The Changing Structure of U.S. Meat Demand: Implications for Meat Price Forecasting

by

Roger A. Dahlgran

THE CHANGING STRUCTURE OF U.S. MEAT DEMAND: IMPLICATIONS FOR MEAT PRICE FORECASTING

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U.S. consumers' expenditure patterns for meats, as shown in Figure 1, have changed drastically in the past two and a half decades. Especially striking is the steady downward trend in the share of consumers' budgets allocated to meats. Within the meat budget, the relative expenditure on individual meats has also shown substantial change. For instance, beef and chicken's share of the meat budget have grown while pork's share has declined. Several hypotheses can be advanced to explain these reallocations of meat expenditures. One possibility is that real meat prices have changed. Prices may have increased along an elastic demand curve, or decreased along an inelastic demand curve, either of which would result in lower total meat expenditures. Another possibility is that prices may have remained constant but income growth has reduced meat's proportion of expenditures due to an income elasticity that is less than one. A final possibility is that a shift in the demand structure for individual meats has occurred.

Some factors that have been hypothesized to cause or contribute to a change in the meat demand structure are: (1) the Arab Oil Embargo of 1973 and the resulting alteration of consumer spending habits; (2) the institution of a flexible exchange rate policy in August 1971, which caused greater price volatility in the entire economy; (3) the wage and price controls imposed by the Nixon Administration from 1971 through 1974, which affected meat availability and consumption; (4) the meat boycott of 1973; (5) the publication and dissemination of medical evidence linking meat consumption to high blood cholesterol levels and the linking of high blood cholesterol levels to heart disease; and (6) general concerns about nutrition as the "baby boom" generation came to head-of-household age. If meat demand relations have changed in response to these factors or other causes, then forecasts based on meat demands estimated prior to 1970 may contain systematic biases.

The objective of this paper is to investigate the role that meat-demand-structure changes may have played in the reallocation of consumer meat expenditures shown in Figure 1. Should structural change be detected, another objective is to determine whether the structural change is complete. If structural change is found to be presently occurring, forecasts can be adjusted to allow for projected future changes in the demand structure.

Two possible models of structural change from demand D^0 to demand D' are shown in Figure 2. Figure 2a shows successive shifts in demand that are large initially but the size of the shifts decreases in subsequent time periods. Demand ultimately settles at D'. Structural change of this type could be

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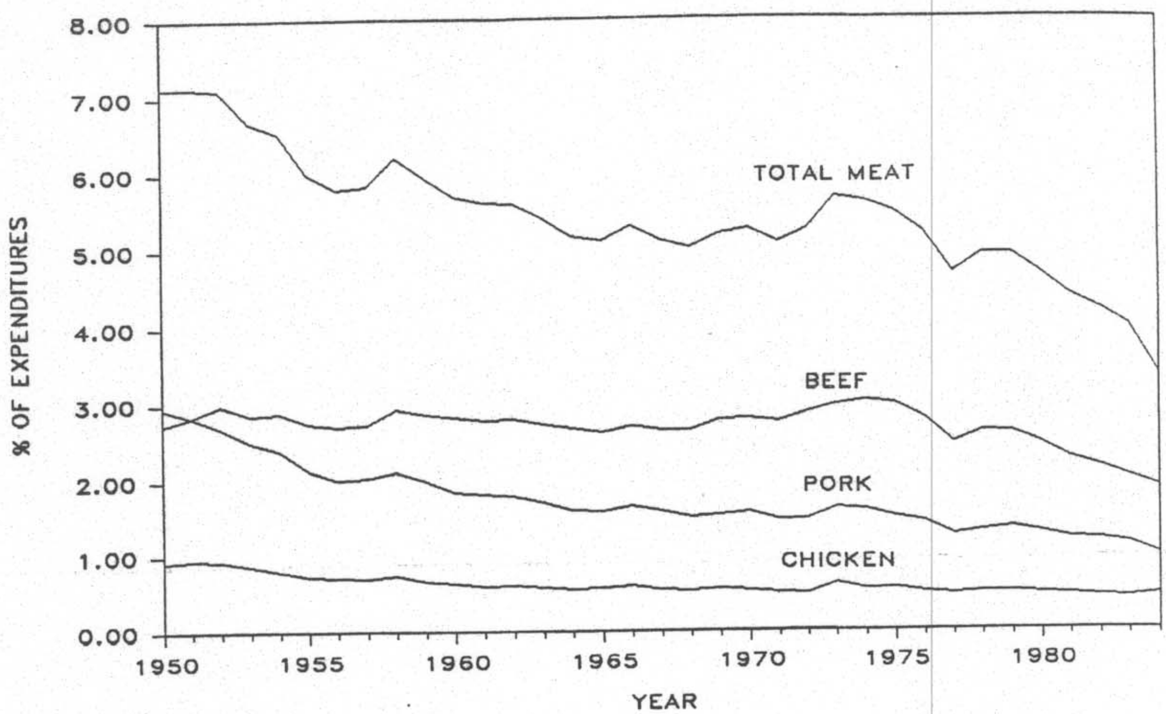

