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Wholesale Demand for USDA Quality Graded Boxed Beef and Effects of Seasonality

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This study estimates wholesale demand for pork, chicken, and quality differentiated beef. We estimate meat retailer own- and cross-price demand elasticities for USDA Choice and Select boxed beef. Results indicate that meat retailers have more elastic demand for lower quality graded beef. Retail beef price has a strong positive relationship with Choice and Select boxed beef demand, and a strong negative relationship with wholesale pork and chicken demand. Seasonal analysis reveals demand for both beef quality grades becomes highly price inelastic during the summer months. The two beef quality grades are substitutes during the winter; however, Select beef is not a substitute for Choice beef in the spring and summer.

Key words: beef, chicken, demand, pork, quality, USDA Choice, USDA Select, wholesale

Introduction

The U.S. Department of Agriculture (USDA) beef quality grading system has been in existence for over 70 years. Recently, the beef sector has experienced increased use of the voluntary grading system. According to USDA data, over 90% of beef from steer and heifer slaughter was quality graded in 1999 as compared to just 67% in 1986. Increased use of the grading system reflects heightened consumer demand for quality information and segregation at the retail level. In a market of increasing differentiation, USDA beef quality grades should play an important role in distributing quality throughout the marketing chain and providing signals of consumer desires at the retail level to cattle producers. Although the amount of beef graded has increased markedly, not much is known about the price sensitivity of the USDA beef quality grades or the substitutability between grades and among other meat products.

Numerous studies have estimated retail demand for beef and other meats such as poultry and pork (e.g., Brester and Schroeder; Eales and Unnevehr 1993; Kinnucan et al.; Lemieux and Wohlgenant). However, little research has been conducted on demand for quality grades of beef. Some work has estimated the demand relationships between various beef cuts such as table cut and ground beef (Brester and Wohlgenant; Eales and Unnevehr 1988), and Marsh (1991) estimated the demand for USDA Choice beef at the

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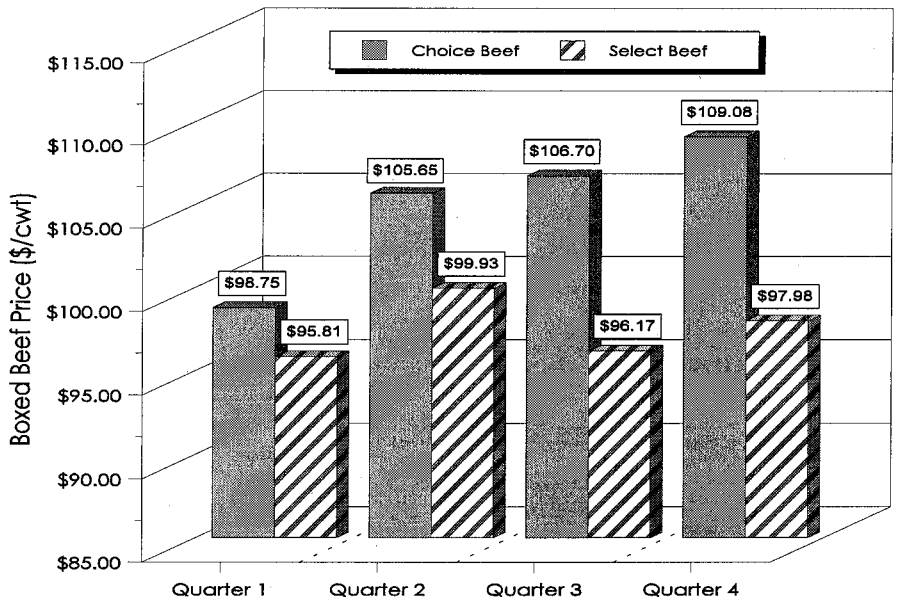

Figure 1. Seasonal pattern of boxed beef prices, 1998–99 average

farm and retail levels, but did not consider the relationship with other beef quality grades. Moreover, much of the research on meat demand has focused on either the retail or farm levels. Little research has been directed at examining the wholesale market between meat packers and meat retailers (work by Hahn and Green is one recent exception).

In addition to the increased use of the grading system by beef packers, many producers are beginning to market cattle on a quality and yield-grade basis (Ward, Feuz, and Schroeder). Transition from live-based to quality and yield-grade cattle pricing has shifted more of the Choice-to-Select price spread risk from the beef packer to the cattle feeder. Producers entering marketing agreements that entail "value-based" pricing will benefit from a better understanding of the determinants of Choice and Select demand. Much of the Choice-to-Select price spread risk associated with value-based pricing results from seasonality of beef production and demand.

Retail demand for meat is seasonal (Brester and Schroeder; Capps; Kinnucan et al.). Wholesale meat demand may be subject to even stronger seasonal effects than retail demand due to retailers' attempts to absorb some of the seasonal changes in supply and demand at the retail level (see Capps et al.; Namken, Farris, and Capps). Figure 1 illustrates the seasonal variability in boxed beef prices during 1998 and 1999. For each quarter, the average of monthly Choice prices is statistically different from the average of monthly Select beef prices—i.e., in quarter 1, the price of Choice ($98.75/cwt) is statistically different from the price of Select ($95.81). Furthermore, the averages of monthly Choice and Select beef prices are statistically different across quarters during this time period—i.e., the price of Choice in quarter 1 ($98.75/cwt) is statistically different from the price of Choice in quarter 2 ($105.65/cwt). Demand for Choice and Select boxed beef likely varies during the year, and the substitutability between the two quality grades may also be seasonal.

