Dept. of AGRICULTURAL ECONOMICS AND RURAL SOCIOLOGY

CLEMSON UNIVERSITY

working paper

WP 070183 July 1983

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Paper presented at the AAEA Annual Meeting, Purdue University, West Lafayette, Indiana, July 31-August 3, 1983.

ABSTRACT

The forecast performances of the fixed coefficient demand model are compared with those of spline function and the Cooley-Prescott varying parameter demand models using consumption and price data for beef, pork, chicken and turkey. In general, the varying parameter models outperformed the fixed coefficient model and the spline function varying parameter model appears to be slightly superior to the Cooley-Prescott model. However, no single model was consistently superior over all the commodities in the capacity to predict either the turning points or commodity levels. Apparently, the explicit specification of structural change using spline rather than random coefficient model offers some improvement in commodity forecasting.

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Introduction

A considerable empirical effort has been invested in the evaluation of forecasting performances of single equation regression models, and evidently, the forecast performance of most models are situation specific. There is, in other words, no single model which apparently performs equally well across commodities and time periods. This is exhibited rather dramatically in a sampling of published results.

Shih compared the forecast performances of two econometric models and and ARIMA (time series) model and found the latter to be superior in short run ex-post predictions of demand for Outward Wide Area Telecommunications Service. On the contrary, Leuthold et al. established, from a comparative evaluation of econometric and time series, that the econometric model yields slightly superior results over the time series model in forecasting daily prices of hogs.

However, there is not enough evidence available to make conclusive statements about the comparative accuracy of one model versus another. Stekler has discussed a number of criteria which may be used to determine the accuracy of a forecast and others have examined more critically the meanings of some of the measures of forecast accuracy (Bliemel, 1973; Leuthold, 1975); but by and large, there is no consensus on the procedures to be used in forecast performance evaluation. Furthermore, forecasting is highly sensitive to the empirical data and, of course, model specification.

Nevertheless, several innovative forecasting approaches have emerged, notably the use of futures markets (Kofi, 1973, Leuthold, 1974; Leuthold and Hartman, 1979; Just and Rausser, 1981; Martin and Garcia, 1981); pooling time series and cross-section data (Lee and Griffiths, 1979; Taub, 1979); and the application of varying parameter models (Dixon and Martin, 1982) in commodity price forecasting.

The first two approaches are similar in that each uses an expanded information base in commodity forecasting but the other addresses explicitly the issue of structural change. This paper follows the latter approach in commodity forecasting. More specifically a spline function varying parameter model (SVPM) is specified and estimated for the U. S. retail demand for beef, pork, poultry and turkey. In each case, measures of forecast performance, are subsequently compared with those obtained from two alternative specifications: the classical linear regression model (OLS) and the Cooley-Prescott varying parameter model (CPVPM).

Varying Parameter Models

The classical assumption of fixed coefficients in regression analysis is rather restrictive given the fact that the economic structure generating sample observations is not stationary. Poor forecasting performances may be attributed, in part, to the failure to capture structural changes by fixed coefficient models.

The problems of structural change have been widely recognized, however, and a variety of techniques have been used to model spatial, temporal, institutional and other behavioral differences. These include the use of dummy variables, data partitioning and pooling cross-section and time series data. Recently, however, several estimation techniques and specifications which explictly consider parameter variations in some systematic way, the variable parameter models, have arisen from several sources which have been extensively covered by Judge et al.

The Models

Meat consumption accounts for the single largest portion of household food expenditure. Compared to the other food groups, meat items have relatively higher unit prices and the per capita consumption has risen steadily over the past several decades. There is, however, considerable substitution in the consumption among individual meat items because of changes in prices, income, season and life-style. Furthermore, lately there have been some changes in the basic diet whereby more and more consumers are having meatless meals and others are turning to vegetarianism.