Figure 1. Budget shares for beef, pork and chicken, 1951 through 1984.

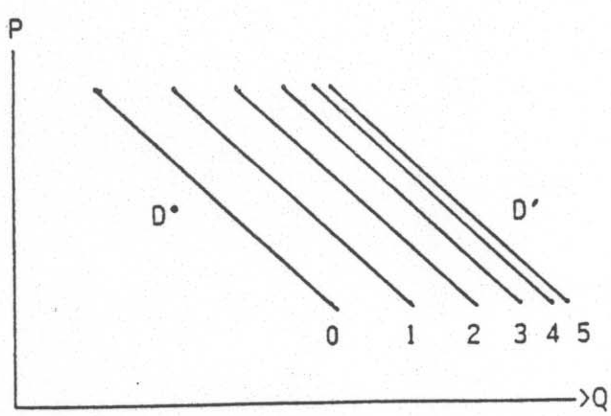

Fig. 2a. Successively decreasing shifts.

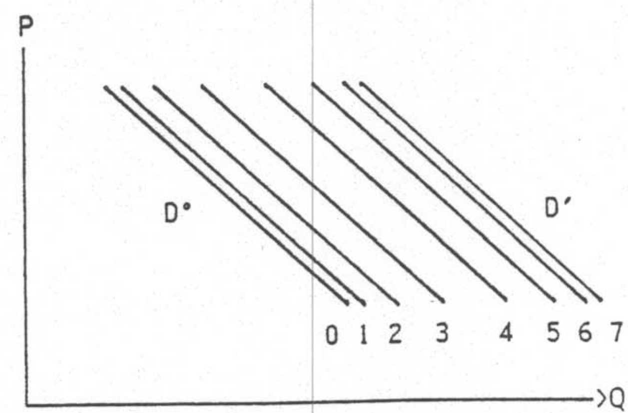

Fig 2b. Successively increasing then decreasing shifts.

Figure 2. Two possible paths of structural change.

caused by release of new information on the healthful benefits of consuming the commodity. Figure 2b shows a different configuration of structural change. Here, successive shifts in demand are small initially, become larger, and then decrease before the new demand stabilizes at D′. This type of structural change could be caused by a combined change in consumption habits as one new generation comes to head-of-household age while another generation of elderly consumers expire. A third type of structural change, implicitly shown in Figure 2, is discrete change. In this case, the elapsed time in moving from D^0 to D′ is less than the observational time unit and thus the system appears to be at D^0 in period t and at D′ in the following time period. While Figure 2 shows only parallel shifts in demand, rotational shifts are also recognized as a possibility. This study will use a demand system to analyze the historical behavior of meat demands. The model employed is capable of displaying gradual or discrete and parallel or rotational structural change. If structural change has occurred, the model will indicate the current level of completeness of the new demand structure's evolution.

Studies on structural change in meat demands have been published by Haidacher, et al., Nyankori and Miller, Chavas, Braschler, Moschini and Meilke, and Dahlgran. Some evidence that structural change occurred in meat demands early in the 1970's is presented. However, these studies contain differing, and sometimes contradictory, results. Table 1 summarizes these results and is useful in comparing the findings of the previous studies as well as for later comparison with the findings of this study. This table shows that the results for beef found by Haidacher, et al., and Moschini and Meilke contradict the results for beef found by Nyankori and Miller, Chavas, and Braschler. Braschler's pork demand findings contradict the findings of Haidacher, et al., Nyankori and Miller, and Chavas. Chavas's and Nyankori and Miller's findings, however, agree.

This study builds on, and extends the previous studies by using a multi-equation flexibility model. The model explicitly incorporates theoretical relationships between the demands for the meats. Specifically, symmetry conditions arising from constrained utility maximization have been formulated for demand models (Johnson, Hassan and Green) and flexibility models (Houck, Anderson). These symmetry conditions can be expected to hold across the equations of meat demand and meat flexibility models. A structural change in the demand for one meat should be reflected as a change in the demand structure for other meats through symmetry conditions.

