Dynamic Taste Change in Meat Demand: An Application of the DYMIMIC Model

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Introduction

Numerous studies of meat demand have attempted to test the assumption of consumer taste change. The results on the occurrence and timing of such a change are mixed. Some studies have found that indeed there has been some type of change in consumer demand indicating that consumer tastes have changed in disfavor of beef and in favor of poultry; while others have found no evidence of significant changes at all. The diversity of empirical results may be due to a combination of factors, such as the time span and periodicity of data, functional form, the number of parameters in the model, the specification of gradual or abrupt change, etc. (vid Alston and Chalfant). The common thread among most of these studies is to estimate a demand system and to infer the occurrence and timing of structural change by identifying parameter changes.

This paper uses a latent variable structural model approach to estimate a taste variable explicitly from a latent variable demand system. Kalman filtering and smoothing is used to solve a Dynamic Multiple Indicator and Multiple Cause (DYMIMIC) model. The latent taste variable index obtained is then used to identify and measure consumer taste changes for beef, pork and poultry.

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Previous Studies

Smallwood, Haidacher, and Blaylock (1989) have an extensive review of recent publications examining structural change in the demand for meats. Of eleven studies cited in that paper, seven of them found evidence of significant structural change. Nyankori and Miller (1982), Braschler (1983), Chavas (1983), Thurman (1987), and Moschini and Meilke (1984) used ad hoc demand functions to test the consistency of the structural change hypothesis. The functions are usually defined in such a way that a quantity-dependent variable (per capita consumption of meat) was a function of consumer income and prices of related goods. Dahlgran (1987), Eales and Unnevehr (1988), Moschini and Meilke (1989), and Choi and Sosin (1990) used a complete demand system.

Eales and Unnevehr compared tests of structural change when aggregate and disaggregate data were used, and concluded that a structural change test may be biased if aggregate data are used. Chalfant and Alston (1988) criticized studies of this type for failing to distinguish between the structural change and errors of specification in their parametric approach and proposed a nonparametric approach for assessing the structural change by using the strong axioms of revealed preferences. Gao and Shonkwiler (1991) used a static latent variable AIDS model solved by multivariate methods and found evidence of taste change for beef and poultry.

General Formulation of The Model

The model used in this study is a special case of the "state-space" model used in engineering to represent a variety of physical processes. As shown by Mehra (1974), a wide range of models used in econometrics can be viewed as special cases of state-space models. The advantage of the state-space specification is that general maximum likelihood estimates are available based upon the Kalman filtering recursive algorithm. The fact that state-space techniques provide an ideal framework for estimating equations with latent variables has been increasingly recognized by economists, see Engle and Watson (1981), Engle et al (1985), Watson and Engle (1985), Burmeister and Wall (1987), Slade (1989).

The state-space model consists of two sets of equations: measurement equations and transition equations. The measurement equations describe the relation between the unobserved states Ξ_t (latent variables) and a n×1 vector of measurements Y_t. The predetermined variables Z_t and a vector of disturbances e_t also enter the measurement equations. The transition equations describe the evolution of the j×1 vector of Ξ_t in response to lagged unobservables and an m×1 vector of exogenous variables F_t and a vector μ_t of disturbances.

The model can be specified as

$$Y_t = \lambda \Xi_t + \Gamma Z_t + e_t \tag{1}$$

$$\Xi_t = \Phi \, \Xi_{t-1} + \Delta F_t + \mu_t \tag{2}$$

and

$$\begin{pmatrix} e_t \\ \mu_t \end{pmatrix} \sim \text{N.I.D.} \left[\begin{pmatrix} 0 \\ 0 \end{pmatrix}, \begin{pmatrix} R & 0 \\ 0 & Q \end{pmatrix} \right] \tag{3}$$

When $\Phi=\Gamma=\Delta=0$, we have a standard factor analysis model for which λ gives the factor loading matrix. This is also called the multiple indicator (MI) model because observable variables y are the indicators of latent variable Ξ. When $\Phi=0$, it is the multiple indicator, multiple cause (MIMIC) model developed by Zellner (1970) and Goldberger (1972, 1977). When $\Phi \neq 0$, the state-space model provides dynamic generalizations of these models and has been termed a dynamic multiple indicator, multiple cause (DYMIMIC) model (Watson and Engle).

The reduced form relation between observables Y and Z is obtained by substituting (2) in (1) to eliminate the unobservable variable Ξ. ML estimation of this reduced form is possible, but the complexity of this reduced form makes the procedure unwieldy during the computational process. The Kalman filter algorithm provides a general solution to this problem and provides estimates of the Ξ_t. There are two sets of unknowns in the state-space model. There are the unknown parameter matrices λ, Γ, Φ, Δ, Q, R, and there are the unobserved states (latent variables), Ξ_t. The first class of unknowns is obtained with the Kalman filter by maximizing a likelihood function defined in terms of the innovations implied by the model. The latent state variables are then obtained by smoothing based on all the information through time T and conditional on the parameter estimates.