A better understanding of the seasonal pattern of beef demand and the substitution between "high" and "low" quality beef should provide useful information to cattle producers and beef processors interested in value-based marketing, as well as to marketers interested in introducing differentiated beef to the market. In the past five years, more branded or "high" quality beef has entered the market. Even though products such as Hormel's "always tender" beef or Coleman's "hormone-free" beef have enjoyed recent success, little is known about the substitutability between "high" and "low" quality beef. Further, if a firm wishes to predict success of a differentiated beef product with "high-quality" attributes, understanding the seasonal pattern of demand for Choice versus Select beef should provide insight into choosing appropriate times for debuting a new product and forecasting intra-year profitability.

The primary objective of this research is to contribute to the sparse literature on the demand for quality graded beef. Specifically, we focus on the following areas of investigation: (*a*) estimating wholesale demand for meat (as opposed to primary consumer demand), (*b*) distinguishing the difference in demand for Choice and Select beef, and (*c*) determining the demand interrelationships among Choice beef, Select beef, pork, and chicken across seasons. Monthly data from July 1987 through December 1999 are used to estimate market-level wholesale demand for USDA Choice and Select boxed beef, wholesale pork, and wholesale chicken.

The Model

Data limitations prohibit demand analysis in the traditional fashion (i.e., utility maximization modeled via a flexible functional form such as the Rotterdam or AIDS models) because no aggregate retail price series exists that segregates beef prices or quantities by quality grade. The USDA, however, reports boxed beef prices and production for USDA Choice and Select, the two most frequently assigned beef quality grades. Because boxed beef is an intermediary product, these prices can be viewed as wholesale prices.

The boxed beef market is characterized by decisions of beef packers and beef retailers. Beef packers supply boxed beef to the wholesale market, and meat retailers—who utilize boxed beef as an input into their production process—serve as the source of demand. Development of the conceptual model proceeds as follows: (*a*) first, a firm-level profit maximization model is outlined to identify the appropriate determinants of wholesale (retailer) demand; (*b*) limitations and restrictions imposed by data availability are discussed and incorporated into the model; (*c*) the firm-level factor demands are aggregated into market-level demands; and (*d*) issues such as simultaneity, seasonality, and exogenous trends are discussed.

On a firm-level basis, demand for boxed beef is derived from a retailer's profit maximization decision. Assuming a nonconstant returns-to-scale production technology, the indirect profit function (π) of the retailer is represented by both input and output prices:

$$\pi = \pi^r\left(w_{bp}, w_{bc}, w_{bs}, w_{bo}, w_{pk}, w_c, \mathbf{z}, p_{bp}, p_{bc}, p_{bs}, p_{bo}, p_{pk}, p_c\right), \tag{1}$$

where the w's represent wholesale (input) meat prices, $\mathbf{z}$ represents a vector of other input prices (labor, packaging, storage, etc.), and the p's represent output meat prices. The subscripts bp, bc, bs, bo, pk, and c denote USDA Prime beef, Choice beef, Select beef, other beef, pork, and chicken, respectively. Consistent with Hahn and Green, this

formulation assumes separability in the profit function between meat and all other potential outputs that the retailer may sell.

The factor demands for boxed beef, wholesale pork, and wholesale poultry are derived using the envelope theorem:

$$(2) \qquad q_i = -\frac{\partial \pi}{\partial w_i} = -q_i(\mathbf{w}, \mathbf{z}, \mathbf{p}), \qquad i = bp, bc, bs, bo, pk, c,$$

where $\mathbf{w}$ is a vector of input prices, $\mathbf{p}$ is a vector of output prices (both previously defined), and q_i represents wholesale quantities. Output supply equations for the various meats as well as factor demand for other inputs could be derived in a similar fashion to complete the retailer factor demand/output supply system.

Ideally, one would aggregate to the market level, choose a functional form for the production system, and proceed with an estimation technique; but data limitations prohibit estimation of the complete system. Thus, for practical purposes, the firm-level system of factor demands in (2) is reduced to:

$$(3) \qquad q_i = -\frac{\partial \pi}{\partial w_i} = -q_i(\mathbf{w}, \mathbf{z}, \mathbf{p}), \qquad i = bc, bs, pk, c,$$

where q_i = wholesale meat quantities; $\mathbf{w} = w_{bc}, w_{bs}, w_{pk}, w_c$; $\mathbf{p} = p_b, p_{pk}, p_c$; and $\mathbf{z}$ = an index of food marketing costs.

The retailer's system of factor demands is reduced to equation (3) for several reasons. Availability of reported boxed beef prices is limited to Choice and Select. However, this is not overly restrictive because: (*a*) substitutability between Choice/Select and Prime or other grades is likely to be small, and (*b*) the Choice and Select grades account for over 90% of USDA quality graded beef.[1]

Evidence for the assumed low level of substitution between Choice/Select and other low quality beef can be found in the 1995 "National Beef Quality Audit," a survey of beef purveyors, packers, restauranteurs, and retailers, in which no market segment (export, food service, retail) requested beef graded USDA Standard or lower (Smith et al.). Wholesale (retailer) demand for lower than Select graded beef is relatively insignificant in the context of demand for boxed beef. At the other end of the spectrum, supply of Prime beef typically represents only 1–2% of graded beef, and mostly goes to upscale restaurants; consequently, very limited opportunity exists for substitution to higher than Choice quality grade by retailers. A second limitation on data exists with regard to output prices because no retail price series is available that is uniquely segregated by quality grade. Thus, one retail beef price (p_b) will be used as a proxy for all beef output prices. Choice of the appropriate retail price is discussed in the following section.