These, together with the everchanging economic environment, suggest that the demand structure for individual meat items is subject to change. Consider the classical linear regression model of the demand for beef given by,

$$\begin{aligned} c_t = \alpha + \beta_1 p_{1t} + \beta_2 p_{2t} + \beta_3 p_{3t} + \beta_4 p_{4t} \\ + \beta_5 y_t + \beta_6 D_{1t} + \beta_7 D_{2t} + \beta_8 D_{3t} + u_t \end{aligned} \tag{1}$$

where t, refers to time periods (quarters) and c_t is the per capita demand for beef; p_{1t}, p_{2t}, p_{3t}, and p_{4t} are the retail quarterly prices for beef, pork, chicken and turkey, respectively; y_t is the per capita income; D_{it}, D_{2t} and D_{3t} are seasonal dummies; α and the β are the parameters to be estimated; u_t is the error term. The same specification (1) is applied to the demand for chicken, pork and turkey. To the relationship (1), two types of variable parameter models: the Cooley-Prescott and linear spline models, are specified. The nature and properties of these variable parameter models have been formally treated elsewhere (Judge et al., Poirier) and will not be repeated here. The Cooley-Prescott varying parameter model (CPVPM) is given by,

$$c_t = p_t'\beta_t, \qquad t = 1,2,\ldots,79 \tag{2}$$

where p_t is a vector of observations on k explanatory variables, the right-hand side of equation (1); c_t is the dependent variable and β_t is the parameter vector subject to stochastic variations as:

$$\beta_t = \beta^p{}_t + u_t \tag{3}$$

$$\beta_t = \beta_{t-1} + v_t \tag{4}$$

where β_t is the permanent component of the parameter vector; u_t and v_t are independent normal random vectors with mean vector zero and covarience matrices $E(u_t u_t') = (1 - \gamma)^2\sigma\, \Sigma_u$ and $E(v_t v_t') = \gamma^2\sigma\, \Sigma_v$.

Finally, the spline function varying parameter model (SVPM) is of the form

$$c_t = \alpha + \sum_{i=1}^{k} \beta_i p_{it} + \beta_{k+1} y_t + \sum_{i=1}^{k} \theta_i w_{it} + e_t \tag{5}$$

where c_t, p_{it}, and y_t are interpreted as in (1); e_t is the error term, α, β, θ are the parameters to be estimated, and w_{it} is the spline transformation such that for any p_{it}:

$$w_1 = p \tag{6}$$

$w_j = \max(p - \bar{p}_{j-1}, 0)$ if $p > \bar{p}_{j-1}$, otherwise $w_j = 0$, for all $j = 2,3,\ldots,K$ where $P = (\bar{p}_1, \bar{p}_2, \ldots, \bar{p}_{j-1})$ are preselected ordinate values.

Equation (1) is the familiar fixed coefficient representation of a demand model in which the per capita consumption is a function of own price, prices of other products, income and seasonal variations. Structural changes are specifically attributed to seasonal differences in consumption relationships. The alternate representation, equations (2)-(4), the Cooley-Prescott model, permits all the parameters to vary continuously over time such that between successive time periods, the values of the estimated coefficients may or may not be the same. This pattern of parameter variations differs substantially from that of the linear spline functions (5-6) in which parameters are permitted to vary a few (and predetermined) times over the sample period.

Although the parameters of both the CPVPM and SVPM vary over the sample period, there is a marked difference in the nature and consequently, the interpretations of the variations. In the former, the response coefficients are permitted to be different for each observation but the latter allows the regression coefficients to be constant over a subset of the observations but different across subsets.

Parameter variations across subsets of the observations, in this case different time intervals, reflect more realistically the adjustment behavior of consumers. Consumers do not typically adjust their consumption behaviors to changes in the socioeconomic environment instantaneously and continuously because of habit persistence and imperfect information. Changes in consumption behavior are, therefore, discontinuous over time, and once an adjustment is made the resulting behavior is sustained over several time periods. This is more closely reflected in the SVPM than the CPVPM formulation of demand parameter variations.

Empirical Results--Comparative Forecasting Performances

The demand function for each commodity is estimated in linear and nonlinear form using, alternately, fixed and varying parameter specifications. In the former, the OLS and CPVPM were applied to each commodity and for the linear form an additional varying parameter model, SVPM, was estimated. The results in Tables 1 and 2 express the computed forecast statistics of the varying parameter models as a percentage of that computed from the OLS, the fixed coefficient model.

Root mean square is a summary statistic that measures the accuracy of a model in predicting the levels of the dependent variable. In the nonlinear formulations (Table 1), CPVPM is superior to OLS in the prediction of all except the per capita demand for turkey. It does best in predicting beef consumption and, clearly much better than the OLS in both pork and chicken.