The flexibility model used in this study is more appropriate than a demand specification. When compared to beef and pork, poultry would presumably have the greatest annual price elasticity of supply because of the relatively short reproductive and growth period for broiler production. Using annual data, Heien estimated the supply elasticity of broiler production to be 0.11. Kenyon (p. 215) states, "... more careful consideration of the biological processes involved in broiler production indicates that it takes nine months to substantially increase broiler production." Both of these studies support the contention that with an observation period of a year, the supplies for beef, pork and poultry are highly inelastic. Therefore, specifying a demand model with quantity as the dependent variable and price given has less intuitive appeal than specifying a flexibility model which uses price as the dependent variable and assumes that quantities are given. Furthermore, the flexibility formulation is useful for price forecasting.

Table 1. A summary of the results found in other studies of structural change in the retail demand for meats.

Author(s)	Data	Meats	Findings
Haidacher, et al.	Annual 1950-1977 Cross section 1965 and 1977-1978	Beef and veal, pork, other red meat, chicken, turkey, fresh and frozen fish, canned and cured fish	No structural change for any of the meats
Nyankori and Miller	Quarterly 1965-1979	Beef, chicken Pork, turkey	Structural change No structural change
Chavas	Annual 1950-1979	Poultry, beef Pork	Structural change - after 1975 No structural change
Braschler	Annual 1950-1982	Beef Pork	Structural change - 1971 Structural change - 1969
Moschini and Meilke	Quarterly 1966-1981	Beef	No structural change
Dahlgran	Annual 1950-1984	Poultry, beef Pork	Chicken more substitutable for beef and pork. Demands more variable.

Theoretical Model

The income-constrained utility maximization model of consumer behavior gives a complete system of demand functions with one demand function for each of the n goods available for consumption. This system may be represented as

$$d\ln \mathbf{Q} = \mathbf{E}\, d\ln \mathbf{P} + \mathbf{a}'\, d\ln m \tag{1}$$

where **Q**, **P**, and m, respectively, designate a per capita consumption vector of length n, a commodity retail price vector of length n, and consumer income; **E** is the n by n retail price elasticity matrix; and **a'** is a income elasticity vector with n rows. Due to the underlying utility maximization model, the demand system displays the well-known homogeneity, symmetry and additivity properties (Johnson, Hassan and Green).

Houck (1965, 1966) and Anderson investigated the properties of a flexibility system, which assumes that the quantities in (1) are given instead of the prices. The flexibility system can be written as

$$d\ln \mathbf{P} = \mathbf{E}^{-1}\, d\ln \mathbf{Q} - \mathbf{E}^{-1}\mathbf{a}'\, d\ln m \tag{2}$$

The homogeneity property of elasticity matrices, $\mathbf{E}\,\mathbf{1}' = -\mathbf{a}'$, implies $\mathbf{E}^{-1}\mathbf{a}' = -\mathbf{1}'$, and provides the homogeneity property of flexibility matrices, $d\ln \mathbf{P}/d\ln m = \mathbf{1}'$, where $\mathbf{1}'$ is a length n column vector of 1's. In a flexibility formulation, (2) becomes

$$d\ln \mathbf{P} - \mathbf{1}'\, d\ln m = \mathbf{F}\, d\ln \mathbf{Q} \tag{3}$$

where the flexibility matrix, $\mathbf{F}$, is defined as $\mathbf{E}^{-1}$.

Houck (1966) also derived the symmetry property for flexibility matrices. The symmetry property of flexibility matrices can be expressed as

$$\alpha_i\, \phi_{ij} = \alpha_j\, \phi_{ji} - \alpha_i\, \alpha_j \left[\sum_{k=1}^{n} \phi_{jk} - \sum_{k=1}^{n} \phi_{ik} \right] \tag{4}$$

where ϕ_{ij} is the i,j^{th} element of $\mathbf{F}$ and α_i is commodity i's share in the consumer's budget. If the budget shares are small or if the flexibility row sums are nearly the same, then the symmetry condition can be reduced to

$$\alpha_i\, \phi_{ij} \doteq \alpha_j\, \phi_{ji} \tag{5}$$

Corresponding to (3), an econometric model of a meat[1] flexibility subsystem can be written in discrete differenced logarithms as

$$\Delta\ln p_{it} = \sum_{j=1}^{4} \phi_{ij}\, \Delta\ln q_{jt} + \phi_{im}\, \Delta\ln m_t \qquad i = 1,2,3,4 \tag{6}$$

where the subscripts i and j designate commodity, 1 designates beef, 2 designates pork, 3 designates chicken, and 4 designates all other goods and services available for consumption; the subscript t designates time period; and the $\Delta\ln$ operator is defined as $\Delta\ln X_t = \ln X_t - \ln X_{t-1}$.

