SOME EVIDENCE AND IMPLICATIONS OF STRUCTURAL CHANGE IN RETAIL DEMAND FOR MEATS

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Economic theory suggests that demand behavior is time variant, but does not offer much insight into the nature of the temporal variation. For practical purposes, at least two interpretations regarding the time behavior of demand relationships may be advanced. Considering behavior of demand parameters, demand relations may be regarded as continuously varying over time (Cooley and Prescott), or, alternately, changing between successive time intervals (Goldfeld and Quandt).

A problem area to which the former is applicable is exemplified by recent work of Ward and Tilley; the latter has been discussed by Tomek (p. 350) and is reflected in the real world by episodic changes in demand relations—the result of such factors as seasons, advertisements, taste, public policy, or business cycles. Within this framework, demand relations are envisaged as changing over time, but once the change occurs, the effect prevails and is observable over a definite time period. That is, the effect may last one or more months, one or more seasons, or one or more years.

On the basis of the behavior of the parameters under these circumstances, a structural change is said to occur whenever the parameters of a model change a "small" number of times within the sample period in response to forces within or outside the model. As such, the overall relationship can be represented by a continuous piecewise function (Poirier, p. 1).

The explicit recognition and parameterization of such structural changes have important implications in demand and price analysis to the extent that they underlie several decisions related to marketing programs and plans, and to public policy in the areas of trade, food, nutrition, and commodity programs. In particular, in both the private and public sectors, specific programs, plans, and policies are periodically evaluated. A more accurate estimation and a clearer understanding of past relationships improve the reliability of the evaluations and suggest more decisively the program areas that need to be sustained or revised.

There are several instances in which researchers select a "typical" time period for analysis, and it is presupposed that no structural change occurred within the period. If the structure has changed, the estimated equation would be a hybrid, neither applicable to the period before nor after the structural change (Tomek and Robinson, p. 305). Still the equation might be incorrectly judged as acceptable according to conventional statistical tests.

Therefore, this paper examines the nature of structural change in the U.S. retail demand for meats in the light of the preceding discussion. Meat production occupies an important role in the U.S. agricultural sector and is linked to the other agricultural subsectors in a complex way. On the demand side, meat is the single commodity group that accounts for the highest proportion of consumer food expenditures, with several substitution and complementarity consumption relations among specific meat items. These suggest that the demand structure of specific meat items is considerably exposed to forces of change.

THE MODEL

With a maintained hypothesis concerning the functional form, a linear per capita consumption quantity of each commodity is expressed as a function of own price, prices of other meats, income, and seasonal dummy variables. A linear spline transformation is incorporated in the basic specification to permit parameter variations that characterize and enable easy and straightforward evaluation of structural change.

Consider a linear demand model of the form:

$$(1) \quad c_{it} = b_o + b_i p_{it} + b_i y_{it} + Y_j p_{jt} + e_{it}$$

where c_{it} is per capita consumption quantity and p_{it} is the price of the ith commodity in the tth period, respectively; y_{it} is the per capita income during t, p_{jt} are the prices of other commodities $(j = 1,2, \ldots, J)$ during t; and the error terms, ϵ_{it}.

Equation (1) is respecified as a linear spline function by first making some transformations, using the following notations. For any independent variable form, say p_{it}, there is a set V such that:

$$(2) \quad V = | \bar{p}_{1i} < \bar{p}_{2i} < \ldots < \bar{p}_{m-1,i} |$$

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where the elements of (2), conventionally referred to as knots, are specific values of p_{it}. Define:

$$(3)\quad \begin{aligned} W_{1i} &= p_{it} \\ W_{mi} &= p_{it} - \bar{p}_{m-1,i}, \text{ if } p_{it} > \bar{p}_{m-1,i} \\ &= 0 \qquad\qquad , \text{ if } p_{it} \leqslant \bar{p}_{m-1,i} \\ &\text{for } m = 2,3, \ldots, M. \end{aligned}$$

Then for p_{it} a linear spline $S_\Delta p_{it}$ can be expressed as:

$$(4)\quad S_\Delta p_{it} = \beta_{1i} W_{1i} + \beta_{2i} W_{2i} + \ldots + \Delta_{mi} W_{mi}$$

such that $S_\Delta p_{it} = E\{c_i|p_i\}$. Substituting (3) into (1) leads to a respecified demand function for a specific commodity, i:

$$(5)\quad c_t = \alpha_0 + \beta_1 W_1 + \beta_2 W_2 + \ldots + \beta_m W_m + by_t + Y_j p_{jt} + e_t$$

The transformations (3) and the reformulation of the demand model as a linear spline function can be done on the desired number of independent variables.