The market-level demands for wholesale meats are constructed by summing across the N individual retail demands as shown in equation (4):

$$(4) \qquad Q_i = \sum_{j=1}^{N} q_{ij}(\mathbf{w}, \mathbf{z}, \mathbf{p}), \qquad i = bc, bs, pk, c.$$

These market-level wholesale demands are equivalent to those outlined in the conceptual model presented by Wohlgenant or by Marsh (1994). The aggregate factor demands can also be equivalently viewed as factor demands from an aggregate profit function.

[1] Shackelford, Wheeler, and Koohmaraie found, in their sample of cattle, that the current USDA quality grading system segregated carcasses as follows: 1% Prime, 47% Choice, 47% Select, and 5% Standard.

Shumway, Saez, and Gottret found similar results from aggregating regional factor demand estimates into a national U.S. factor demand and directly estimating aggregate factor demands, using estimates from flexible functional forms with cross-equation restrictions. In addition, Williams and Shumway found that nonparametric tests support the notion of aggregate profit maximization behavior.

On the market level, several issues require attention. First, there is potential for simultaneity between Q_i and w_i. This relationship can be tested and, if necessary, can be accounted for by three-stage least squares. Consistent with Marsh (1994, 1999), we also consider factors such as seasonality and exogenous shifts in technology or retail demand when aggregating to the market level and using monthly data.

Seasonality plays an important role in the market-level demand for wholesale meat, and is a result of seasonal variation in consumer demand and packer supply. Capps et al. found strong seasonal variation in wholesale demands for disaggregated meat products. On the supply side, seasonal increases (decreases) in beef supply reduce (increase) the wholesale price and increase (decrease) quantity demanded. These are essentially movements along the demand curve. Seasonal shifts in the wholesale demand curve may occur because of changes in retail consumer demand by season. Consumers may demand more beef, especially of the higher quality grade, in the summer when cookouts and grilling are more prevalent.

These potential structural shifts in retail demand can translate back to the wholesale level in two ways. First, wholesale demand may shift because of increases or decreases in retail price. Second, wholesale demand may shift (or rotate) to "match" retail demand such that product shrinkage is minimized, supply channels are coordinated, and sequencing of slaughter and delivery are optimized (see Thompson and Wilson for a discussion of the impacts of seasonality on the entire marketing chain for another food with short shelf life, bagged salads).

In the context of fixed proportions, wholesale demand must change systematically with retail demand. Under the strong assumption of fixed proportions, Marsh (1991) and Tomek and Robinson illustrate the link (via simple mathematical formulas) between wholesale and retail demand. Under less restrictive assumptions, Gardner; Marsh (1991); Wohlgenant; and Wohlgenant and Mullen provide alternative formulas to link wholesale and retail demands. In these studies, estimated derived demand elasticites have some mathematical relationship to retail demand elasticities. The exact relationship may not be known, but if some relationship exists, changes in retail demand (such as seasonal shifts due to the cookout season) can be linked back to wholesale demand through market equilibrium conditions (Gardner; Marsh 1991; Tomek and Robinson; Wohlgenant and Mullen; Wohlgenant). To accommodate these factors, the market-level demand equations become:

$$Q_i = Q_i(\mathbf{w}, \mathbf{z}, \mathbf{p}, S, T), \quad i = bc, bs, pk, c, \tag{5}$$

where S represents seasonality (to be empirically specified later), and T represents a trend variable that captures exogenous factors such as improvements in retailer technology or exogenous retailer demand shifts.[2]

[2] Traditional studies estimating factor demands derived from production theory (e.g., Shumway, Saez, and Gottret) implicitly assume technology does not exhibit seasonality. However, traditional marketing studies (e.g., Marsh 1994) that estimate derived demands (which should theoretically be equivalent to the aggregate input demands) include seasonality because of market equilibrium conditions linking retail, wholesale, and farm levels. In our analysis, we include seasonality, but empirically test hypotheses regarding whether and how it should be incorporated into the model.

Data

Data for the total pounds of Choice and Select beef were obtained from the Livestock Marketing Information Center (LMIC). Beef (steer and heifer), pork (barrow and gilt), and chicken slaughter data and retail prices were also obtained from the LMIC. Data for quality graded beef slaughter were recorded as pounds of slaughter over nonuniform time periods. Therefore, values were converted to average daily slaughter (total pounds of slaughter divided by the number of working days in the time period) and were aggregated into monthly values. Such calculation reduced the random variation in the data set that was present due to inconsistent reporting of the slaughter quantities (data were not always monthly, and some periods encompassed several "uneven" months). The same procedure was followed for all quantity variables. Total pounds of hog slaughter were calculated as the number of barrows and gilts slaughtered times the weighted average of barrow and gilt dressing weights. Likewise, total beef slaughter was determined by multiplying all steer and heifer slaughter by the weighted-average steer and heifer dressing weights. Total pounds of chicken slaughter per month were also obtained from the LMIC.

One issue that warrants attention is the rise in popularity of the USDA Select quality grade. In 1986, the USDA changed the name of the existing beef quality grade from Good to Select. The amount of beef graded Select has increased markedly since that time. In 1986, only 1.3 million pounds per month were graded Select as compared to 30.2 million pounds per month in 1999 (LMIC). During this time period, the production of Choice beef remained relatively stable at around 46 million pounds per month. A dilemma arises because much of the beef on the market in the late 1980s and early 1990s had the quality characteristics of USDA Select even though it may have been ungraded—suggesting the price of Select boxed beef was actually representative not only of all Select boxed beef, but much of the "no roll" or ungraded boxed beef during that period. To account for this problem, the quantity of Select is calculated as the total pounds of beef from steer and heifer slaughter minus the total pounds of beef graded Choice and Prime over the 1986–99 time period. Thus, the percentage of Select beef produced is overstated, but by an inconsequential amount.

