NCCC-134

APPLIED COMMODITY PRICE ANALYSIS, FORECASTING AND MARKET RISK MANAGEMENT

Estimating the Demand for Dairy Products: Accounting for Taste and Preferences

by

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ESTIMATING THE DEMAND FOR DIARY PRODUCTS: ACCOUNTING FOR TASTE AND PREFERENCES

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1. Introduction

Per capita consumption of some dairy products have declined considerably over the last thirty years. While one can hypothesize that the reason for this is consumer concern for the adverse health effects of milkfat, consumption of cheese has actually increased significantly over this period. Initial evidence suggest that prices and income alone can explain very little of these consumption patterns. An alternative approach that can lend confidence in accounting for changes in taste and preferences will be useful in projecting future consumption patterns.

Thus the objective of this study is to estimate the demand for dairy products accounting for these observed behavior which can be attributed to changes in taste and preferences. Two approaches are adopted in this study. First, a nonparametric test for changes in taste and preferences is performed using what Varian (1983) characterized as the Generalized Axiom of Revealed Preference (GARP). This is essentially a test for violation of both the weak and strong axiom of revealed preference. This test is performed to confirm the hypothesis that taste and preferences have changed over the historical period, and that these changes can be accounted for in some theoretically consistent fashion. Violation of this test implies that either the theory of demand is wrong or that prices and income alone cannot explain consumption patterns. The second approach is a parametric procedure. It is different from other approaches in that we do not specify any point in the sample at which the structural change (changes in taste and preference) occur and/or the rate at which it is taking place. All that is required for this approach is that changes in taste and preferences can be expressed in a state-space formulation (discussed below) so that the Kalman filter can then be used to estimate the demand equations. This approach allows us to isolate the effects of changes in taste and preferences. In this study four dairy products are considered; per capita consumption of whole milk, low fat dry milk, cheese, and butter.

In Section 2, the non-parametric test is briefly discussed and the results interpreted. Section 3 discusses the formulation and motivation for using the state-space approach to model changes in taste and preferences. In Section 4, the empirical results of the state-space demand function are presented and discussed. For comparison, a linear or non-random trend model is also presented. Section 5 presents concluding remarks.

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2. The Non-Parametric Approach

Increasing attention has been given in recent years to the question of structural change in the dairy industry, (Haidacher et al, Novakovic and Bunch). Per capital consumption of whole milk products have declined in recent years, and it is widely suggested in industry circles that this reflects a shift of consumer preferences due mainly to dietary concern. The notion that preferences have shifted has resulted in attempts to increase consumption via promotion, the development of low fat products and other product innovations.

To study the demand for dairy products in the U.S., one issue remain unresolved. This relates to what products constitute the group designated "dairy". The products that make up the dairy group varies from study to study and as a result there is no general agreement as to what products to include in this group. A solution to this problem might be important in that it would then be possible to determine substitutes and complements for the "dairy products" which would to some extent give a complete picture of the structure of the dairy industry. For this study, the products considered are whole and low fat milk, cheese, and butter.

To test for changes in taste and preferences for dairy products, the concern is whether the observed data conform to the restrictions implied by a stable set of well-behaved preferences. An additional restriction is that the dairy products constitutes a weakly separable group and that it is appropriate to analyze per capita consumption data as having been generated by maximization of a utility function by the representative consumer.

According to the weak axiom of revealed preference, a bundle of goods say x_1 is revealed preferred to any other bundle x_2 (denoted x_1Rx_2) that could have been purchased instead. In other words, x_1 is preferred to all points within the budget line that applies when it is purchased. This axiom is violated if any other bundle x_2 is also revealed preferred to x_1 or if x_1 lies inside the budget set that applies when x_2 is purchased. This would imply that x_1Rx_2 and x_2Rx_1 which would occur only if there are some inconsistency in preferences.

If no violations are observed it does not however rule out the question of intransitivity. It is thus also necessary to check for consistency with the strong axiom of revealed preference. This involves a search for intransitivity in the data, i.e. to see if bundles x_1, x_2, x_3 can be found that together imply that x_1Rx_2, x_2Rx_3, and x_3Rx_1. The number of bundles of goods that can come between x_1 and x_3 is limited only by the size of the data set. The data are thus consistent with GARP if there are no violations in both the weak and strong axiom.

Fig. 1 shows the result of this test. Since the mid 60's, there has been an increase in violations of the generalized axiom of revealed preference (GARP). This started out gradually but picks up faster by the mid 70's in which over half the data set violated the assumption of stable preferences. A marked decline in the number of violations is noted around 1983 which could be explained by the introduction of low fat dairy products. The results of the test thus suggest that the data for per capital consumption of whole milk, low fat milk, cheese and butter are not consistent with the stable preference theory as implied by utility maximization. In the next section we develop the parametric approach.