The problem is then to estimate the parameters of (5); and with the estimates of β_m's, it is a simple matter to test statistically (t-test) for parameter variations based on:

$$(6)\quad \begin{aligned} H_N&: \beta_m = 0, \\ H_A&: \beta_m \neq 0, \\ &\text{for each } \beta_m,\ m = 2,3, \ldots, M \end{aligned}$$

and for structural change in the overall relationship (5), an F-test is undertaken based on:

$$(7)\quad \begin{aligned} H_N&: \beta_2 = \beta_3 = \ldots = \beta_m = 0 \\ H_A&: \beta_2 \neq \beta_3 \neq \ldots \neq \beta_m \neq 0 \\ &\text{for all } \beta_m\text{'s},\ m = 2,3, \ldots, M. \end{aligned}$$

IDENTIFYING POINTS OF STRUCTURAL CHANGE

Usually the points of structural change or knots [in the spirit of (2)] are not known precisely, yet need to be prespecified. However, these could be determined statistically, using the cumulative sums of squares (CUSUMSQ) test suggested by Brown, et al. Based on recursively computed residuals, the CUSUMSQ test examines structural stability by plotting against time the values for :

$$(8)\quad S_r = \sum_{j=k+1}^{r} e_j^2 \Big/ \sum_{j=k+1}^{T} e_j^2,\ r = k+1, \ldots, T$$

where e_j's are the residuals.

The expectation of S_r, $E[S_r] = r-k/T-k$ and the pair of significance lines take the form $(r-k/T-k) \pm C$. The value of C is obtained from the Table of Significance Values for CUSUMSQ Test. The significance lines lie symmetrically about the mean value line, $E[S_r]$, and when superimposed on the plot of (8) provide a basis for the test of constancy of the regression coefficients. More specifically, given any level of significance, the point at which the sample path moves outside the significance lines denotes a point of coefficient change.

The CUSUMSQ test was applied to detect points of structural change in the following demand equations:

$$(9)\quad BEEFC_t = b_0 + b_1PBEEF + b_2PPORK + b_3PCHICK + b_4PTURK + b_5INCOME + b_6DUM1 + b_7DUM2 + b_8DUM3 + u_t$$

$$(10)\quad CHICKC_t = b_0 + b_1PBEEF + b_2PPORK + b_3PCHICK + b_4PTURK + b_5INCOME + b_6DUM1 + b_7DUM2 + b_8DUM3 + u_t$$

$$(11)\quad PORKC_t = b_0 + b_1PBEEF + b_2PPORK + b_3PCHICK + b_4PTURK + b_5INCOME + b_6DUM1 + b_7DUM2 + b_8DUM3 + u_t$$

$$(12)\quad TURKC_t = b_0 + b_1PBEEF + b_2PPORK + b_3PCHICK + b_4PTURK + b_5INCOME + b_6DUM1 + b_7DUM2 + b_8DUM3 + u_t$$

where per capita quantity consumption of beef (BEEFC), chicken (CHIKC), pork (PORKC), and turkey (TURKC) is specifically expressed as a linear function of prices of beef (PBEEF), pork (PPORK), chicken (PCHICK), turkey (PTURK), income (INCOME) and the seasonal dummies (DUM1, DUM2, DUM3), respectively. The error term is denoted by u, and t refers to time period.

Quarterly data from several issues of *Food Consumption, Prices and Expenditures,* and from *Livestock and Meat Statistics* were used in the study. All prices and consumption data are for the retail level, and the monetary measurements are based on 1971 prices. The period covered is 1965(I) to 1979(III), inclusive.