To impose symmetry and homogeneity on the system defined by (6), set $\phi_{im} = 1$ in each equation and multiply each equation by its budget share for the base period of the differenced logarithm. The result is

$$\begin{aligned}\alpha_{i,t-1}\,(\Delta\ln p_{it} - \Delta\ln m_t) = {} & \alpha_{i,t-1}\,\phi_{i1}\,\Delta\ln q_{1t} + \alpha_{i,t-1}\,\phi_{i2}\,\Delta\ln q_{2t} \\ & + \alpha_{i,t-1}\,\phi_{i3}\,\Delta\ln q_{3t} + \alpha_{i,t-1}\,\phi_{i4}\,\Delta\ln q_{4t} + u_{it} \qquad i=1,2,3,4\end{aligned} \tag{7}$$

Because the symmetry approximation, (5), requires $\alpha_i\phi_{ij} = \alpha_j\phi_{ji}$ to hold over the entire sample period, the symmetry condition can be imposed in a manner similar to that used in[2] the "Rotterdam" demand model (Theil, pp. 326-330) as $\alpha_{i,t-1}\phi_{ij} = \alpha_{j,t-1}\phi_{ji}$. Defining π_{ij} as $\alpha_{i,t-1}\,\phi_{ij}$ gives a simpler form to the symmetry relation

$$\pi_{ij} = \pi_{ji} \qquad j > i = 1,2,3,4 \tag{8}$$

so that the model in (7) becomes

$$\begin{aligned}\alpha_{i,t-1}\,(\Delta\ln p_{it} - \Delta\ln m_t) = {} & \pi_{i1}\,\Delta\ln q_{1t} + \pi_{i2}\,\Delta\ln q_{2t} + \pi_{i3}\,\Delta\ln q_{3t} + \\ & \pi_{i4}\,\Delta\ln q_{4t} + u_{it} \qquad i=1,2,3,4\end{aligned} \tag{9}$$

where the u_{it} are assumed to be distributed as multivariate normal random variables with mean **0** and contemporaneous covariance matrix Σ.

Structural change can be added to the model, (9), and restrictions, (8), by expressing

$$Y_{it} = X_{it} \Pi + \delta_t X_{it} \Delta + u_{it} \qquad i=1,2,3,4 \quad t=1,2,3, \ldots T \tag{10}$$

where $Y_{it} = \alpha_{i,t-1} (\Delta \ln p_{it} - \Delta \ln m_t)$ in (9), X_{it} is a row vector of differenced logarithmic quantities[3], Π is a column vector of structural parameters corresponding to the initial demand structure, δ_t is a dummy variable that depends on t, and Δ is a column vector of structural adjustments to Π that occur under the new structural regime.

Various forms and specifications of this model were fit to annual data covering a period from 1950 through 1984. Per capita consumption of beef, pork and chicken are available in Food Consumption, Prices, and Expenditures (USDA). Annual average retail prices of beef and pork are available in Livestock and Poultry Outlook and Situation Report (USDA). Annual average retail chicken prices are available in Developments in Marketing Spreads for Agricultural Products (USDA). Per capita personal consumption expenditure is used to represent consumer income (m_t) and is also available in Food Consumption, Prices, and Expenditures. An index of the quantity of other goods available for consumption is derived by subtracting per capita meat expenditures from per capita consumption expenditures and deflating the result by the consumer price index. In a macroeconomic sense, this variable is an index of the retail supply of all other real goods and services, excluding the three meats being explicitly studied. The price of these other goods is assumed to be the consumer price index which is also available in Food Consumption, Prices, and Expenditures.