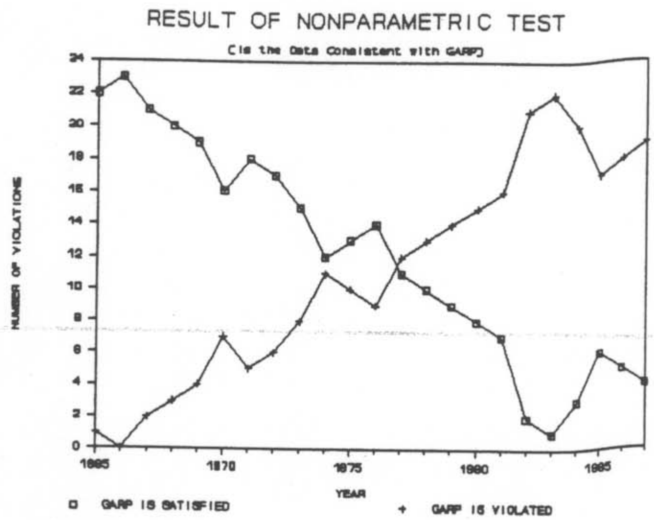

Figure 1

3. The Parametric Approach

Previous studies on structural change have approached the problem using switching regression models with peacewise linear time trends. The problem with this approach is that the point of the switch varies from researcher to researcher and the degree of trend polynomial are assumed linear at each point of the switch. From the result of the non-parametric test, the rate of structural break evolves into different polynomial types through time, so using a linear trend for the whole data period would give results that are misleading.

Another approach is that of a systems approach. This approach has done well in the past but a problem of theoretical concern relates to the issue of separability. This concern is often neglected so we don't know what are the true relationships between the equations in the system.

For this study, we propose to use a single equation for each of our demand equations which also includes a stochastic trend term to account for changes in taste and preferences over time. This approach, referred to as the state-space method, was first developed by control engineers and has been introduced into economics by Harvey (1981, 1984, 1989). A discussion of the state-space approach is given below. In this approach no switch point need be specified nor the degree of trend polynomial.

Following the discussion by Harvey (1981 and 1989), a particular form of the general univariate state space time series model consists of two equations. The first is the measurement equation which is given by:

$$(1) \qquad y_t = x_t^T \alpha_t + u_t \qquad (t=1,\ldots..n)$$

where T denotes transpose. The (dynamic) transition equation is given by:

$$(2) \qquad \alpha_t = G\alpha_{t-1} + e_t \qquad (t=1,\ldots..n)$$

The observation/measurement equation (1) is similar to a regression equation with the regression coefficient vector α_t(mx1) called the state at time t, x_t(mx1) is a known matrix of regressors, and u_t is the measurement disturbance. In the next equation G is referred to as the transition matrix. The disturbance terms u_t and e_t are white noise with zero mean. They are assumed to be serially uncorrelated, uncorrelated with each other for all time periods, and uncorrelated with the initial state vector, α_0. The variance of u_t is σ^2h and the variance of e_t is σ^2H, where H is a diagonal matrix.

The Kalman Filter provides recursive equations for predicting, updating and smoothing. Under the normality assumption, the solutions to the equations yield the minimum mean square estimators (MMSE). In the absence of the normality assumption, the estimators are still the minimum mean square linear estimators (MMSLE).

For a discussion of the Kalman Filter, let a_{t-1} denote the known MMSLE of α_{t-1} based on all information available up to and including time t-1, (i.e., a_{t-1} is the updated estimator of α_{t-1}). Also, let $\sigma^2 Q_{t-1}$ denote the known covariance matrix of a_{t-1}. At time t-1, the MMSLE of α_t is given by the following prediction equation:

$$(3) \qquad a_{t|t-1} = Ga_{t-1}$$

and the covariance matrix of $a_{t|t-1}$ is:

$$(4) \qquad Q_{t|t-1} = GQ_{t-1}G^T + H$$

When y_t becomes available, the MMSLE of α_t, and a_t, is given by:

$$(5) \qquad a_t = a_{t|t-1} + \frac{Q_{t|t-1}x_t(y_t - x_t^T a_{t|t-1})}{f_t}$$

where

$$(6) \qquad f_t = x_t^T Q_{t|t-1} x_t + h.$$

The covariance matrix for the updated estimator a_t is:

$$(7) \qquad Q_t = Q_{t|t-1} - \frac{Q_{t|t-1}x_t x_t^T Q_{t|t-1}}{f_t}$$

Equations (3) and (4) are known as the prediction equations, while (5) and (7) are the updating equations. Together these two sets of equations are known as the Kalman Filter. The updated equations make use of new information which is available through the prediction error $(y_t - x_t^T a_{t|t-1})$. The weight attached to this information, $Q_{t-1|t}x_t/f_t$, is referred to as the "Kalman gain".