The results of the CUSUMSQ tests to determine points of structural change in equations (9)–(12) are presented in Figures 1–4, where the

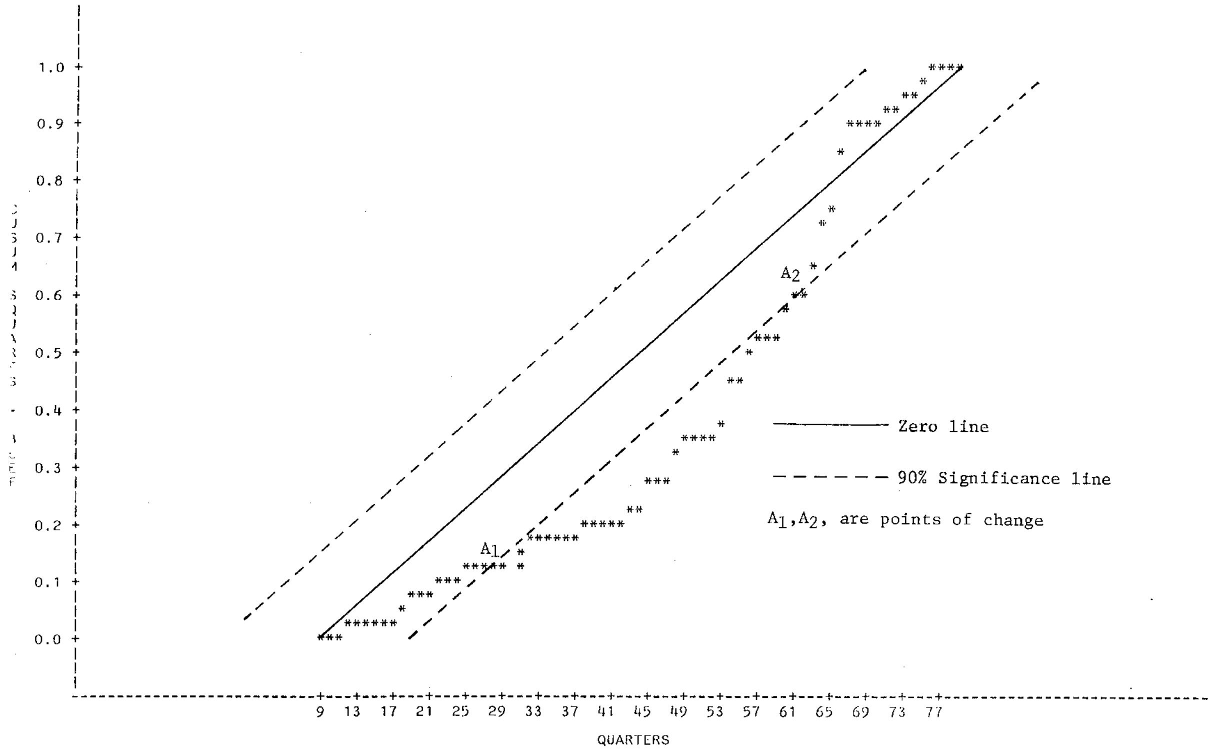

FIGURE 1. CUSUM Squares Residual Plot—Beef

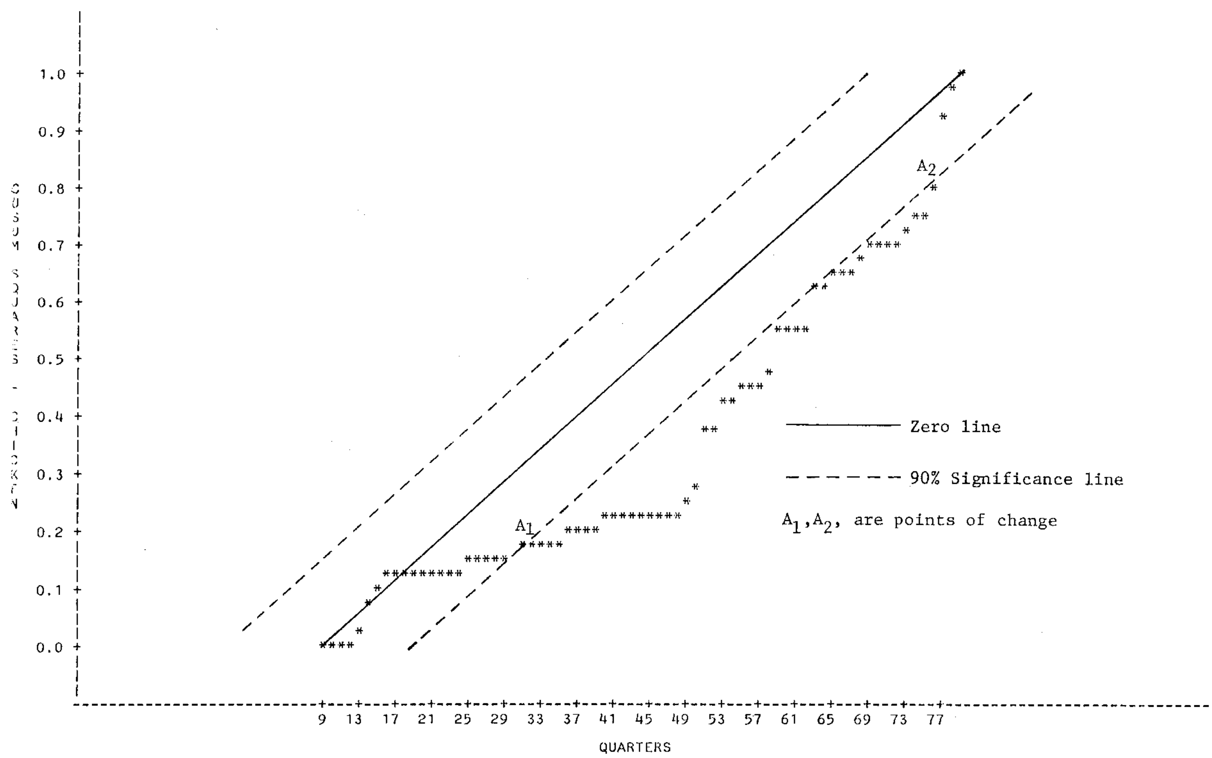

FIGURE 2. CUSUM Squares Residual Plot—Chicken

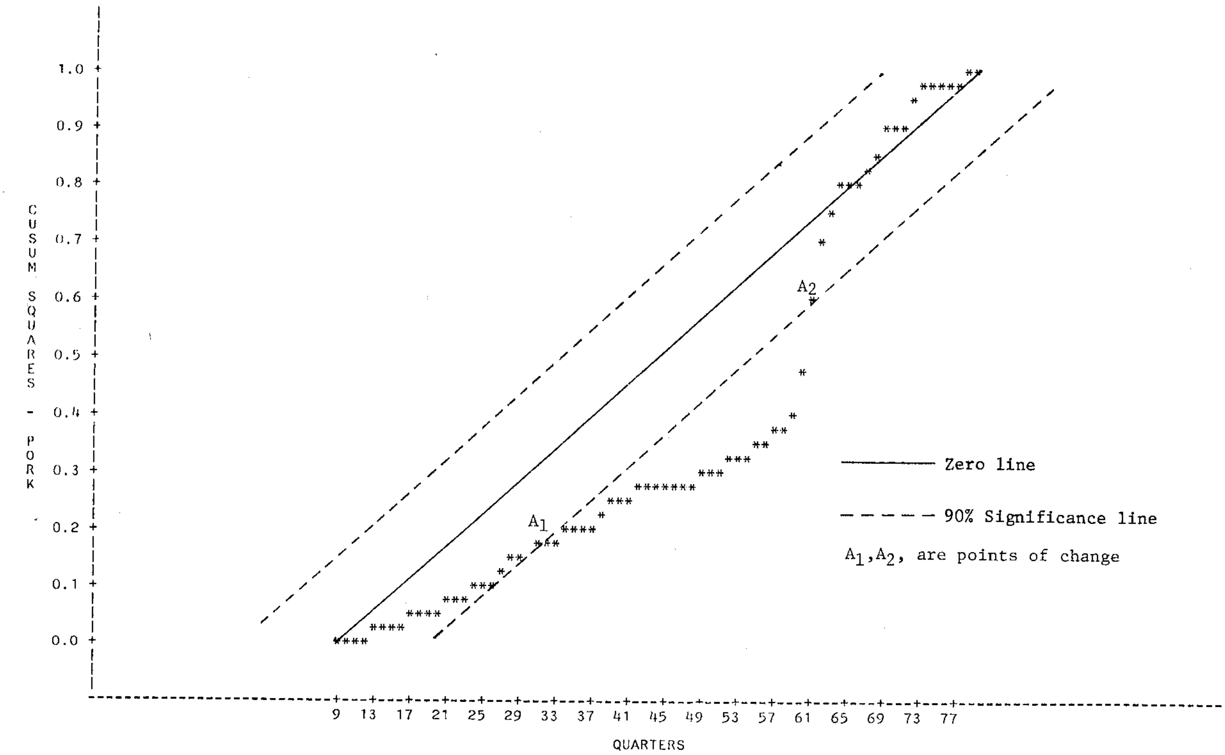

FIGURE 3. CUSUM Squares Residual Plot—Pork

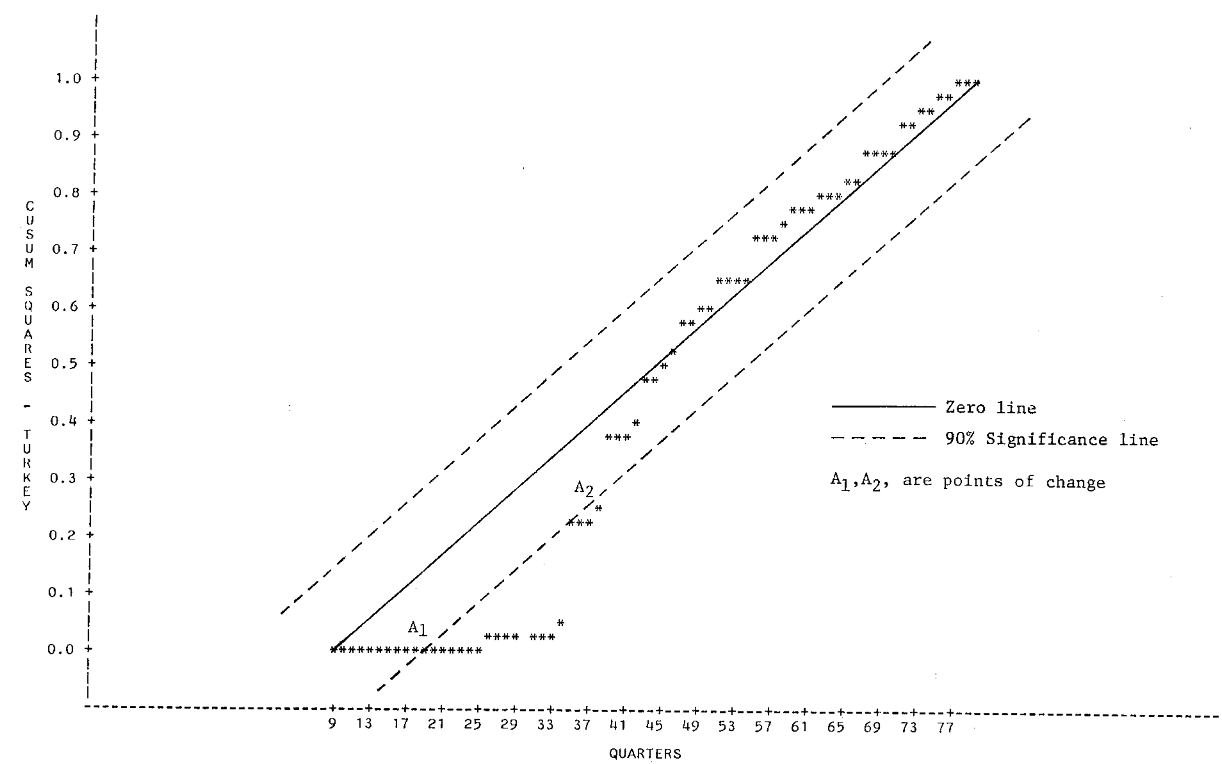

FIGURE 4. CUSUM Squares Residual Plot—Turkey

cumulative sums of squares residuals are plotted against time with the mean value line (solid), and the significance lines (hashed) are superimposed. The intersections between the sample path and the significance lines, A_1 and A_2 in Figures 1–4, denote points of coefficient changes. The corresponding values of p_{it} at A_1 and A_2 become p_{1i} and p_{2i} of (2), respectively. Then, for example, the independent variable PBEEF by (3) becomes PBEEF1 and all PBEEF greater than p_1 and PBEEF2 for all values of PBEEF greater than p_2, where p_1 and p_2 are the values of p_{it} corresponding to A_1 and A_2, respectively. The same procedure is repeated for all applicable independent variables. The transformed variables and the estimated coefficients are reported in Table 1.

RESULTS

In general, the estimated own price and income coefficients have the expected signs and high t-ratios. The R^2 are generally high, and there is no conclusive evidence of serial correlation on the basis of computed Durbin-Watson statistics. Based on the tests (6) for individual independent variables, there is evidence of slope changes in the beef demand equation for own price, income, pork, and chicken price coefficients. The chicken demand equation shows evidence of slope changes in the turkey and own price coefficients; the pork equation shows evidence of slope changes in all except the turkey price coefficient; and the turkey demand equation shows evidence of slope changes only in the income coefficient.

TABLE 1. Estimated Coefficients of the Demand Equation

	Dependent variables			
	BEEFC	PORKC	CHICKC	TURKC
CONSTANT	14.067	9.357	2.829*	-6.917
	(4.25)	(1.78)	(0.64)	(-1.14)
DUM1	-0.257	-0.346	-0.288	-3.241
	(-1.74)	(-1.48)	(-1.70)	(-52.2)
DUM2	0.356	-1.555	0.205	-2.999
	(2.27)	(-4.24)	(1.13)	(-45.1)
DUM3	0.133*	-1.264	0.346	-2.134
	(0.13)	(-5.43)	(1.90)	(-34.5)
PBEEF	-0.139	0.122	0.058	0.199
	(-3.38)	(1.88)	(1.19)	(2.41)
PBBEF1	0.115	-0.169	-0.051*	-0.282
	(2.00)	(-1.85)	(-0.82)	(-2.88)
PBEEF2	-0.14*	-0.008*	-0.017*	0.082
	(-0.31)	(-0.11)	(-0.36)	(2.53)
PPORK	0.061	(-0.123	0.068	-0.086