Data on boxed beef prices (cutout value) for Choice and Select, as well as wholesale prices for pork (wholesale value) and chicken (Georgia dock weighted-average wholesale broiler price) were also obtained from the LMIC. Weekly boxed beef prices for Choice and Select were averaged across weight ranges and were aggregated into monthly values. Data for the Index of Food Marketing Costs (IFMC) were obtained from the USDA/Economic Research Service (ERS). The USDA reports two retail beef price series: the Choice beef retail price series and the "all-fresh" beef retail price series. According to the USDA/ERS (1995), the all-fresh price series was developed in 1987 to give a better representation of fresh beef at the retail level than the Choice retail price series: "The Choice beef series tracks differences in value (price spreads) for equivalent quantities of product at different levels in the marketing chain while the all-fresh beef series represents the quantities of products that move through all consumer markets." Because the all-fresh price series is more representative of all retail beef, it is used for this analysis.[3] The USDA did not

[3] Both the Choice and all-fresh beef retail price series could be used in the factor demand system to attempt to capture the differing effects of quality at the retail level. In practice, however, estimates were not appealing when both variables were added to the model. Standard errors were large, and unintuitive signs were obtained for parameter estimates. One reason for the unappealing results may be that the model was not able to identify separate effects for both variables because the two retail price series are highly correlated (correlation coefficient of 0.94).

Table 1. Variable Definitions and Summary Statistics: Monthly Observations, July 1987–December 1999

Variable	Description	Mean [a]	Standard Deviation
w_{bc}	Choice boxed beef price ($/cwt) [b]	110.46	8.30
w_{bs}	Select boxed beef price ($/cwt)	104.50	8.58
w_{pk}	Pork wholesale value ($/cwt)	106.17	11.60
w_c	Georgia dock weighted avg. broiler price ($/cwt)	54.72	6.41
Q_{bc}	Choice boxed beef quantity (avg. daily slaughter, mil. lbs.)	42.36	3.04
Q_{bs}	Select boxed beef quantity (avg. daily slaughter, mil. lbs.)	32.65	4.80
Q_{pk}	Wholesale pork quantity (avg. daily slaughter, mil. lbs.)	65.51	6.75
Q_c	Wholesale chicken quantity (avg. daily slaughter, mil. lbs.)	90.79	17.52
p_b	"All-Fresh" retail beef price ($/cwt) [b]	255.60	14.96
p_{pk}	Retail pork price ($/cwt)	211.07	22.96
p_c	Retail chicken price ($/cwt)	92.75	7.82

Source: Livestock Marketing Information Center.
[a] Number of observations = 150.
[b] Prices are not deflated.

report the all-fresh price series until July 1987; therefore, the data set begins at this date. Table 1 presents summary statistics of the data.

The Empirical Model

The normalized quadratic was chosen as the functional form for estimation. This functional form is commonly used in production analysis (see Moschini, or Shumway, Saez, and Gottret for examples) and is theoretically as flexible as most commonly used forms because it is derived from a second-order Taylor series expansion. The normalized quadratic was the preferred form (as opposed to the translog or Leontief) in this analysis because of its constant Hessian matrix and the use of absolute quantities as dependent variables as opposed to profit shares (which were unknown due to the incomplete nature of the production system).

The inability to estimate the complete system of factor demand and output supply equations reduces the efficiency of the estimation, but should not cause bias or inconsistency in the coefficient estimates. Regarding imposition of economic regularity conditions in the functional form, we cannot with a large degree of confidence be sure that the aggregate model has the same properties of a firm-level model. Thus, convexity and monotonicity in prices are not maintained in the estimation. As a practical matter, linear homogeneity and symmetry are imposed (see Anderson et al., or Shumway, Saez, and Gottret for examples of imposition of regularity conditions in a market-level model with the normalized quadratic).

To impose homogeneity of degree zero in factor demands, input and output prices were normalized by IFMC. The elasticity estimates for IFMC were recovered by calculating the negative sum of the elasticities in each meat equation. Cross-price symmetry conditions were also imposed during estimation. For example, the derivative of the

Choice beef demand equation with respect to Select beef price was forced to equal the derivative of the Select beef demand equation with respect to Choice beef price. Such restrictions accomplish two goals: (*a*) they conserve valuable degrees of freedom by reducing the number of estimated parameters, and (*b*) they restrict coefficient estimates to have intuitive interpretations (i.e., two goods cannot be both a complement and a substitute).

In the most restricted form of the model, the factor demand equations are written as:

$$(6) \qquad Q_i = \alpha_i + \sum_{k=1}^{4} \beta_{ik} w_k' + \sum_{j=1}^{3} \gamma_{ij} p_j' + \mu_i T + \varepsilon_i, \qquad i = bc, bs, pk, c,$$

where Q_i are the quantities (calculated as average daily pounds slaughtered in millions) of Choice and Select beef, wholesale pork, and wholesale chicken; w_k' are normalized wholesale prices of Choice and Select beef, pork, and poultry; and p_j' are normalized retail prices of beef, pork, and chicken. T is a trend variable added to account for exogenous factors not included in the model.[4] Both retail and wholesale prices were normalized by IFMC. Estimable parameters are represented by α, β, γ, and μ. Symmetry was imposed by restricting $\beta_{ik} = \beta_{ki}$.

