand is significantly less than the level of the absolute decrease in live hog price flexibility of demand observed in the Fall of 1998 (Parcell, Mintert, and Plain).

For Pork Loin, Boston Butt, and Boneless Picnic, the estimated first quarter price flexibility of demand is greater than twice the magnitude of the estimated price flexibility of demand when not accounting for seasonal fluctuations. During other periods within the year, the difference in magnitude is less. The price flexibility of demand for Boston Butt was found to have increased in magnitude by about five times during the past two years, -0.30 to around –1.50. However, the price flexibility of demand 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 and off-set large price fluctuations.

Results of this study are important for two specific reasons. First, the disaggregated price flexibilities of demand estimated in this study are significantly different than aggregate wholesale price flexibility of demand 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, helps processors make better quarterly cash flow and income projections, and suggests that future research analyzing structural change and market power needs to consider seasonality. Lastly, this study uses parametric analysis to validate claims that the own-quantity flexibility at the wholesale level increased in magnitude over time. However, the change in own-quantity flexibility magnitude is not necessarily apparent or consistent across wholesale pork primals.

As with all studies, this study has limitations. First, separability among the wholesale pork primals is assumed due to data limitations common with analysis of this type. Secondly, a proxy variable is computed as an own-quantity for different pork primals. Numerous researchers test the assumption of fixed proportions; however, Hahn and Green noted 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* = $QUART_1$)	(?)		

Table 2. Estimation Results of Determinants of Wholesale Poultry Cut Prices Estimated Following Equation 10 (Dependent Variable is Wholesale Cut Price, Coefficients are Flexibilities).

	Wholesale 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
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. Observations (131) are monthly between February 1989 and December 1999.

[a]p-values in parenthesis under parameter estimates

Table 3. Estimation Results of Seasonal Wholesale Pork Primal Flexibilities Estimated from Equation 12 (Dependent Variable is Wholesale Cut Price).

	Wholesale Pork Primal Equation					
	Pork Loin	Boston Butt	Pork Rib	Ham	Pork Belly	Boneless Picnic
Own Cut Flexibility						
$Q_1^{flexibility}$	-1.058***	-0.982***	-0.093	0.008	-0.604	-0.619***
	(<0.01)[a]	(0.01)	(0.67)	(0.98)	(0.17)	(<0.01)
$Q_2^{flexibility}$	-0.434***	-0.710***	-0.125	-0.138	-0.081	-0.306***
	(0.01)	(<0.01)	(0.40)	(0.59)	(0.79)	(0.01)
$Q_3^{flexibility}$	-0.312**	-0.135	0.187	0.104	-0.265	-0.085
	(0.03)	(0.50)	(0.13)	(0.63)	(0.29)	(0.42)
$Q_4^{flexibility}$	-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 Costs	0.542 (0.21)	0.850 (0.15)	-0.326 (0.37)	0.098 (0.88)	-0.425 (0.57)	0.205 (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)
Specification 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 from Equation 10 for the Own-Quantity Flexibility Estimate.

	Wholesale Pork Primal Equation					
8	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 Pork Rib Price between February 1989 and December 1999.