Empirical Evidence

Difficulties were encountered in estimating the model because the fourth equation is nearly an identity. The identity property of this equation is most easily seen from the macroeconomic definition $y_t \equiv Y_t / CPI_t$ and the result $\Delta \ln CPI_t - \Delta \ln Y_t \equiv - \Delta \ln y_t$ where y_t represents real per capita income, Y_t represents nominal per capita income, and CPI_t represents the consumer price index. In (9), CPI_t is represented by p_{4t}, Y_t is represented by m_t and y_t differs from q_{4t} only by the comparably small real meat consumption. The budget share weighting the right-hand side to the fourth flexibility function is nearly a constant with minimum and maximum values over the sample of 0.934 and 0.964, respectively. This near identity in the fourth equation results in a nearly singular estimated contemporaneous covariance matrix, Σ. Since interest is in the behavior of the parameters of the first three equations of the system, the fourth equation will be dropped and the remaining parameters will be estimated.

The usual treatment of structural change models is to let δ_t equal 0 if $t < t_0$ and equal one if $t \geq t_0$. The problems with this treatment are first, the point of structural change must be specified *a priori*, and second, the model cannot move gradually from one structural regime to another. A more general model of structural change can be specified using the logit model[4]

$$\delta_t = \delta(t) = \frac{1}{1 + e^{-(\alpha+\beta t)}} = \frac{1}{1 + e^{-\beta(t-t_0)}} \tag{11}$$

This model is a generalized simple dummy variable model in that as β gets large, the logit function takes values of zero to the left of t_0 and takes values of one to the right of t_0. In addition to modeling discrete structural shifts, the logit dummy model can also model gradual structural change when β takes small values. The time path of the structural adjustment (i.e. from Π to $\Pi + \Delta$) is $\Pi_{ij} + \delta(t;\alpha,\beta)\,\Delta_{ij}$, which is time dependent due to $\delta(t;\alpha,\beta)$.

Although the logit model generalizes the simple dummy variable model, it also introduces additional complexities. Two more parameters, α and β, must estimated and the model is nonlinear in these parameters. Second, the introduction of the logit dummy variable introduces the possibility of creating a singular regressor matrix. This singular regressor matrix can be created (1) as $\beta \to 0$, (2) when $\beta \to \infty$ as $3t_0 < k$, the number of columns in $\mathbf{X}$, or (3) when $\beta \to \infty$ as $3t_0 > T-k$, where T is the total number of observations.

The structural change model (10), with the fourth equation deleted, and with a logit specification of the dummy variable as in (11), was fit to the data using a nonlinear iterative seemingly unrelated regressions procedure. The estimates generated by this procedure did not converge and tended to go into the regions of α and β that generated singular regressor matrices. In light of the failure of direct estimation, a grid search was used. Values of t_0 and β were specified prior to using the iterative seemingly unrelated regressions procedure to estimate the parameter vectors Π and Δ. Values of β considered were from 0.05 to 0.95 by increments of 0.05 and from 1 to 21 by increments of 1. At $\beta = 21$, the logit function behaved like a binary dummy variable, with values of zero to the left of t_0 and values of one to the right of t_0. The years corresponding to the selected values of t_0 were from 1954 through 1984 in half year increments. The resulting 2400 specifications of structural change were summarized by their likelihood function values. Figure 3 contains a graphical presentation of the likelihood values for numerous combinations of t_0 and β. The likelihood function of t_0 and β is thereby approximated and the best model of structural change is the values of $_5t_0$ and β is that correspond to the maximum value of the likelihood function.

Two points of interest are marked in Figure 3. Point A, along the left margin of the plot is the global maximum, and point B, along the bottom margin is a local maximum. That both of these points lie on the margin of the search space may cause some concern but Figure 4 plots the logit functions corresponding to points A and B and should reduce this concern. For point B, the logit function generates sample values of only zeros and ones so it is doubtful that values of β larger than 21 will significantly increase the likelihood function in this region. The likelihood function increases only slightly as β takes values larger than 16, while holding t_0 constant at a value corresponding to the year 1972.5. For point A, values of t_0 smaller than the value that corresponds to the year 1954 may result in a singular regressor matrix so that the parameters are not estimable.