Empirically, seasonality may be incorporated into the model in a number of ways. First, one may contend that the wholesale demands should not exhibit seasonality [i.e., equation (6)]. Alternatively, seasonality can simply be modeled as dummy variables that shift the constant term. Further, the demand for wholesale meat in different quarters may also have different elasticities. That is, there may be structural shifts in meat demand by quarter. Seasonal changes in retail demand may cause wholesale demand to shift because of market equilibrium conditions relating retail and wholesale demand (discussed and illustrated in Gardner; Marsh 1991; Tomek and Robinson; Wohlgenant and Mullen; and Wohlgenant).

The most general version of the wholesale meat demand model, which accounts for both forms of seasonality, is specified as:

$$(7) \qquad Q_i = \alpha_i + \sum_{k=1}^{4} \sum_{t=1}^{4} \beta_{ikt} w_{kt}' d_t + \sum_{j=1}^{3} \gamma_{ij} p_j' + \sum_{t=1}^{3} \lambda_{it} d_t + \mu_i T + \varepsilon_i, \qquad i = bc, bs, pk, c.$$

In this formulation, quarterly dummy variables are represented by d_t, where d_1 takes the value of one for January, February, and March; d_2 takes the value of one for April, May, and June; d_3 takes the value of one for July, August, and September; and d_4 takes the value of one for October, November, and December. Here, the normalized wholesale prices are multiplied by the quarterly dummy variables. Thus, there are unique own- and cross-price effects for each meat group for each quarter. In addition to these seasonally varying own- and cross-price elasticities, the constant term is also shifted by quarter [i.e., the λ coefficients in equation (7)]. Homogeneity of degree zero in prices was maintained and symmetry was imposed for each quarter by restricting $\beta_{ikt} = \beta_{kit}$.

Using the general model, presented in equation (7), several hypotheses can be tested regarding the influence of seasonality on wholesale demand. First, there may be no seasonal influence [i.e., $\beta_{ik1} = \beta_{ik2} = \beta_{ik3} = \beta_{ik4}\ \forall\, i, k$, and $\lambda_1 = \lambda_2 = \lambda_3 = 0$ in equation (7)]. These

[4] The sign and statistical significance of the parameter estimates are generally unchanged by the inclusion or exclusion of the trend variable.

restrictions would essentially produce equation (6). Second, seasonality may exist, but only by shifting the constant term [i.e., equation (7), with $\beta_{ik1} = \beta_{ik2} = \beta_{ik3} = \beta_{ik4} \forall\ i, k$]. Third, own- and cross-price estimates may vary by quarter, but the constant may not shift by quarter [i.e., equation (7), with $\lambda_1 = \lambda_2 = \lambda_3 = 0$]. Finally, own- and cross-price estimates may vary seasonally and the constant may shift by quarter [i.e., equation (7)]. Likelihood-ratio tests are used to identify the appropriate model.

Elasticity estimates for changes in wholesale meat quantities with respect to changes in wholesale meat prices are calculated as:

$$\varepsilon_{ik} = \frac{\partial Q_i}{\partial w_k} \frac{\bar{w}_k'}{\bar{Q}_i} = \hat{\beta}_{ik} \frac{\bar{w}_k'}{\bar{Q}_i}, \tag{8}$$

where $\bar{w}_k'$ and $\bar{Q}_i$ are the mean values for w_k' and Q_i, respectively.

Results

Table 2 shows the results of tests for seasonal specification in the empirical model. Likelihood-ratio test statistics strongly support the presence of seasonality in the model. The simplest model [equation (6)/model 1 in table 2] is enhanced with the introduction of seasonal dummy shifters (model 2 in table 2); however, the most general version of the model [equation (7)/model 4 in table 2] provides the best fit of the data.[5] We report the results for two models: (*a*) a "traditional model" with seasonal dummy shifters and constant own- and cross-price elasticities across season, and (*b*) a model with seasonal varying constants and own- and cross-price elasticities [equation (7)/model 4 in table 2].

The traditional model with quarterly shifters and constant own- and cross-price elasticities was estimated using seemingly unrelated regression procedures (table 3). Durbin-Watson (DW) and R^2 statistics are reported for each equation.[6] The R^2 statistics indicate a reasonably good fit of the model. The Hausman test for exogeneity of wholesale prices was performed using lagged own-prices, lagged meat production for beef, pork, and chicken, fed cattle prices, lean hog prices, a trend variable, and quarterly dummy variables as instruments. The null hypothesis that prices were exogenous could not be rejected (p-value = 0.21).

Consistent with economic theory, beef and pork own-price effects are negative, indicating meat retailers demand less quantity as the price of each respective meat increases, ceteris paribus. All own-price effects are statistically different from zero, except chicken, at the 0.01 level of significance. Results indicate that Choice and Select boxed beef are substitutes. Pork is a substitute for both Choice and Select beef, but chicken is only a substitute for Select beef. Thus, chicken may be substituted for low quality, but not high quality beef. Further, estimates suggest that pork and chicken are substitutes. Other than Choice beef and chicken, for which there is no statistical relationship, all meats are substitutes for meat retailers.

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[5] The exact cause of the statistical significance of the seasonal model specifications is unknown. Meat demands may be seasonal due to a myriad of factors, such as shifts in retail demand, changes in packer supply, dynamic processes not captured by the model, etc. Given the nature of the estimates, it appears that seasonal shifts in retail demand may be driving much of the significance; however, we cannot rule out other factors.

