Using Nonparametric Demand Analysis in a Meat Demand System

by

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Empirical demand system analysis is often used as a basis for testing for the existence of a change in preferences for U.S. meat products (Eales and Unnevehr, Moschini and Mielke (1984, 1989), Thurman). The coefficients of a specific functional form are estimated using price and quantity information. Diagnostic tests, conditional upon the correct specification of the underlying functional form, are then used to detect for the existence of a change in preferences. The identification of a change in preferences may be due to the failure of the functional form to model the the data or the true existence of a change in preferences.

Nonparametric demand analysis is another method used to test for the consistency of preferences over time. Unlike parametric procedures, this method does not require the specification of a particular functional form. Pairs of observations are tested for their consistency with revealed preference axioms. The existence of a true change in preferences corresponds to inconsistency of the data with the utility maximization hypothesis.

Through use of nonparametric demand analysis, annual U.S. meat prices and quantities were shown to be consistent with the utility maximization hypothesis (Chalfant and Alston; Thurman). Because of a steady growth in real expenditures, the power of nonparametric test when used as a test for consistency with utility maximization or stable preferences has been questioned (Thurman). In the presence of growth in real expenditures, budget lines will shift out over time. This would make it impossible to detect crossing budget lines which indicate unstable preferences. Chalfant and Alston adjusted for the growth in real expenditures over time and still found that the meat demand data did not indicate a change in preferences.

The results of nonparametric demand analysis, as with parametric demand analysis, are conditional upon the separability and representative consumer assumptions. In previous nonparametric meat demand analysis, it has been assumed that the meat commodities constitute a weakly separable group. Therefore, only changes in preference between commodities included in the choice set could be detected. For example, in a choice set of beef, pork, poultry, and fish, it would be possible to detect a change in preferences between beef and poultry, but impossible to detect a change in preferences between beef and pasta.

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Although the results of nonparametric demand analysis are not conditional upon the correct specification of a functional form there is a limited amount of information that this type of analysis can provide. Parametric information, such as elasticity estimates, is not derivable from this type of analysis. However, nonparametric demand analysis may provide information which could be useful when estimating parametric demand systems. Specifically, the non-parametric test for consistency with utility maximization identifies pairs of observations which are inconsistent with revealed preference theory. By deleting these observations, a data set in which all of the pairs of observations are consistent with the revealed preference axioms parametric demand system parameters can be formed. The indirect translog utility function performed better when applied to data sets consistent with utility maximization and separability assumptions. Performance in these test was measured by an acceptance of theoretical restriction. The performance of both the direct and indirect translog demand systems were improved by dropping observations found to be outliers using nonparametric analysis (Barnhart and Whitney).

This paper examines whether nonparametric demand analysis can improve the performance of a linear approximate Almost Ideal Demand System of meat products. Nonparametric analysis is used to detect outliers, or pairs of observations which are inconsistent with the utility maximization hypothesis. These observations are then deleted from the data set, and a linear approximate AIDS model is estimated. The performance of the model is evaluated using out of sample forecasts and tests for utility maximization.

Nonparametric Test for Consistency With Utility Maximization

The properties of a consumer's preference ordering can be described using both calculus and algebraic approaches. The former uses derivatives of the demand functions to define a set of necessary and sufficient conditions for a well-behaved demand function. These conditions include Engel and Cournot aggregation, Slutsky symmetry, and concavity restrictions.

Samuelson derived the algebraic conditions necessary for a demand function to be consistent with the utility maximization hypothesis. These conditions are known as "revealed preference theory." In order for a set of preferences to be consistent with the utility maximization hypothesis, it must satisfy both the weak and strong axioms of revealed preference. The weak axiom of revealed preference (WARP) states that a bundle x_i is revealed preferred to any other bundle x_j that could have been purchased instead. The weak axiom is violated if bundle x_j is also revealed preferred to x_i. The weak axiom compares two bundles, but consistency with utility maximization requires that transitivity holds across all bundles. The strong axiom of revealed preferences insures the transitivity of this relationship across all nxn bundles in the data set, where n is the number of observations.

Nonparametric tests for examining the consistency of a data set with the Strong Axiom of Revealed Preference (SARP) were developed by Afriat. The data must satisfy four equivalent conditions to be consistent with utility maximization. Afriat's Theorem states that for a given finite number of observations on k-vectors of prices and quantities (p_i and q_i), the following conditions are equivalent:

1. there exists a non-satiated utility function that rationalizes the data;

2. the data satisfy SARP;

3. there exists numbers (the Afriat numbers) U^i , $L^i > 0$ i = q,...,n that satisfy the Afriat inequalities: $U^i < U^j (x_i - x_j)$ for i, j=1,...,n. (The Afriat numbers U^i and L^i can be interpreted as measures of the utility level and marginal utility of income at the observed demands.)