	(2.86)	(-3.62)	(1.88)	(-2.31)
PPORK1	-0.107*	-0.337	-0.122	0.117
	(-0.33)	(-1.43)	(-1.96)	(2.55)
PPORK2	0.056*	0.763	0.027*	0.033
	(0.17)	(1.50)	(0.63)	(-1.71)
PCHICK	-0.053	0.078	-0.176	0.0024*
	(-1.19	(1.10)	(-2.11)	(0.15)
PCHICK1	-0.312	0.208*	0.075*	0.028*
	(2.15)	(0.90)	(0.28)	(0.44)
PCHICK2	0.316	-0.247*	0.116*	-0.013*
	(1.93)	(-0.95)	(0.36)	(-0.17)
PTURK	0.076	-0.021*	-0.084	-0.0512
	(2.23)	(-0.39)	(-1.39)	(-2.77)
PTURK1	0.225	0.087	-0.112	-0.0245*
	(4.39)	(1.08)	(-1.63)	(-0.87)
PTURK2	-0.217	0.032*	0.190	0.0591
	(-3.54)	(0.34)	(2.02)	(1.72)
INCOME	0.0044	(0.0007	0.0025	0.00091
	(8.89)	(0.92)	(4.96)	(2.53)
INCOME1	0.0009	0.0032	0.0005*	-0.00013*
	(1.08)	(2.21)	(0.56)	(-0.25)
INCOME2	-0.0012	-0.0016*	0.025	-0.00017*
	(-9.36)	(-0.78)	(3.04)	(-0.39)
R^2	.96	.74	.91	.98
D-W Statistics	5.4	7.2	6.1	5.9

*Not significant at 10% significance level.