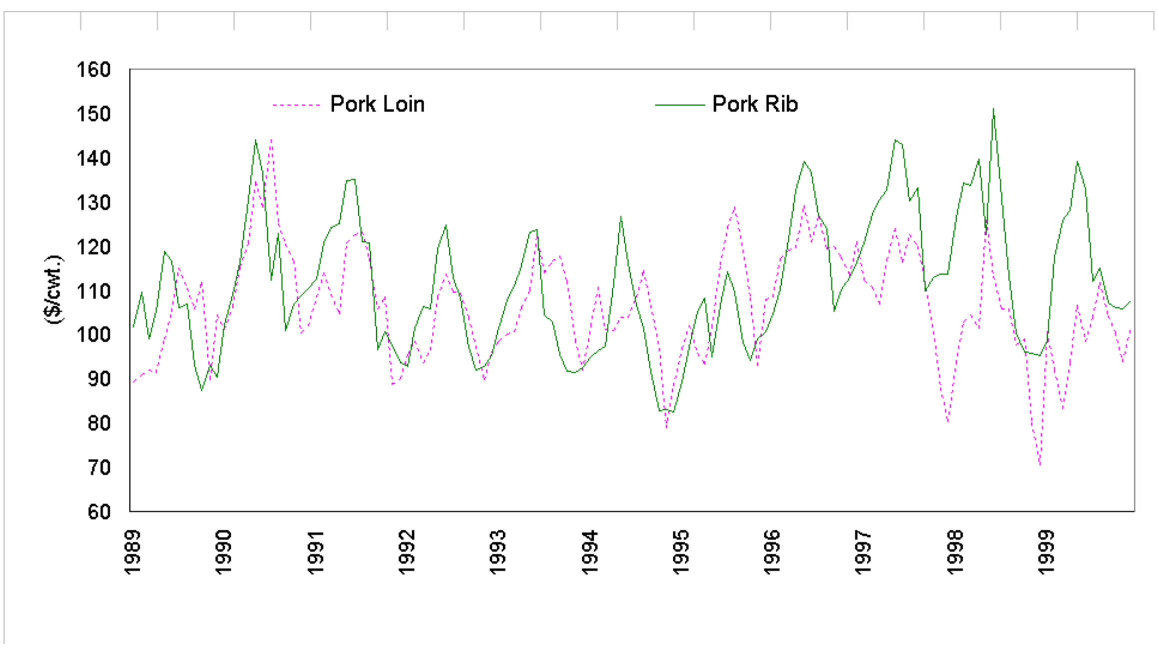

Figure 2. Monthly Average Nominal Wholesale Pork Belly and Boneless Picnic Price between February 1989 and December 1999.

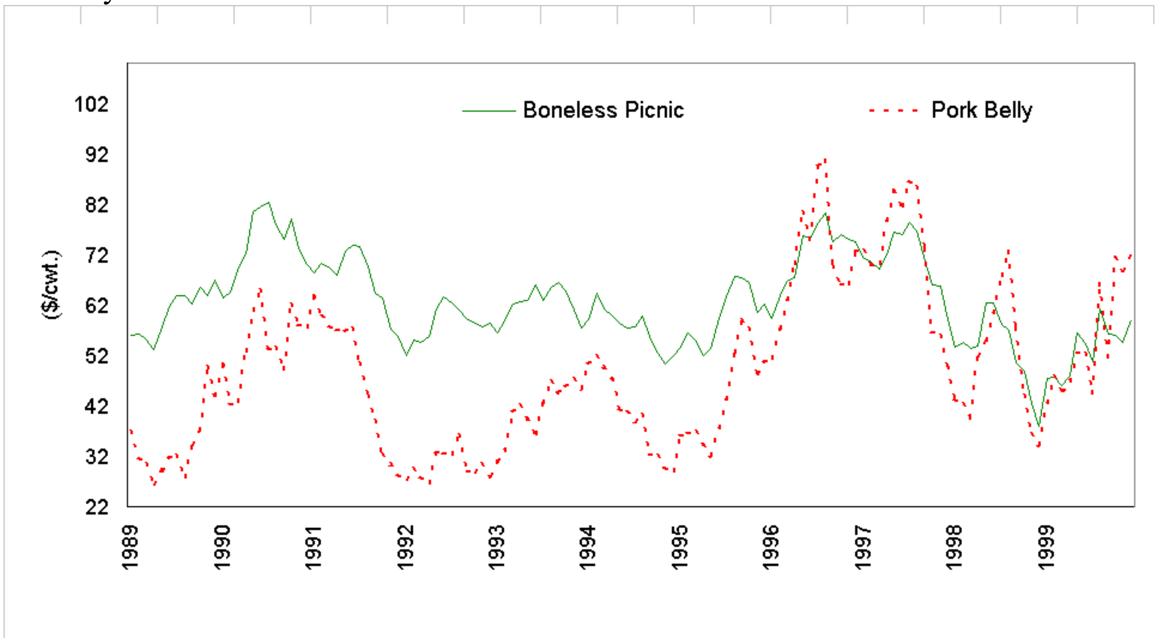

Figure 3. Monthly Average Nominal Wholesale Boston Butt and Ham Price between February 1989 and December 1999.