4. there exists a concave, monotonic, continuous, nonsatiated utility function that rationalizes the data.

Varian (1982) has stated that if any of these four conditions is satisfied, then the general axiom of revealed preference (GARP) is satisfied. The demand functions satisfying the strong axiom of revealed preferences (SARP) are a subset of those satisfying GARP. GARP is compatible with multivalued demand functions while SARP requires only single valued functions (Varian, 1982).

In this paper, only nonparametric test for consistency with the utility maximization hypothesis are used. However, test for separability assumptions, homotheticity, and a variety of other properties have been developed and utilized in empirical work (Varian (1983), Barnhart and Whitney, Swofford and Whitney).

Data

Quarterly data on beef, pork, young chicken, and turkey are used in the analysis. Per-capita retail quantities and prices are from various issues of the USDA's Livestock, Poultry Situation and Outlook Reports. The price series are: retail prices of choice, yield grade 3 beef, retail prices of pork, U.S. average retail prices of young chickens, and 4-region average retail prices for whole turkeys. The data series covers the years 1963-1987.

Results of Testing for Consistency with Utility Maximization

Varian's program Nonpar is used to test the data for consistency with the utility maximization hypothesis. Testing the data series revealed 21 pairs of observations which are inconsistent with the utility maximization hypothesis.[2]

It can be argued that seasonality in meat demand, or changing preferences within a annual interval would influence any stable preference test based on quarterly data. For example, one may prefer beef on the grill in the summer months to other months. However, only one of the 21 pairs of observations consisted of two observations within the four quarter span.

When the data series in this analysis is aggregated from quarterly observations into annual observations, no violations of the revealed preference axioms are found. This result is similar to those of Chalfant and Alston who found no violations in annual data for beef, pork, poultry, and fish over the years 1947-1978 and 1960-1984. The inconsistency between the results in this paper using the annual and quarterly data suggest that the nonparametric tests are conditional upon the length of observation used.

The Linear Approximate Almost Ideal Demand System

The linear approximate Almost Ideal Demand System is used to estimate parameter coefficients. This model closely approximates results from the AIDS model (Deaton and Muellbauer). The linear approximate AIDS model explains how changes in relative prices and income can impact the budget share of a good. The budget share for the i^{th} good in time t is explained by:

$$W_{it} = \partial_i + \sum_j g_{ij}\, p_{jt} + \beta_j X_t + \sum_k \partial_{ik} D_k + e_{it}$$

The log of nominal prices for good i is denoted p_i. The log of total expenditures deflated by Stones Price Index $\sum_i W_i P_i$ is denoted by X. The three seasonal dummy variables for quarters one through three are denoted by D, and e denotes the error term.

In the AIDS model, the adding up restrictions hold automatically and are written:

$$\sum_i \partial_i = 1 \quad \sum_i g_{ij} = 0 \quad \sum_i \beta_i = 0 \quad \sum_{ik} D_k = 0$$

The homogeneity restriction is denoted:

$$\sum_j \beta_j = 0.$$

[2] The pairs of observations are for the years: (64:4,73.1), (65.4,67.2), (66.4,68.3), (66.4,69.3), (66.4,79.1), (66.4,79.2), (67.2,65.4), (68.3,66.4), (68.3,69.3), (69.1,64.4), (69.3,66.4), (72.2,74.2), (73.1,64.4), (73.1,69.1), (74.1,66.4), (74.2,72.2), (79.2,74.1), (79.2,74.1),(79.2,79.1),(83.1,87.1),(87.1,83.1).

and Slutsky symmetry is denoted by:

$$g_{ij} = g_{ji}.$$

For estimation purposes, the model is used in first difference ($\triangle$) form:

$$\triangle W_{it} = \sum_j g_{ij} \sum_{pjt} + \beta_i \triangle x_t + \sum \partial_{ik} \triangle D_k + U_t.$$

The error term is assumed to be normally distributed and contemporaneously correlated. It is assumed:

$$E(U_{it}) = 0 \quad E(U_{it} U_{jt}) = W_{ij} (U_{it} U_{js}) = 0 \text{ for } t \neq s.$$

The first difference linear approximate AIDS model is estimated using the iterative seemingly unrelated regression procedure found in SAS. Three specifications are estimated for each system of (n-1) equations: unrestricted, with homogeneity imposed, and with symmetry imposed. Two systems of equations are estimated: one over the entire data series which consisted of 100 observations of quarterly data for the years 1963-1987, and one spanning the same years of quarterly data but with outliers deleted.