The prediction equations refer to the estimators for time t based on information available through time t-1. The updating equations refer to estimators for time t based on information available through time t. Also of interest are estimators for time t based on all of the sample information, i.e., based on information available through time n. These estimators are referred to as smoothed estimators and the Kalman Filter provides a set of smoothing equations for these estimators. The smoothed estimator for α_t is given by:

$$(8) \qquad a_{t|n} = a_t + Q_t^*(a_{t+1|n} \; Ga_t)$$

where

$$Q_t^* = Q_t G^T Q_{t+1|t}^{-1} \qquad (t=n-1,.....1) \tag{9}$$

The covariance matrix for $a_{t|n}$ is given by:

$$Q_{t|n} = Q_t + Q_t^*(Q_{t+1|n} - Q_{t+1|t})Q_t^{*T}. \tag{10}$$

In the smoothing equations (8) - (10), $a_{n|n} = a_n$ and $Q_{n|n} = Q_n$.

In order to start the Kalman Filter recursion equations, the MMSLE for $\alpha_0(a_0)$ and its covariance matrix (Q_0) need to be known. In addition, the hyperparameters h (the variance of the measurement disturbance) and H (the covariance matrix of the transition equation disturbances) need to be known. One possibility, followed in this paper, is to start the recursions with $a_0 = 0$ and $Q_0 = kI_m$ for some large k, where I_m is the identity matrix of order m. Maximum likelihood procedures are then be used to estimate h and H using only the prediction errors for t > m. Assuming normality, the likelihood is given by:

$$L = -\frac{(n-m)}{2}\log 2\pi - \frac{1}{2}\sum_{t=m+1}^{n}\log(\sigma^2 f_t) - \frac{1}{2}\sum_{t=m+1}^{n}\frac{\epsilon_t^2}{\sigma^2 f_t}\ ; \tag{11}$$

where ϵ_t is the one-step ahead prediction error

$$\epsilon_t = y_t - y_{t|t-1} = y_t - x_t^T a_{t|t-1}. \tag{12}$$

An important difference between the model presented in this paper and earlier models is the specification of the stochastic trend term. The empirical state space model is given by the measurement equation:

$$y_t = \mu_t + x_t^{*T}\theta_t + u_t \tag{13}$$

and the transition equations

$$\mu_t = \mu_{t-1} + \beta_{t-1} + e_{1t} \qquad (\textit{level}) \tag{14a}$$

$$\beta_t = \beta_{t-1} + e_{2t} \qquad (\textit{slope}) \tag{14b}$$

$$\theta_t = \theta_{t-1} \qquad \text{(14c)} \qquad \textit{(fixed regression)}$$

where y_t is U.S. per capital consumption of whole milk, low fat milk, cheese and butter, μ_t is a state variable representing the level of consumption due to taste and preferences and possibly other factors not included in the model, x_t^* is a vector of explanatory variables assumed to have the fixed but unknown coefficients Θ_t, and the usual white noise and correlation assumptions are made about the disturbances (u_t, e_{1t}, and e_{2t}). The stochastic trend assumption is embodied in the transition equations (14a) and (14b).

4. Empirical Model of Dairy Demand

Tables 1-4, provides the results of estimating the state-space demand equations via the Kalman filter and the linear trend model. All variables are clearly defined in the table with the respective equations. The data where obtained from the FAPRI (Food and Agricultural Policy Research Institute) data bank at the University of Missouri-Columbia.

Table 1 compares the estimated coefficients for both the stochastic trend (state-space) and linear trend for the butter demand equation. The stochastic slope for the state-space model indicates that butter consumption is expected to drop by about .2291 pounds per person in the next period. The own-price coefficient (real butter price) is statistically significant with the expected sign and magnitude. All of the other variables are significant and of reasonable magnitude. The linear trend model, on the other hand, gave results that are not consistent with theory. The own-price coefficient is positive and disposable income has a negative sign. This pattern was observed for all three demand equations except for cheese in which both the stochastic and linear trend models gave inconsistent results. In the cheese equation (Table 4), both the linear and stochastic trend models have own-price effects that are positive though statistically significant. A similar problem was observed by Novakovic and Thompson which suggest that the demand for cheese still poses a problem.