STRUCTURAL CHANGE

The effect of an individual coefficient change may be offset or reinforced by changes in the coefficients of the other independent variables. An appropriate test for structural change in the whole equation is given by (7), and the test results (Table 2) indicate structural changes in the beef and chicken demand equations, but not in the pork and turkey demand equations over the sample period.

IMPLICATIONS TO PRICE AND INCOME ELASTICITIES OF DEMAND

Focusing on the structure of the responsiveness of demand quantity to prices and income, evidently own price, cross price, and income elasticities of demand have not been constant over the sample period. The computed price elasticities of beef, chicken, and turkey consistently decreased; in each case, the demand was less price elastic toward the end of the sample period

TABLE 2. Test for Structural Change in Demand Equations

Equation	F-Ratio
Beef	15.156*
Chicken	3.258*
Pork	1.714
Turkey	0.809

*Significant at one percent significance level.

TABLE 3. Computed Elasticities over the Time Intervals

Quarters		Items				
		Beef	Pork	Chicken	Turkey	Income
1 - 28	Beef	-0.664	0.221	-0.126	0.189	0.576
1 - 63	Beef	-0.107	0.210	-0.370	0.357	0.302
1 - 79	Beef	-0.106	0.408	-0.097	0.084	0.216
1 - 32	Pork	0.698	-0.528	0.219	0.263	0.494
1 - 60	Pork	-0.273	-0.375	0.203	0.266	0.564
1 - 79	Pork	-0.276	-0.392	0.198	0.261	0.597
1 - 32	Chicken	0.604	0.542	-0.890	-0.668	0.712
1 - 74	Chicken	0.544	-0.389	-0.721	-0.947	0.729
1 - 79	Chicken	0.539	-0.384	-0.704	-0.030	0.726
1 - 19	Turkey	1.025	-0.085	-0.051	NC	1.193
1 - 38	Turkey	-3.386	0.318	-0.051	NC	1.195
1 - 79	Turkey	0.466	-0.001	-0.051	NC	1.220

NC indicates no change.

than at the beginning (Table 3). In the case of pork, the demand was less price elastic in the middle than at either end of the sample period.

Measured by the signs and magnitudes of cross elasticities, three basic changes in the demand interrelations are evident over the sample period. First, as exhibited by the cross elasticities of pork on beef, chicken on pork, and turkey on beef, there were structural shifts from substitutions to complementarity relationship in the middle of the sample period. Second, a shift from complementarity to substitution relationship was revealed, as in the case of turkey on beef. Finally, and more prevalent, there were unidirectional changes in the magnitudes of cross elasticities.

There were consistent increases in the income elasticities of demand for pork and turkey, but that of beef declined consistently. No clear pattern emerged with respect to the change in the income elasticity of demand for chicken where, over the three time intervals, the highest income elasticity prevailed over the second interval and the lowest over the first interval.

SUMMARY

Retail demand functions for beef, chicken, pork, and turkey were specified with linear spline transformations to permit explicitly the evaluation of structural changes over the sample period. The results show evidence of structural changes in the beef and chicken demand functions. However, there were some individual coefficient changes in the four demand equations. Subsequently, own price, cross and income elasticities for periods between the points of changes were computed.

Our estimated elasticities may differ, more or less, from estimates by other researchers, but within our analytical framework, it is evident that the demand interrelationships, and the price and income responses of beef, pork, chicken, and turkey have changed considerably within the sample period.

Although the discussion in this paper has been limited to structural change within the specific context of a piecewise function, there are several varying parameter models that are suitable for application in the general area of functional stability and structural change.

Over a period of time, there are known and unknown forces that influence specific commodity price levels, demand interrelations within and between food groups, income levels, food expenditures, and supply situations. Most of these cannot be explicitly incorporated in a single equation demand model. But to the extent that some aspect of their joint influences can be captured within the context of structural change, a signal issue becomes that of identifying and parameterizing the elements of such changes. This has strategic importance in a wide range of policy, planning, and control activities.

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