[6] Likelihood-ratio tests, as described by Judge et al., indicated the presence of systemwide autocorrelation. Thus, estimates reflect an adjustment for a first-order autoregressive process in each equation (as shown in Judge et al.).

Table 2. Likelihood-Ratio Test Results for Seasonality in the Wholesale Meat Demand Models

Model	Seasonal Constant	Seasonal Slopes	LogL Value	χ^2 Statistics from Likelihood-Ratio Test		
				Model 4	Model 3	Model 2
1	No	No	-1,314	190*	164*	152*
2	Yes	No	-1,238	38*	12	—
3	No	Yes	-1,232	26*	—	—
4	Yes	Yes	-1,219	—	—	—

Note: An asterisk (*) denotes statistical significance at the 0.05 level.

Table 3. Wholesale Meat Demand Estimates for Traditional Model: Normalized Quadratic with Seasonal Shifters, July 1987–December 1999

Independent Variable	Dependent Variable			
	Q_{bc} Choice Beef	Q_{bs} Select Beef	Q_{pk} Pork	Q_c Chicken
Constant	-29.680* (-1.62)	-2.006 (-0.17)	103.160*** (15.67)	66.455*** (7.96)
w'_{bc}	-69.719*** (-3.14)	—	—	—
w'_{bs}	33.500** (1.65)	-83.245*** (-3.52)	—	—
w'_{pk}	24.049*** (2.25)	20.760** (1.87)	-122.800*** (-12.588)	—
w'_c	-10.259 (-0.63)	30.784* (1.62)	18.954** (1.68)	-13.800 (-0.57)
p'_b	83.621*** (4.09)	39.403*** (2.80)	-34.960*** (-4.18)	-20.012** (-1.78)
p'_{pk}	24.986 (1.31)	8.313 (0.67)	21.345*** (2.73)	-17.118** (-1.69)
p'_c	22.281 (0.69)	2.664 (0.12)	-49.173*** (-2.67)	-8.436 (-0.29)
d_1 [a]	2.961*** (5.77)	-0.591 (-1.02)	-5.297*** (-9.62)	0.861 (1.33)
d_2	2.850*** (4.72)	3.243*** (5.06)	-7.058*** (-10.89)	1.459*** (2.07)
d_3	0.995*** (2.05)	1.157*** (2.11)	-5.818*** (-8.65)	0.804 (1.20)
Trend	0.078* (1.60)	0.084*** (4.57)	0.054*** (5.20)	0.407*** (29.60)
R^2	0.61	0.84	0.87	0.98
DW Statistic	2.28	1.93	1.93	1.96

Notes: Single, double, and triple asterisks (*) denote statistical significance at the 0.15, 0.10, and 0.05 levels, respectively. Numbers in parentheses are t-statistics for the parameter estimates. Number of observations = 150.

[a] d_i are dummy variables for each quarter.

Table 4. Wholesale Meat Demand Elasticities, July 1987–December 1999

	Wholesale Price of:					Retail Price of:		
Demand for:	Choice Beef	Select Beef	Pork	Chicken	IFMC[a]	Beef	Pork	Chicken
Choice Beef	-0.432***	0.196**	0.142***	-0.031	-1.476***	1.192***	0.292	0.115
	(-3.14)	(1.65)	(2.25)	(-0.63)	(-3.48)	(4.09)	(1.31)	(0.69)
Select Beef	0.269**	-0.633***	0.160**	0.122*	-0.790***	0.729***	0.126	0.018
	(1.65)	(-3.52)	(1.87)	(1.62)	(-2.09)	(2.80)	(0.67)	(0.12)
Pork	0.096***	0.079**	-0.471***	0.037**	0.584***	-0.322***	0.162***	-0.164***
	(2.25)	(1.87)	(-12.59)	(1.68)	(6.24)	(-4.18)	(2.73)	(-2.67)
Chicken	-0.030	0.084*	0.052**	-0.020	0.160**	-0.133**	-0.094**	-0.020
	(-0.63)	(1.62)	(1.68)	(-0.57)	(1.82)	(-1.78)	(-1.69)	(-0.29)

Notes: Single, double, and triple asterisks denote statistical significance at the 0.15, 0.10, and 0.05 levels, respectively. Elasticity estimates are calculated at the mean price and quantity values. Numbers in parentheses are *t*-statistics.

[a] Index of Food Marketing Cost (IFMC) elasticities are calculated using homogeneity properties.

Retail meat prices have a strong influence on wholesale demand. Of the four own-commodity retail price coefficients, only the chicken retail price was insignificant. One would expect the quantity of meat demanded by retailers to increase as retail price of the respective meat rises. Increases in beef retail price increase the quantity of Choice and Select boxed beef demanded; likewise, increases in pork retail price increase the quantity of wholesale pork demanded. Cross-commodity retail prices were also significant determinants of wholesale meat demand. Increases in retail beef price have a negative influence on the amount of wholesale pork and chicken demanded by meat retailers. Changes in retail beef price appear to have almost as much if not more of an impact on wholesale pork and chicken demand than equivalent changes in wholesale pork and chicken prices, respectively. Last, wholesale chicken demand is negatively influenced by increases in retail pork price.