Two other features of Figure 4 are also noteworthy. First, both of the logit functions defined by points A and B in Figure 3, model a structural change

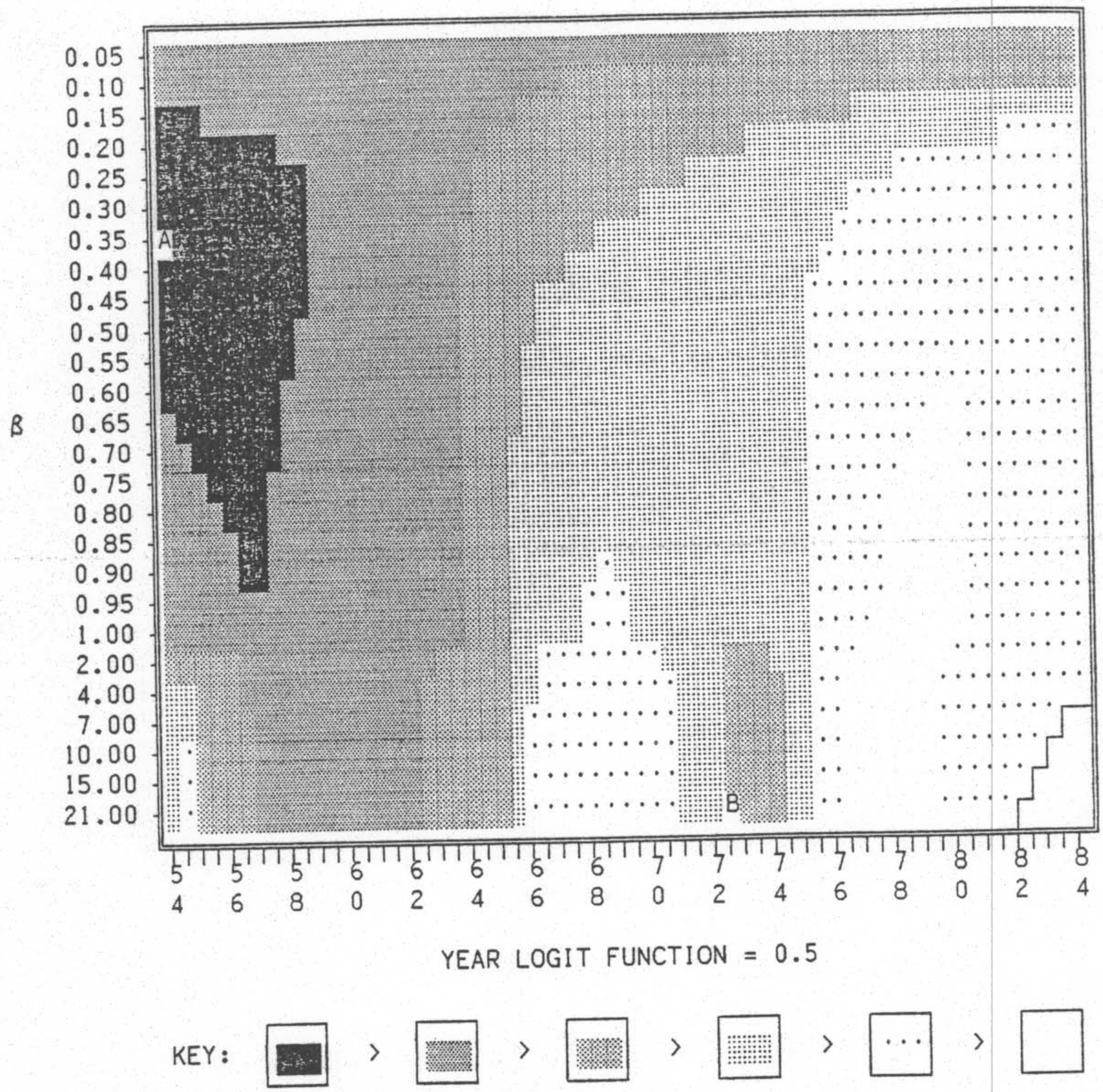

Figure 3. Contour plot of likelihood function values using various specifications of a logit function to model structural change.

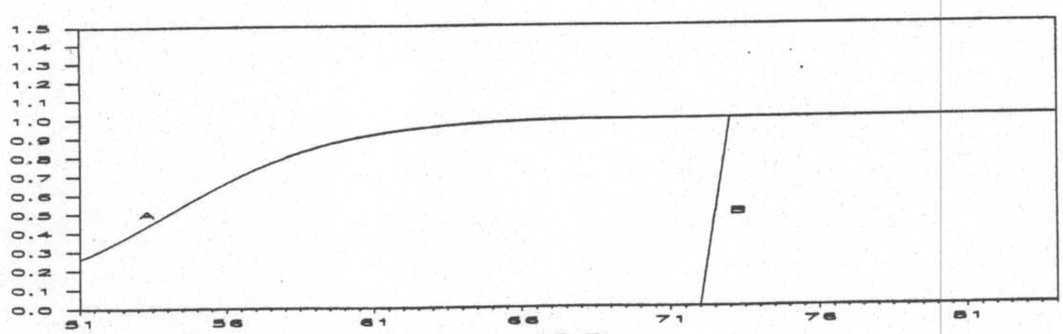

Figure 4. Logit functions corresponding to points A and B in Figure 3.