In the linear formulations, the CPVPM performs slightly better than OLS in chicken and pork but worse in beef and turkey predictions. On the other hand, the spline varying parameter model outperforms CPVPM in all except the per capita demand for turkey. It is, however, just slightly superior than CPVPM in chicken and much worse in turkey predictions. As in the nonlinear formulations, both varying parameter models perform worse than the fixed coefficient model in predicting the per capita demand for turkey.

The U_2 statistic measures the accuracy of a model in predicting turning points of the dependent variable. In the nonlinear formulation, the fixed coefficient model performs better than the Cooley-Prescott

Table 1. Root Mean Square Error for Linear and Non-linear Demand Models: Comparative Forecast Accuracies of OLS, CPVM and SVPM.

	Logarithmic Form		Linear Form		
	OLS Actual	CPVPM[a] (%)	OLS Actual	SVPM[a] (%)	CPVPM[a] (%)
Beef	2.296	55	4.165	51	232
Chicken	2.836	73	5.959	97	99
Turkey	91.776	373	4.935	521	291
Pork	2.995	65	5.601	75	85

a. These are expressed as percentages of the RMSE of the OLS model. Ordinary least squares (OLS); Cooley-Prescott varying parameter model (CPVPM); Spline function varying parameter model (SFVPM).

Table 2. Theil's U_2 Statistics For Linear and Non-linear Demand Models: Comparative Forecast Accuracies of OLS, CPVM and SVPM.

	Logarithmic Form		Linear Form		
	OLS Actual	CPVPM[a] (%)	OLS Actual	SVPM[a] (%)	CPVPM[a] (%)
Beef	1.621	126	5.859	29	37
Chicken	1.969	95	1.026	186	174
Turkey	0.426	113	1.164	43	42
Pork	2.234	100	1.921	101	78

a. These are expressed as percentages of the U_2 of the OLS model. Ordinary least squares (OLS); Cooley-Prescott varying parameter model (CPVPM); Spline function varying parameter model (SFVPM).

model in beef and turkey predictions. It does equally well in the pork situation but worse in predicting the per capita demand for chicken.

In the linear formulation, both varying parameter models perform worse than the fixed coefficient model in predicting the per capita demand for chicken. In the case of turkey, the varying parameter models perform about equally well; both are worse than the OLS model. Both varying parameter models outperform the fixed coefficient model in predicting beef demand. In the case of pork, the fixed coefficient model is slightly better than the spline varying parameter model but worse than the Cooley-Prescott model.

It is not evident from the results that a consistent pattern of the relative forecasting performances emerges. The CPVPM is apparently superior to the fixed coefficient regression model in predicting levels but less superior in predicting turning points in the nonlinear formulations. In the linear formulation, the spline varying parameter model is superior to the Cooley-Prescott model in predicting levels and both are equally good in predicting turning points.

Commodity by commodity, SVPM is best in beef and CPVPM in pork predictions. For turkey and chicken, the forecast performances of both the CPVPM and SVMP are similar. In general, however, the spline varying parameter model appears to be more appropriate to the extent that in three out of four cases, the computed root mean squares were lower than those computed from the Cooley-Prescott model.

Conclusions

A large amount of literature exists in commodity forecasting. Recent innovative approaches include the application of varying parameter models. This is particularly appealing because of the rather restrictive nature of the fixed coefficient assumptions. This paper reports the comparative forecasting performances of two varying parameter models, the Cooley-Prescott and spline function models.

By comparing the root mean squares and U_2 statistics of fixed coefficient, Cooley-Prescott and spline function models, used in estimating the per capita consumption of chicken, beef, pork and turkey, no consistent pattern of forecast performance was established. That is, on the basis of the two forecast statistics, no single model could be identified as the best for all the four commodities, in the linear and nonlinear formulations.

But singly, the root mean squares forecast statistic suggests that the Cooley-Prescott varying parameter model is superior, generally, to the fixed coefficient model in the nonlinear formulation. Similarly, in the linear formulation, the spline function model is, generally, superior to both the Cooley-Prescott and fixed coefficient models. This may be attributed to the nature of the structure of parameter variations inherent in the spline formulation which is more representative of consumer adjustment behavior.

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