Wholesale meat demand elasticies calculated at the mean price and quantity values are reported in table 4. The magnitudes of the own-price elasticity estimates are consistent with prior expectations. Choice and Select beef have own-price elasticities of demand of -0.43 and -0.63, respectively. Respective wholesale demand elasticity estimates for pork and chicken are -0.47 and -0.02. The own-price wholesale demand elasticity estimates are lower than those found in retail demand studies (Eales and Unnevehr 1993; Brester and Wohlgenant), which is consistent with the traditional concept of derived demand where one would expect wholesale demand elasticities to be lower in absolute value than retail demand elasticities.[7]

Table 4 results also reveal that a 1% increase in the price of Choice is associated with a 0.27% increase in the quantity of Select demanded, whereas a 1% increase in the price of Select is associated with a 0.20% increase in the quantity of Choice demanded by meat retailers. Price changes in Choice have a larger impact on the quantity of Select demanded than the reverse. Although Choice and Select are substitutes, elasticity estimates indicate that changes in own-price and retail beef price have a larger influence on wholesale beef demand than changes in the price of the opposing beef quality grade.

[7] In a more general framework, Gardner discussed a special case where own-price derived demand elasticities can actually be greater in absolute value than retail demand elasticities.

Elasticity estimates for IFMC are calculated using homogeneity properties. Based on these elasticities, an increase in IFMC reduces the amount of Choice and Select beef demanded, but increases the quantity of wholesale pork and chicken demanded.

Table 5 shows the estimation results for the most general model specification [equation (7)].[8] Each wholesale meat product has four own-price effects, one for each quarter of the year. Cross-price effects for each meat are also differentiated by season. Negativity of own-price effects holds for Choice beef, Select beef, and pork in all quarters of the year. However, Choice beef own-price effects are statistically significant only in quarters 1 and 4, and Select beef own-price effects are significant in quarters 1, 3, and 4. Pork own-price effects are statistically different from zero in all quarters of the year. Chicken own-price effects are not significantly different from zero in any quarter of the year.

Choice and Select boxed beef are substitutes in quarter 4; however, this relationship is not statistically significant in the first, second, or third quarters. As compared to the previous estimation (table 3), segregating the meats into quarterly estimates provides more information about the interaction between meats. For example, while the earlier estimation did not find a statistically significant cross-price effect between Choice beef and chicken, table 5 reveals these meats are complements during the second quarter of the year. Choice and Select beef are substitutes for pork in the second, third, and fourth quarters of the year.

Table 6 presents the estimated elasticities of Choice and Select beef by quarter. The elasticity estimates are calculated at the mean values of each quarter. As seen from the table 6 estimates, demand for both beef quality grades becomes more inelastic during the second and third quarters than in the first or fourth quarters of the year. These findings may be an artifact of retailers responding to changes in retail demand. The second and third quarters (April through September) are typically considered "grilling" months. Retailers may adjust their demand for beef during this time period to accommodate changes in consumer demand. Retailer elasticity of demand for Choice varies from -0.11 to -0.46 in quarters 3 and 4, respectively. Additionally, retailer demand for Select is two and a half times more elastic in quarter 1 as compared to quarter 2. In all four quarters of the year, retailer demand for Select beef is more elastic than demand for Choice beef. Cross-price elasticities between Choice and Select also vary seasonally. Choice and Select are substitutes for each other in the fourth quarter of the year. However, in quarters 2 and 3 (the "grilling" months), Choice and Select beef are not substitutes. During this time of increased steak consumption, retailers are not willing to accept low quality beef as a replacement for Choice, even at significant price discounts.

Conclusions and Implications

In recent years, the beef industry has experienced increased labeling and product differentiation as it attempts to meet consumer preferences. One type of differentiation is provided via the USDA beef quality grading system. Demand for quality graded beef at the retail level has resulted in beef packers offering cattle producers premiums and discounts based upon the quality and yield grades of their cattle. Although increasing

[8] The system was estimated using seemingly unrelated regression procedures with an adjustment for first-order autocorrelation.

Table 5. Wholesale Meat Demand Estimates for General Model: Normalized Quadratic with Seasonal Own- and Cross-Price Effects, July 1987–December 1999

Independent Variable	Dependent Variable			
	Q_{bc} Choice Beef	Q_{bs} Select Beef	Q_{pk} Pork	Q_c Chicken
Constant	-32.442***	1.493	104.700***	74.273***
	(-2.01)	(0.13)	(15.01)	(8.48)
$w'_{bc} \times d_1$ [a]	-58.727**	—	—	—
	(-1.91)			
$w'_{bc} \times d_2$	-30.966	—	—	—
	(-1.09)			
$w'_{bc} \times d_3$	-18.028	—	—	—
	(-0.52)			
$w'_{bc} \times d_4$	-72.141***	—	—	—
	(-3.16)			
$w'_{bs} \times d_1$	19.164	-71.023***	—	—
	(0.66)	(-2.25)		
$w'_{bs} \times d_2$	-21.222	-33.938	—	—
	(-0.72)	(-1.00)		
$w'_{bs} \times d_3$	-2.811	-65.960**	—	—
	(-0.09)	(-1.87)		
$w'_{bs} \times d_4$	55.458***	-113.170***	—	—
	(3.29)	(-3.64)		
$w'_{pk} \times d_1$	8.957	14.343	-123.28***	—
	(0.67)	(0.95)	(-8.33)	
$w'_{pk} \times d_2$	22.757**	31.167***	-118.45***	—
	(1.95)	(2.43)	(-8.96)	
$w'_{pk} \times d_3$	25.625***	28.937***	-121.49***	—
	(2.09)	(2.15)	(-9.56)	
$w'_{pk} \times d_4$	23.011**	19.566*	-123.57***	—
	(1.86)	(1.50)	(-9.32)	
$w'_c \times d_1$	-18.935	15.772	10.002	14.980
	(-0.96)	(0.70)	(0.59)	(0.42)
$w'_c \times d_2$	-35.764**	63.732***	15.494	33.399
	(-1.69)	(2.66)	(1.05)	(1.02)
$w'_c \times d_3$	8.683	40.921***	8.112	-20.976
	(0.47)	(2.04)	(0.53)	(-0.70)
$w'_c \times d_4$	-1.47	11.588	29.927**	-29.876
	(-0.07)	(0.487)	(1.97)	(-1.04)
p'_b	84.724***	43.115***	-36.079***	-22.629***
	(5.54)	(3.40)	(-4.58)	(-2.09)
p'_{bk}	16.279	4.980	20.015***	-16.532*
	(0.90)	(0.42)	(2.78)	(-1.60)
p'_c	23.227	3.992	-51.944***	-29.456
	(0.98)	(0.18)	(-3.04)	(-1.02)