Of significant interest are the stochastic trend estimates for low fat dry and whole milk (Tables 2 and 3). The stochastic slope for low fat milk is increasing at a rate of .0263 pounds per person annually while that for whole milk is decreasing at a rate of .0465 pounds per person. The own-price and income elasticities of -.2516 and .1389 for low fat milk and -.1445 and .1202 for whole milk compare well with that obtained by Johnson, Hassan, and Green (1984) who used a systems approach. In a study by Huang and Raunikar (1983), the authors found significant differences in consumption patterns for low fat and whole milk between family life cycles for the Southern U.S. Their result compares well with that of the present study. Preferences are thus moving away from high fat to low fat products. These effects are accounted for in our state-space demand models.

In figure 2 we present the smoothed stochastic trend and the actual trend for both low fat and whole milk. The effect of tastes and preference on the consumption of these two dairy products can be explained by the behavior or the smoothed stochastic trend. From 1965 to the late 70's low fat milk experienced an increasing trend which tapers off thereon to the mid 80's and has been increasing thereafter. For whole milk on the other hand, the impact of taste and preferences have been on a gradual decline from 1965 to 1975 after which a very steep decline in consumption is observed. This decline is less rapid during the mid 80's. Whole milk experienced a mean drop in consumption of over one-hundred pounds per person while a similar increase is experienced for low fat milk.

5. Concluding Comments

The results of this study have several implications for the dairy industry. The results indicate that preferences for dairy products have shifted over time. Therefore, prices and income alone cannot explain demand. The use of the "stochastic trend" help account for these observed changes in preferences over time which are important in projecting future consumption patterns. The state-space method used in this study is superior over conventional techniques in that it requires no knowledge of the point of the structural shift nor the rate at which the shift is taking place. Harvey (1984, 1989) discusses several other interesting problems that could be addressed easily using the state-space analysis. The results are good for butter, whole and low fat milk, but cheese presents a problem. The own-price coefficient consistently had the wrong sign. However the results of this study suggest that consumer taste and preferences for high fat products such as whole milk and butter have decline over time. This, thus conflicts with cheese consumption which has increased over time.

Future studies should focus on cheese consumption. It is also possible to use the state-space approach in a demand systems framework. In a systems approach, the issue relating to separability should be examined which would make it possible to determine substitutes and compliments for dairy products.

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ESTIMATION RESULTS
LINEAR AND STOCHASTIC TREND ESTIMATES

Table 1. Per Capita Butter Consumption

Dependent Variable:-	Per Capita Butter Consumption (Natural log)	
Independent Variable:(Natural Log)	Linear Trend Model Estimates	Stochastic Trend Model Estimates
Linear Trend	.3552 (9.988)	
Stochastic Level		4.1099 (7.510)
Stochastic Slope		-.2291 (-2.701)
Real Butter Price	.0216 (.0654)	-.2291 (-1.957)
Real Disposable Income	-1.609 (-31.539)	.0258 (4.101)
Per Capita Butter Donations	-.4580 (-1.582)	-.0272 (-2.398)
Dumbut (-1 in 1967, 0 elsewhere)	.0614 (.9084)	.0454 (2.956)
R-Square	.7443	.6927

Table 2. Per Capita Whole Milk Consumption

Dependent Variable:-	Per Capita Whole Milk Consumption (Natural log)	
Independent Variables: (Natural log)	Linear Trend Model Estimates	Stochastic Trend Model Estimates
Linear Trend	.0662 (15.720)	
Stochastic Level		7.564 (57.837)
Stochastic Slope		-.0465 (-3.690)
Real Whole Milk Price	2.988 (7.210)	-.1445 (-2.221)
Real Disposable Income	-2.751 (-69.589)	.1201 (2.181)
Dumilk (1 in 66, 76, 85; 0 elsewhere)	-.002 (-.0301)	-.0272 (-.2398)
R-Square	.7021	.9964

Table 3. Per Capita Low Fat Dry Milk

Dependent Variable:-	Per Capita Low Fat Dry Milk Consumption (Natural log)	
Independent Variables: (Natural log)	Linear Trend Model Estimates	Stochastic Trend Model Estimates
Linear Trend	.1437 (37.6018)	
Stochastic Level		7.8455 (25.819)
Stochastic Slope		.02631 (1.9001)
Real Low Fat Milk Price	3.3834 (9.0068)	-.2516 (-2.702)
Real Disposable Income	-1.9706 (-55.3278)	.1389 (2.1181)
R-Square	.9625	.9971