Table 2. Iterative seemingly unrelated regression results for the flexibilit[illegible] system with two structural changes.

Equation:[a]	Beef	Pork	Chicken
Estimated behavioral structure:[b]			
Base period coefficients on $\Delta\ln$ quantity of:			
Beef	-1.409 1.186 0.119		
Pork	-0.795 0.864 0.180	-4.795 1.092 0.000	
Chicken	0.291 0.345 0.200	0.404 0.431 0.175	-0.758 0.423 0.3[illegible]
Other goods&serv	-9.457 4.484 0.019	-8.097 3.030 0.004	-3.439 1.191 0.0[illegible]
Period II adjustments in coefficients on $\Delta\ln$ quantity of:			
Beef	-2.361 1.773 0.093		
Pork	0.612 1.037 0.278	2.843 1.223 0.011	
Chicken	-0.458 0.474 0.168	-0.699 0.490 0.078	-0.009 0.544 0.4[illegible]
Other goods&serv	10.454 5.026 0.020	7.180 3.350 0.017	3.323 1.349 0.0[illegible]
Period III adjustments in coefficients on $\Delta\ln$ quantity of:			
Beef	0.481 1.054 0.325		
Pork	-0.310 0.461 0.252	0.353 0.351 0.158	
Chicken	-0.424 0.264 0.056	0.078 0.145 0.298	-0.229 0.249 0.1[illegible]
Other goods&serv	-3.369 1.571 0.017	-0.060 0.997 0.467	-0.770 0.444 0.0[illegible]
Estimated covariances across equations:[c]			
Beef	10.200	4.471(0.657)	1.175(0.445)
Pork		4.541	1.130(0.642)
Chicken			0.683
Weighted R-square = 0.8741		Log likelihood = 167.5118	

a/ The dependent variables are $\alpha_{i,t-1}$ $(\Delta\ln p_{it} - \Delta\ln m_t)$ for i representing beef, pork and chicken.

b/ Values shown for each meat are estimated parameters $\times 10^{-2}$, estimated standard errors $\times 10^{-2}$, and significance levels.

c/ Variances and covariances $\times 10^{-3}$. Correlations in parentheses.

The estimated parameters reported in Table 2 can be combined into a single time parameterized vector showing the reaction of the dependent variable with respect to the independent variables as

$$\boldsymbol{\Pi}(\mathbf{t}) = \boldsymbol{\Pi} + \delta_A(t;\alpha=0.35,t_0=54)\ \boldsymbol{\Delta}_1 + \delta_B(t;\alpha=21,t_0=72.5)\ \boldsymbol{\Delta}_2$$

where $\boldsymbol{\Pi}$, $\boldsymbol{\Delta}_1$, and $\boldsymbol{\Delta}_2$ correspond to the three groups of parameters reported in Table 2; $\delta_A(t)=\{1+\exp(-0.35\{t-54\})\}^{-1}$; and $\delta_B(t)=\{1+\exp(-21\{t-72.5\})\}^{-1}$. When the elements of $\boldsymbol{\Pi}(\mathbf{t})$ are divided by the appropriate budget shares at time t, for time t-1, the flexibility matrix can be generated. The flexibiltiy matrix can be inverted to generate the elasticity matrix. The structure of the flexibility and elasticity matrices can be analyzed to ascertain the nature of the structural change in the meat markets.

Summary and Implications

Table 3 shows the impact of the structural change reported in Table 2 by reporting the implied flexibility and elasticity matrices at three different points in time. The general tendency has been for the price flexibilities of meat to increase over time. The greatest and most dramatic increases occur in the direct price flexibility for chicken, and the cross flexibilities of both the beef price with respect to chicken production and the chicken price with respect to beef production. Table 3 also shows the significant changes that have occurred in the beef and chicken price flexibilities with respect to the availability of all other goods and services. In contrast to earlier periods, the cross flexibility of beef prices with respect to other goods and services is strongly negative, while the cross flexibility of chicken prices with respect to all other goods and services is strongly positive.