Both systems for each of the three specifications are first estimated with the j^{th} equation deleted and again with the i^{th} equation deleted. This is done so that the standard errors of each equation can be reported.

Summaries of the results from each system with homogeneity imposed are presented in Tables I and II. Table I reports the results from the homogeneous system estimated with all of the data points. Table II reports the homogeneous system estimated over the data set with outliers deleted.

Testing for Homogeneity

In the model estimated with each observation in the data range, the homogeneity restriction is rejected in the turkey equation at the 5 percent significance level. In the system with outliers deleted, however, the homogeneity restriction is rejected in both the beef and turkey equations at the 1 percent significance level but accepted at the result 5 percent significance level. This result is different from a priori expectations. Because the data set is consistent with the utility maximization hypothesis, it was expected that the homogeneity restrictions would hold. This result may imply that the model is misspecified -- relevant price and quantity information may be omitted -- or that the functional form fails to model the preferences implied by the data.

One could argue that the nonparametric utility maximization test did not adjust for seasonality. Therefore, to be consistent, the parametric counterpart should not adjust for seasonality. The parametric homogeneity test were estimated using similar models to those estimated previously, except without the dummy variables adjusting for seasonality. The results of these test showed that the homogeneity restriction was rejected in the turkey equation in both of the models. The results from this estimation are available from the authors.

Parameter Coefficients and Elasticities

The expenditure coefficient, β_i, measures the effect of a real increase in total meat expenditures on the budget share of the i^{th} meat product. The expenditure elasticity is derived using the formula $N_i + 1 + \beta_i / W_i$ with a positive expenditure elasticity denoting a superior good. Because of the adding up restriction, $\sum_i \beta_i = 0$, at least one of the goods will automatically be superior ($N_i > 1$) and the least one will be a necessity ($N_i < 1$).

The price coefficients, g_{ij}, measure the effects of a change in the price of the j^{th} good on the budget share of the i^{th} good. The Marshallian price elasticities are calculated using the formula found in Green and Alston,

where $E_{ij} = - d_{ij} + g_{ij} / W_i - \beta_i W_j / W_i - \beta_i / W_i - \sum_k W_k P_k(E_{ij} + d_{kj})$.

The $d_{ij} = 1$ for $i = j$ and $d_{ij} = 0$ for $i \neq j$. All of the elasticities are estimated with the mean budget share.

In the model estimated with all of the observations, the signs for a given coefficient are the same in each of the three specifications (unrestricted, homogeneous, and symmetric). The signs of each of the price and expenditure elasticities are also stable across each of the three specifications. The turkey budget share is the most positively impacted by changes in total meat expenditures. The expenditure coefficient in the chicken and beef equations are negative and significant implying that positive changes in total meat expenditures will negatively impact the shares going to these products. Pork is the product most sensitive to changes in own price. However, neither the own price or expenditure coefficients in the pork equation are significant.

The model estimated with selected data points shows only a slight variation in coefficient signs when examined across restriction specifications. The beef price coefficient in the turkey equation changes from positive to negative when homogeneity and symmetry are imposed on the model. When the symmetric results are compared to the other specifications, the pork price coefficient changes from positive to negative in the beef equation. However, the coefficients which change signs in each specification are statistically insignificant.

The expenditure coefficients in the specification estimated with the outliers deleted are significant in three of the four equations. In the homogeneous specification estimated with all of the data points, the expenditure coefficient in the chicken equation is the only significant one. The expenditure coefficients in the beef and chicken equations are both negative indicating that an increase in total meat expenditure will reduce the proportion of meat expenditures going to these products. The own price coefficient in each of the equations are positive; however, it is only significant in the chicken equation.

The Predictive Accuracy of the Models

The predictive accuracies of the system estimated with all of the data points and the system estimated with the outliers deleted are evaluated using out of sample forecast. The models are estimated over the years 1963-1987. Out of sample forecasts are estimated for the years 1988-1989. These two years of quarterly data are used to verify or validate the predictive performance across the alternative model specifications.

The root mean square (RMS) percentage error, or RMS percentage error = $(1/T\sum_t ((A_t - P_t)/A_t)^2)^{-1/2}$ where A_t = actual budget share and P_t = predicted budget share is used to evaluate the predictive accuracy of the models. The values for the RMS percentage error are calculated for each of the model specifications. The rankings of the specifications are presented in Table IV.