(continued . . .)

Table 5. Continued

Independent Variable	Dependent Variable			
	Q_{bc} Choice Beef	Q_{bs} Select Beef	Q_{pk} Pork	Q_c Chicken
d_1	14.058***	-0.896	2.137	3.897
	(2.97)	(-0.18)	(0.39)	(0.61)
d_2	15.632***	-5.878	-9.406**	-6.946
	(2.87)	(-1.01)	(-1.83)	(-1.14)
d_3	-0.878	-1.42	-6.431	-4.295
	(-0.17)	(-0.25)	(-1.19)	(-0.63)
Trend	0.084**	0.084***	0.052***	0.403***
	(1.75)	(4.89)	(5.31)	(27.325)
R^2	0.61	0.85	0.88	0.98
DW Statistic	2.27	1.92	1.92	1.95

Notes: Single, double, and triple asterisks (*) denote statistical significance at the 0.15, 0.10, and 0.05 levels, respectively. Numbers in parentheses are t-statistics for the parameter estimates. Number of observations = 150.

[a] d_i are dummy variables for each quarter.

Table 6. USDA Choice and Select Beef Own-Price and Cross-Price Demand Elasticities by Quarter, July 1987–December 1999

	Wholesale Price of Choice				Wholesale Price of Select			
Demand for:	Quarter 1	Quarter 2	Quarter 3	Quarter 4	Quarter 1	Quarter 2	Quarter 3	Quarter 4
Choice	-0.360*	-0.194	-0.108	-0.461**	0.114	-0.126	-0.016	0.331**
	(-1.91)	(-1.09)	(-0.52)	(-3.16)	(0.66)	(-0.72)	(-0.09)	(3.28)
Select	0.173	-0.163	-0.021	0.453**	-0.625**	-0.247	-0.460*	-0.862**
	(0.66)	(-0.72)	(-0.09)	(3.28)	(-2.25)	(-1.00)	(-1.87)	(-3.64)

Notes: Single and double asterisks (*) denote statistical significance at the 0.10 and 0.05 levels, respectively. Elasticity estimates are calculated at the mean price and quantity values for each quarter. Numbers in parentheses are t-statistics.

importance at the retail and farm levels has been placed on the USDA beef quality grading system, little research has been conducted regarding demand and supply of different beef quality grades.

This research contributes to the sparse knowledge of the demand for Choice and Select beef. Meat retailer factor demand equations were estimated using monthly data from July 1987 through December 1999. Retailer demand for Choice beef is more inelastic than that for Select. The two beef quality grades are substitutes for each other during the winter. During the summer, however, Select beef is not a substitute for Choice. Apparently, retailer demand for Choice beef cannot be met by changes in relative prices of lower quality beef during the cookout season. In addition, demand for both Choice and Select beef becomes much more inelastic during the spring and summer than during the fall and winter.

Results of this study indicate that changes in retail beef prices have a strong influence on wholesale meat demand. For Choice beef, Select beef, and chicken, the beef retail price elasticity is larger in absolute value than own-price elasticity estimates. For pork,

the two elasticity estimates are similar in magnitude. Changes in consumer preferences that increase retail beef demand result in increases in Choice and Select boxed beef and decreases in the quantities of wholesale pork and chicken demanded.

Using the estimates in this study, beef packers may be better able to predict losses or gains in sales associated with relative price changes. For example, a 1% increase in boxed beef price would cause a larger reduction in sales in the fall and winter than during the spring and summer. Moreover, in response to an increase in the price of Choice beef in the second or third quarters of the year, sales of Select beef may not decline as much in comparison to a similar price increase during winter.

The relative inelasticity of Choice beef demand has interesting implications for the beef industry. Our findings show that large changes in the price of Choice beef (i.e., an increase in the Choice-to-Select price spread) will result in relatively small changes in the amount of Choice beef on the market. Estimates suggest the Choice-to-Select price spread would have to change by a large amount to induce retailers to demand more Choice beef, and thus encourage cattle producers to produce more Choice cattle, especially in the summer and in the short run.

The estimates presented here help to explain a recent phenomenon in the beef industry. In 2000, the Choice-to-Select price spread fell from over $14/cwt in June to less than $4/cwt in August; however, the percentage of quality graded beef that graded Choice or higher only increased from 59.41% in June to 59.48% in August. The beef industry's attempt to meet consumer desires and increase the quality of beef in the market appears to be hindered by the finding that relatively large premiums for high quality beef have only a small impact on retailers' demand for higher quality beef, especially during certain times of the year.

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