Table 4. Per Capita Cheese Consumption

Dependent Variable:-	Per Capita Cheese Consumption (Natural log)	
Independent Variables (Natural log)	Linear Trend Model Estimates	Stochastic Trend Model Estimates
Linear Trend	.2337 (7.7618)	
Stochastic Level		11.9088 (6.6606)
Stochastic Slope		.0549 (2.1721)
Real Cheese Price	.3584 (3.1139)	.4355 (2.5896)
Real Disposable Income	.9930 (5.7093)	.2557 (1.4373)
Per Capita Cheese Donations	.0051 (1.5591)	-.0101 (-1.5006)
R-Square	.8819	.9118

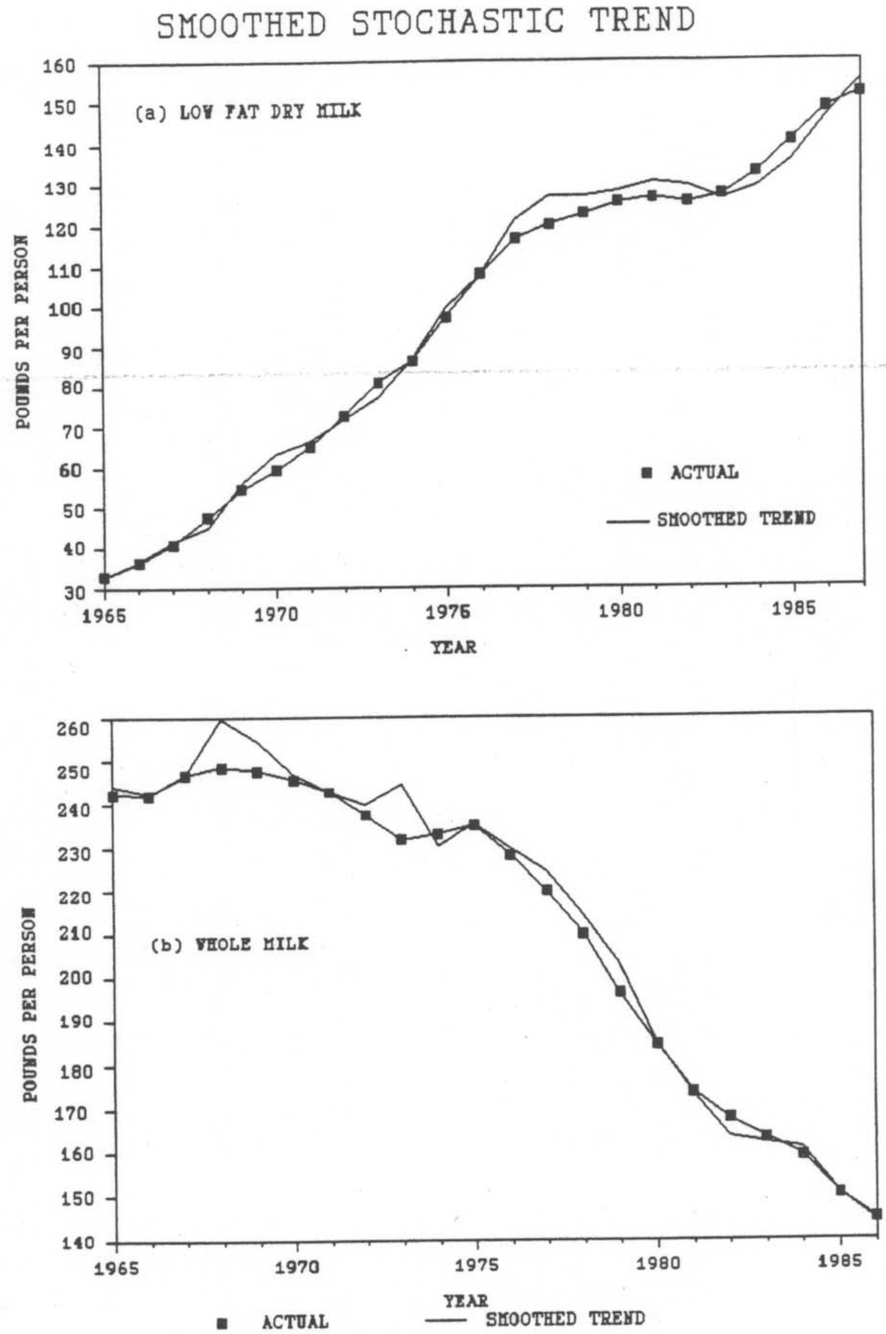

Figure 2. Smoothed and Actual Per Capita Low Fat Milk and Whole Milk Consumption (1965-1987)