The model specifications estimated with the data set in which the outliers are deleted consistently outperform the model specifications estimated over all of the data points. The homogeneous model estimated over the data series has the lowest RMS error in two of the four commodities. And the budget share forecasts estimated using the unrestricted specification over all of the data points are ranked lowest in three of the four specifications.

The objective of this exercise is to be determine if the information provided by nonparametric demand analysis will improve the forecasting performance of the linear approximate AIDS model. Using the nonparametric demand analysis to detect outliers, and then deleting this observation from the data makes it possible to derive parameter coefficients with superior forecasting performance to those coefficients derived from the unadulterated data series. As a whole, the forecast estimated with the data in which the outliers are deleted outperformed the alternative specification. However, it is impossible to determine if the performance of any of the restriction specifications is superior.

Conclusions

Chalfant and Alston (p. 391) state that "using nonparametric demand analysis, we find that meat consumptions patterns in the United States and Australia can be explained using only relative prices and expenditures. Only imposing particular functional forms can reverse the conclusion, suggesting that specification errors in econometric demand studies can account for findings of tastes changes." This study suggests that changing the length of this observation interval can impact the results from nonparametric demand analysis.

Change from a quarterly to annual time period resulted in differing results for the utility maximization test. When analyzed using quarterly data, nonparametric demand analysis detected a change in preference in U.S. meat demand.

Nonparametric test for consistency with utility maximization were used to identify observations which were inconsistent with the revealed preference axioms. This information was useful in improving the forecasting accuracy of a linear approximate almost ideal demand system. Further research needs to be done to see if this result is consistent with other functional forms and other data sets.

The results of the nonparametric demand analysis were used to derive a data set consistent with utility maximization. However, the failure of the data set to accept the restrictions derived from utility maximization in the linear approximate AIDS model framework was contrary to a priori expectations.

In summary, the strongest conclusion that can be drawn from this effort is that like parametric estimation, the results from nonparametric test are conditional upon the underlying assumptions used to specify the analysis.

Table I

Model Estimated with All Data Points Homogeneous 1963-1987

	Expenditure Coefficient	Own Price Coefficient	F Statistic on Homogeneity Test *	Durbin Watson	Mean Budget Share	Expenditure Elasticity	Own Price Elasticity
Beef	-.0178 (-.45)	.0295 (1.43)	.86	2.10	.557	.97	-.93
Pork	.0183 (.51)	.0246 (1.22)	1.24	2.44	.305	1.06	-.94
Chicken	-.0753 (-4.33)	.0936 (11.77)	.53	2.01	.107	.30	-.10
Turkey	.0109 (1.17)	.0748 (2.74)	5.81*	2.48	.031	3.42	-.72

Asterisk denotes significance at 5 percent level.

Table II

Model Estimated with Selected Data Points Homogeneous 1963-1987

	Expenditure Coefficient	Own Price Coefficient	F Statistic on Homogeneity Test *	Durbin Watson	Mean Budget Share	Expenditure Elasticity	Own Price Elasticity
Beef	-.1329 (-3.50)	.0854 (3.60)	4.95	1.95	.557	.64	-.68
Pork	.0297 (.81)	.0215 (.89)	.039	2.36	.304	1.10	-.96
Chicken	-.1052 (-6.02)	.0927 (8.67)	.595	2.65	.108	.03	-.10
Turkey	.2084 (7.61)	.0207 (1.27)	5.34	2.15	.031	7.67	-.51

Asterisk denotes significance at 5 percent level. The F statistics in the beef and pork equation denote rejection at the 1 percent level but acceptance at the 5 percent level.

Table III
A Comparison of the Predictive Accuracy of the AIDS Models Estimated with All Data Points and Selected Data Points over the Years 1963-1987

Root Mean Squared Percentage Error

	All Data			Outliers Deleted		
	OLS 0	Homogeneous H	Symmetric S	OLS 0′	Homogeneous H′	Symmetric S′
1) Beef	.88	1.070	.81	.79	.52	.45
2) Pork	4.01	3.84	3.74	3.35	3.40	3.51
3) Chicken	7.70	7.54	7.45	5.89	5.63	5.68
4) Turkey	1.27	.95	1.08	1.38	1.12	1.15

Table IV
Rank of Models Based on Root Mean Squared Percentage Error

	1	2	3	4	5	6
1) Beef	S′	H′	O′	S	O	H
2) Pork	O′	H′	S′	S	H	O
3) Chicken	H′	S′	O′	S	H	O
4) Turkey	H′	S′	O′	S	S	O

Appendix A. References

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