The elasticity matrix implied by the flexibility matrix is also reported in Table 3. All direct elasticities have the expected negative signs and over time, the demands for these three meats appears to have become more inelastic. Cross elasticities between chicken and beef have increased over time indicating that chicken and beef have become better substitutes. These elasticity results also indicate that the income elasticity for beef has become smaller (though probably not negative as reported) while at the same time, the income elasticity for chicken has become positive.

Finally, Table 4 provides a worksheet showing how the empirical results of this work can be used to forecast retail meat prices. The estimated coefficients in Table 4 are the accumulated structural change parameters reported in Table 2. Since the detected structural changes are complete, these parameters can be treated as constants. The user must supply data on the current budget shares for beef, pork and chicken; the forecast percentage changes in beef supplies, pork supplies, chicken supplies; the forecast growth in GNP; and the forecast inflation rate. Flexibilities are computed by dividing the estimated model coefficients by the corresponding budget shares. Forecast percentage price changes are then computed by summing the products of the influencing variables (i.e. supply changes, GNP growth and inflation) with the corresponding flexibilities. The resulting forecast percent price changes are then applied to prevailing prices to derive the price forecasts.

Table 3. Flexibilities and elasticities implied by the estimation results.

	Flexibilities w.r.t quantity :				Elasticities w.r.t price				
	Beef	Pork	Chicken	Other :	Beef	Pork	Chicken	Other	Income
1960									
Beef	-1.228	-0.088	-0.041	-0.050	-0.823	0.057	0.024	-0.025	0.767
Pork	-0.126	-1.134	-0.109	-0.852	0.082	-0.923	0.082	0.724	0.035
Chicken	-0.175	-0.326	-1.144	-0.716	0.103	0.244	-0.903	0.433	0.123
Other	-0.002	-0.018	-0.005	-1.000	-0.001	0.015	0.003	-1.015	0.998
1972									
Beef	-1.364	-0.067	-0.060	0.354	-0.744	0.028	0.026	-0.288	0.978
Pork	-0.127	-1.341	-0.201	-0.638	0.053	-0.796	0.103	0.502	0.139
Chicken	-0.329	-0.579	-1.516	-0.242	0.143	0.297	-0.705	0.032	0.233
Other	0.010	-0.010	-0.001	-1.000	-0.008	0.008	0.000	-1.008	1.008
1984									
Beef	-1.631	-0.245	-0.293	-1.176	-0.724	0.088	0.085	0.908	-0.357
Pork	-0.434	-1.406	-0.190	-0.860	0.157	-0.758	0.043	0.534	0.024
Chicken	-1.404	-0.512	-2.366	1.552	0.408	0.116	-0.486	-1.334	1.297
Other	-0.025	-0.010	0.007	-1.000	0.019	0.006	-0.006	-1.037	1.017

Table 4. Forecasting worksheet based on empirical results.

Forecasts for:		Beef		Pork		Chicken	
Current Budget Shares (%)			BSB		BSP		BSC
	% Change in Supplies	Est'd Coeffs	Implied Flex's	Est'd Coeffs	Implied Flex's	Est'd Coeffs	Implied Flex's
Beef	%ChQB	-3.2891		-0.4934		-0.5912	
Pork	%ChQP	-0.4934		-1.5988		-0.2158	
Chicken	%ChQC	-0.5912		-0.2158		-0.9960	
Real GNP	%ChRY	-2.3725		-0.9776		0.6532	
Inflation	%INFL		1.000		1.000		1.000
Forecast %'age price change							

Endnotes

1/ The differenced logarithmic formulation is appealing for empirical reasons. The undifferenced logarithmic model displays significant serial correlation. The differenced logarithmic model does not.

2/ Theil used the average of the budget shares in the current and lagged periods. Since the budget shares do not change greatly from period to period, the budget share from the previous period closely approximates the average. This method has advantages for price forecasting, in that budget shares are needed to compute flexibilities, and flexibilities are needed construct price forecasts. Future period budget shares will not be available when forecasts are being formulated.

3/ Specifically, **X** is constructed so that the symmetry restrictions are imposed. The parameter vectors **Π** and **Δ** contain only the unique elements, and not the symmetric elements.

4/ In this model α is defined as $-\beta t_0$. The use of t_0 in this expression allows logit functions to be described by the year in which they take a value of 0.5 (i.e. the year when structural change is fifty percent complete). The parameterization on t_0 has more intuitive meaning than parameterization on α.

5/ Likelihood maximization for a seemingly unrelated regressions model is conceptually the same as Braschler's use of the switching regressions methodology and searching for a minimum error sum of squares in a single-equation model of structural change.

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