As shown in Harvey (1989) the likelihood function of the unknown parameters in (1)-(2) is easily formed. Let η_t denote the innovations in y_t, $y_t - E(y_t/y_{t-1},\ldots,y_1, z_t ,\ldots,z_1)$; and let G_t denote the contemporaneous covariance of η_t. The log likelihood can be written as

$$L(\theta) = \text{constant} -1/2 \sum_{t=1}^{t} (\log|G_t| + \eta'_t G_t^{-1}\eta_t) \qquad (4)$$

where θ is the vector of unknown parameters. The innovations and their variances are easily calculated using the Kalman filter.

<u>A Demand Model With Latent Taste Variable</u>

There are a number of ways to incorporate taste variables into the analysis of household behavior. To extend the traditional demand model to include tastes, the assumption of constant taste must first be relaxed. The general consumer decision problem can, in general, be written as (Grandmont, 1983)

$$\text{Maximize } u=u(q, \Xi) \qquad (5)$$

$$\text{subject to } p'q = x$$

where q and p are n×1 vectors of quantities and prices respectively. x is total expenditure or income. The latent variable Ξ can be a single measure of taste, or more generally a vector of taste measures for commodities. In this study, one taste variable will be used for all meat products based on the assumption that health concerns and demand for convenience are the major factors related to changing tastes, and they influence all meat demands.

The demand equations found by solving (5) have the general form

$$q_i = f_i(p, x, \Xi) \quad (6)$$

A theoretically plausible demand system, the almost ideal demand system (AIDS) of Deaton and Muellbauer (1980), will serve as the basic specification. The AIDS model was chosen because of the six desirable properties mentioned by Deaton and Muellbauer (1980). In addition, it allows for consistent aggregation across consumers.

The methods of translating will allow the incorporation of a latent taste variable into the demand model and still satisfy all the requisite properties (Green 1985, Brown and Lee 1989). The translating approach assumes that taste change results in a demand change through an income effect. It has the form

$$q_i = r_i + q_i^*(p, x^*) \quad (7)$$

where x^* is equivalent to a supernumerary income and r_i is a function of the taste variable Ξ. Rossi (1988) simplified budget share translating in AIDS by allowing the aggregate expenditure shares to depend on a household characteristics factor, which augments the intercepts of ordinary demand curves. For time series data this factor can be replaced with a latent preference shifter Ξ.

This AIDS model with a latent preference variable can be written

$$w_i = \alpha_i + \Sigma_j \tau_{ij} \ln p_j + \beta_i \ln[x/p^*] + \lambda_i \Xi + e_i \quad (8)$$

where x is total expenditure on the group of goods being analyzed, p_j is the price of the jth good within the group, p* is the (Stone) price index for the group and w_i is the share of total expenditure allocated to the ith good. The matrix Γ contains the α, τ and β parameters.

The equations in (3) correspond to measurement equations in (1). In addition, indicator equations can be included with (8) augmenting the measurement equations for the purpose of identification and latent variable scaling. The transition equation is formulated by specifying the latent taste variable as a function of its lag and some causal variables, F_t.

Data and Model Specification

Retail prices and per capita consumption data for beef, pork and poultry were obtained from the USDA's "Food Prices, Consumption and Expenditure" and "Livestock and Poultry Situation". The data period ranges from 1960 to 1987. Taste change is assumed to be affected by both health concerns and demand for convenience. This leads to the specification of two indicators for the latent taste variable. They are the ratio of low fat milk to total fluid milk consumption ("MILK"), and the per capita consumption of eggs ("EGG"). The trends of the two indicators represent the results of consumer taste change because of health concerns and convenience demand. The milk ratio is increasing because consumers have increasingly substituted low fat milk for whole milk; while egg consumption is decreasing because of health concerns and the demand for convenience at the breakfast meal (Putler 1989, Shonkwiler and Ford 1989, Brown and Schrader 1990).

Since the milk ratio and egg consumption series are used as indicators of the latent taste variable, these time series were analyzed to determine whether they possessed a unit root (Fuller). The hypothesis of a unit root for the milk ratio series could not be rejected at conventional levels. Therefore this variable was quasi-differenced by using the operator (1-.75L) as suggested by Nerlove, et. al. (p. 67). This led to specifying the other two (one of the share equations must be dropped to avoid a singular residual covariance matrix) measurement equations as

$$\begin{aligned} (1-.75L)MILK_t &= \lambda_3\, \Xi_t + e_{3t} \qquad (9) \\ EGG_t &= \lambda_4\, \Xi_t + \gamma_o + e_{4t} \end{aligned}$$

The parameter λ_3 is normalized to unity in order to provide a scale for the unobservable Ξ. This normalization implies that the latent variable will tend to increase over the sample. Therefore it is hypothesized that λ_4 will be less than zero (and $\gamma_o > o$) since the egg series is declining over the sample.