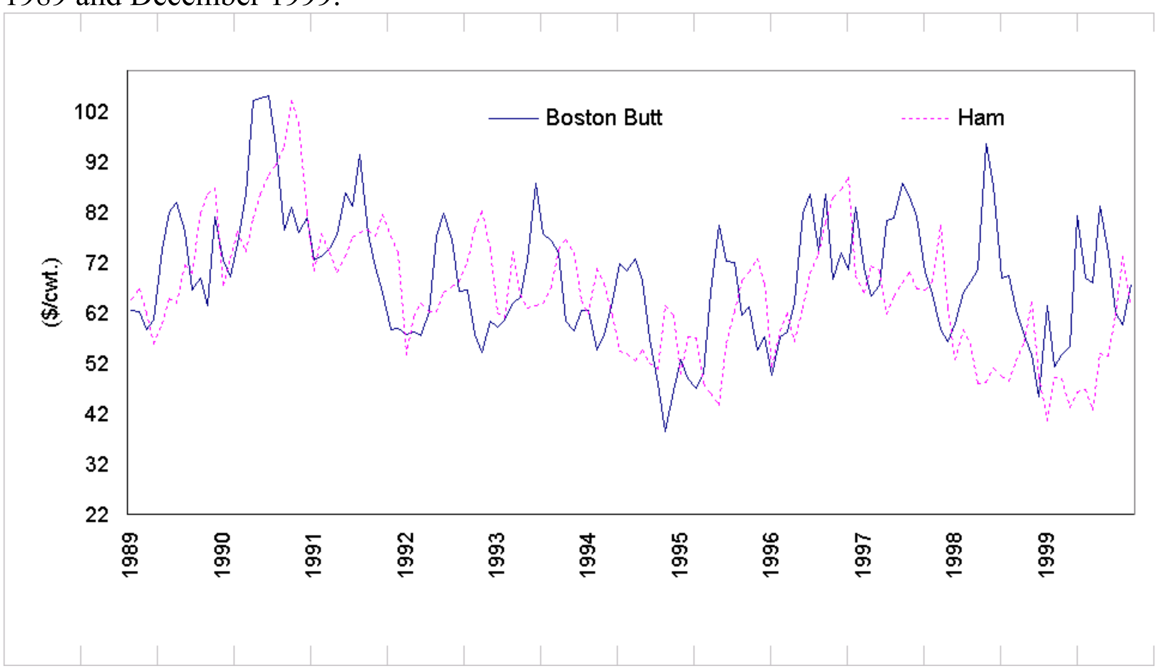

Figure 4. Monthly Time Path of Wholesale Pork Primal Flexibilities from Flexible Least Squares Estimator, 8=0.001, from February 1989 to December 1999.

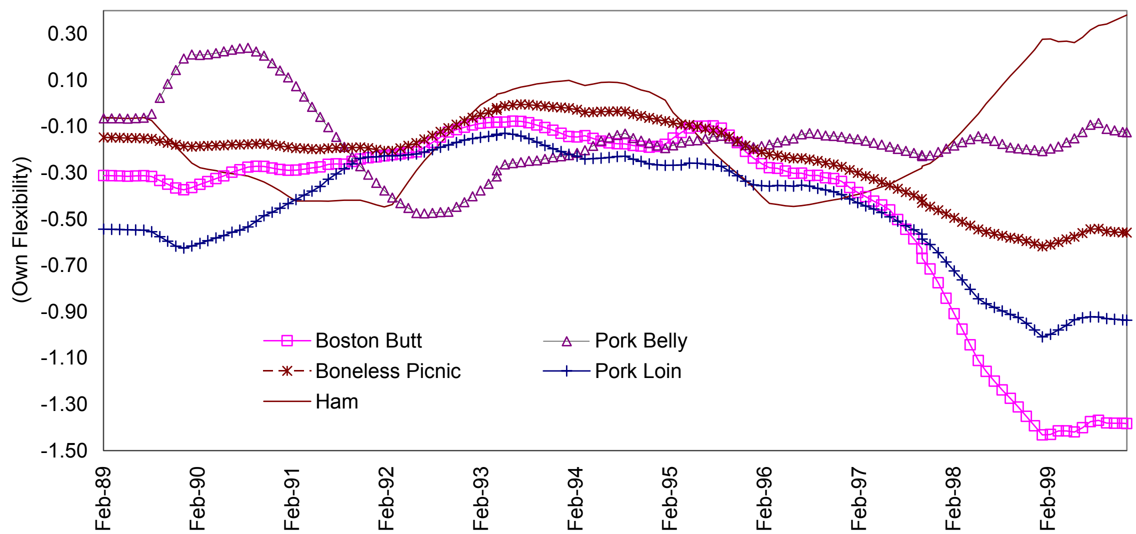

Figure 5. Own-Quantity Flexibility and Cold Storage Stock for Ham, 1989 through 1999.