The latent taste variable is influenced by two cause variables: the cholesterol information index ("CHOL") and the percentage of working women ("WOM"). The cholesterol index serves as a cause variable in this set-up based on our belief that the link between cholesterol intake and cardiovascular disease is arousing consumer concerns and therefore changing consumer tastes. The working women percentage represents changes in the family structure and shows the demand for convenience food. The cholesterol index is from Brown and Schrader (1990). The percentage of working women with respect to the population of women or working age is from "Handbook of Labor Statistics" (USDL,1990).

The single cause or state equation becomes

$$\Xi_t = \phi\ \Xi_{t-1} + \delta_1\ CHOL_t + \delta_2\ WOM_t + \mu_t \qquad (10)$$

It is hypothesized that both δ_1 and δ_2 are greater than zero since increases in these two series should reflect factors related to increasing lowfat milk consumption and decreasing egg consumption.

<u>Results</u>

Coefficients estimates for the DYMIMIC model obtained by maximum likelihood are reported in Table 1. These values reflect the fact that the expenditure shares, w_i, were multiplied by 100 and the CHOL variable divided by 100. Estimated asymptotic standard errors were calculated using White's method and thus should be robust to errors in specification such as non-normality, autocorrelation and heteroskedasticity.

The estimated coefficients λ_1 and λ_2 show that the latent taste variable is an important determinant of meat consumption. Increases in the taste variable reduce the demand for beef and increase the demand for poultry. The significance of this variable in the beef and poultry equations indicates that its omission would yield misspecified demand equations. Furthermore the significance of the variances (R_{33} and R_{44}) in the MILK and EGG indicator equations means that neither of these variables can be incorporated directly into the demand system without introducing measurement error bias. Finally, the cause equation results show that the latent taste variable is best represented as a linear combination of its own lag and the CHOL and WOM variables. Note that the variance of the cause equation is on the boundary of the admissible parameter space, but this in no way affects the validity of the Kalman filter representation (Harvey).

The expenditure and price elasticities for average data are presented in Table 2, under the assumption of the shares are exogenous (Green and Alston). The findings show that other than own price changes have little effect on the demand for these meats and that the changes of expenditure shares depend primarily on non-price factors such as expenditure and taste changes.

The latent variable is estimated from the Kalman filter updating equation and it is graphed in Figure 1. There is no indication that there was an abrupt change of tastes in the 28 year period analyzed. It is of interest to note that the estimated value of ϕ is less than zero. This acts to mitigate the growth in the taste index, and suggests that if and when the CHOL and WOM variables attain a steady state the latent taste variable will begin to decrease.

Concluding Remarks

This paper uses a structural latent variable Dynamic Multiple Indicator and Multiple Cause model to estimate a latent taste variable in meat demand. It assumes that taste change is dependent on consumers' concern for cholesterol and the value of time on meat consumption patterns. The evidence of this study showed significant taste change in beef and poultry demands. The taste change has a negative effect on beef demand and a positive effect on poultry consumption. Its effect on pork demand was of less importance.

Econometric models used to identify structural changes by diagnosing changes of coefficients in demand functions overlook the fact that taste change is likely a smooth, time diffusing process -- not an abrupt change. By specifying a dynamic model of both indicators and cause variables which are hypothesized to affect how consumer tastes may be evolving, we are able to provide parametric tests of the relative importance of these variables in the representation of tastes. Since the analysis is conducted in a framework which specifically accommodates measurement errors, our results do not suffer from the likely measurement error bias that would result from simply including one or more variables thought to be associated with consumer taste change in the demand equations.

Although our results provide strong evidence that taste changes have had a highly significant effect on how consumers allocate expenditure on meat, we must remind readers that our results are highly conditioned by the demand specification used, the separability assumptions made, the data period analyzed and the cause and indicator variables considered.

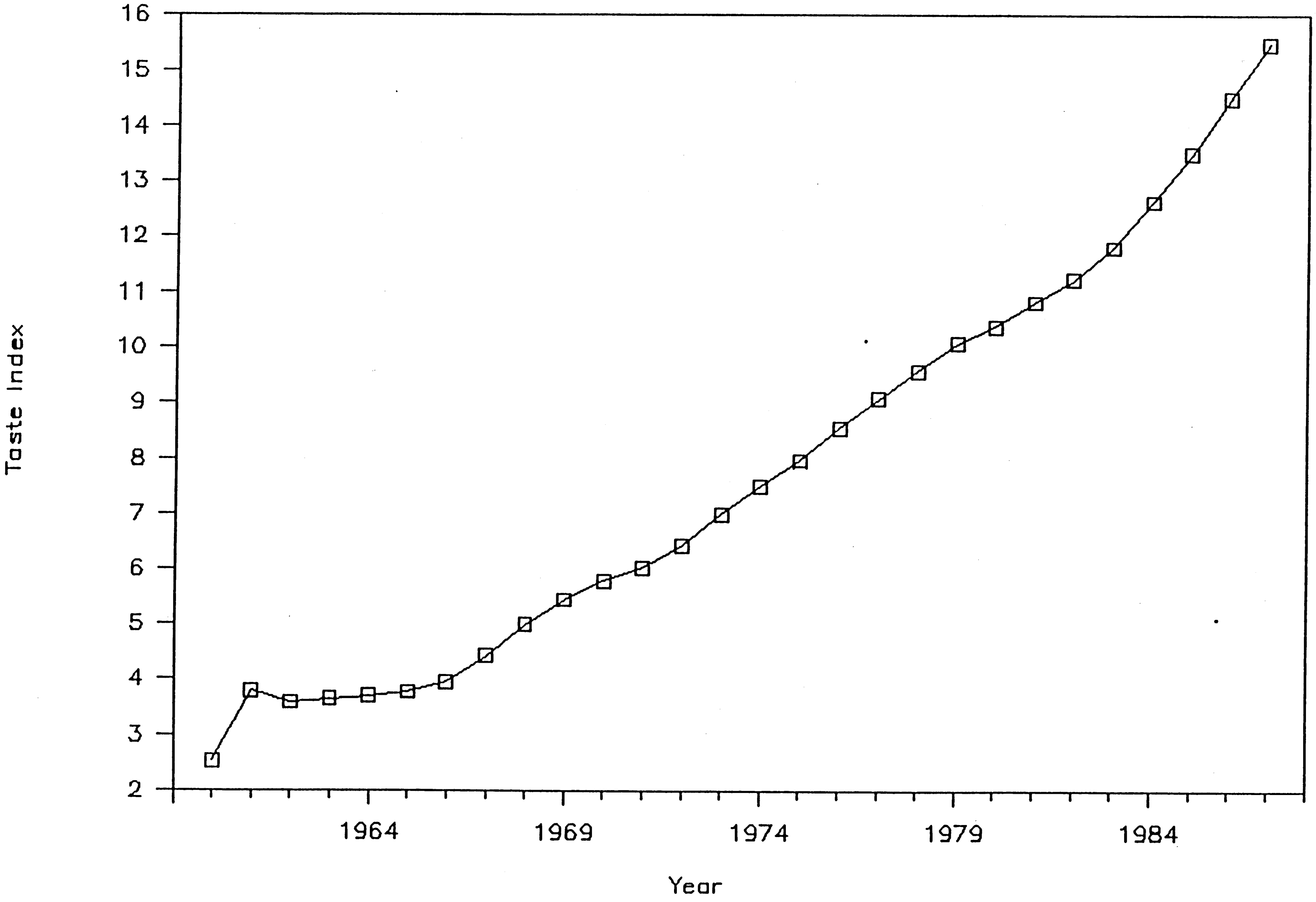
Table 1. DYMIMIC Parameter Estimates

Parameters	Coeff.	Std. Error	Parameters	Coeff.	Std. Error
Beef				Indicator Equations	
α_1	-66.39	14.74	λ_3	1	--
τ_{11}	4.910	1.784	R_{33}	.3886	.0822
τ_{12}	4.760	2.316	λ_4	-.8884	.0335
τ_{13}	-4.514	3.830	γ_o	43.80	.3522
β_1	24.15	2.778	R_{44}	.8580	.1850
λ_1	-1.206	.1635			
				Cause Equation	
			ϕ	-.1693	.0733
Poultry			δ_1	.3470	.0221
α_2	68.06	12.78	δ_2	.1188	.0115
τ_{21}	-4.586	.8283	Q	0	--
τ_{22}	-3.780	1.400			
τ_{23}	5.708	1.920			
β_2	-10.591	2.559			
λ_2	.9159	.0853			
Pork					
α_3	98.30	10.22			
τ_{31}	-.3246	1.440			
τ_{32}	-.9835	1.561			
τ_{33}	-1.187	2.889			
β_3	-13.54	1.966			
$-\lambda_1-\lambda_2$	.2903	.1340			

Table 2. Elasticities from DYMIMIC Model Evaluated at Means of the Data

	Elasticity of		
With respect to	Beef	Poultry	Pork
Beef price	-1.15	.07	.23
Poultry price	-.15	-.53	.03
Pork price	-.05	-.04	-.90
Expenditure	1.45	.33	.55
Taste variable	-.17	.45	.07

Figure 1.Fitted Value of Taste Variable



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