Application of the Least Absolute Value Technique as a Data Filter for Detecting Structural Change in the Demand for Meat

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Introduction

In agricultural commodity modeling, the time period since 1973 has presented estimation problems due to sudden large increases in product and input prices. Among factors contributing to these price increases are the 1973 oil embargo, grain trade with the Soviet Union and decreased yields for some crops due to severe weather conditions. The presence of such extreme values (i.e., large price increases) can obviously affect modeling results when deriving such relationships as supply equations or demand equations.

The livestock market in the 1970's did not escape fluctuating prices and market uncertainty. Several reasons would suggest that structural change in the demand for meat occurred in the 1970's. First, large price fluctuations in various meat prices could change relative substitutability among alternative meats. Second, consumers have become more concerned about healthy diets and reducing cholesterol levels. Third, the beef grading changes in the mid-1970's may influence the demand for beef (Purcell and Nelson).

This paper proposes use of the least absolute value (LAV) estimation procedure as an alternative to ordinary least squares (OLS). The LAV estimation criterion is known to yield robust estimates and should be considered as an alternative to estimating equation parameters when large disturbances are present (Judge, et al.). This technique has been widely cited (Gentle, et al.; Ashar and Wallace; and Taylor), and has received increased attention in the statistical literature. Havlicek used the LAV procedure to estimate broiler prices and commercial beef production.

The first objective of this paper is to illustrate that under certain conditions, the LAV technique is a viable substitute for the more commonly used OLS procedure. Forecasting accuracy is compared for OLS and LAV forecasts of beef, pork and chicken prices. Second, examination of LAV and OLS structural parameters can indicate changes in demand structure.

Current Research

The term "structure" in its application to agriculture has generally referred to farm structure of the entire food and fiber system. The structure of the demand for meat pertains to factors underlying demand for a commodity, i.e., direct and indirect substitution effects and income effects, and socioeconomic factors affecting tastes and consumer preferences. Rausser, et al. state that structured or systematic changes can be caused by the outside environment or by factors within the system.

Regression models oftentimes use dummy variables to capture data shifts. Mayes outlines the three major uses of dummy variables (slope and intercept shifters) as first to take account of structural changes in parameters; second to take account of special events; and third to represent categorical variables. Intercept shifters are often used to detect the latter two cases and slope shifters to indicate structural changes.

Another method for evaluating structural change in linear models is to allow parameters to change as the economic environment changes. This enables the model to incorporate dynamic aspects of the demand structure in approximating new behavioral responses.

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This approach suggests usage of stochastic parameter models as opposed to fixed parameter models (OLS). Recently, Chavas used a Kalman filter specification to show that structural change in the demand for meat occurred in some periods and not in others. By separating the 1970's into two periods, 1970–1974 and 1975–1979, his results indicated no structural change in meat demand for the earlier period. In the 1975–1979 period, the Kalman filter model identified structural change occurring in beef and poultry demands and not in pork.

To capture data shifts with a stochastic model, this paper suggests an alternative technique. The next sections describe the LAV procedure and estimated models and compares the OLS and LAV results.

Least Absolute Values (LAV) Estimation Procedure

The general linear model can be written as:

$$Y = XB + e$$

where Y and e are n × 1 vectors, X is an n × p matrix and B a p × 1 vector of unknown parameters. It is assumed that e is a random variable with zero mean.

The LAV procedure estimates the unknown parameters B in a stochastic model by minimizing the sum of absolute deviations of a set of observations from the values preducted by the model. The objective function is:

$$\text{(1.1)} \quad \min \Sigma_i \mid Y_i - \Sigma_j X_{ij} B_j \mid$$

$$\text{subject to } Y_i = \Sigma_j X_{ij} (B_{1,j} - B_{2,j}) - + u_i - v_i$$

$$B_{1,j}, B_{2,j} \geq 0$$

$$u_i, v_i \geq 0$$

where Y_i is the ith observation of the dependent variable,

X_{ij} is the ith observation of the jth explanatory variable,

B_j is the estimated coefficient corresponding to the jth explanatory variable ($B_j = B_{1,j} - B_{2,j}$), and

u_i and v_i are auxiliary variables.

The parameters obtained from the LAV criteria are calculated by using linear programming algorithms.

There have been criticisms of the LAV technique (Gentle). The first criticism is the possible nonuniqueness of LAV estimators for various data sets. Second, the distributional properties of the LAV procedure are not known with certainty. Last, the LAV estimation technique has a history of computational problems.

The problem of nonuniqueness refers to the existence of multiple estimates in a given model and associated data set. Edgeworth and Harter suggest additional criteria to determine the unique estimate derived from the LAV procedure. Also, Gentle, et al. propose using an OLS estimator restricted to the LAV-estimate space to obtain a unique estimate.

Considerable research has been done on determining the distributional parameters of LAV estimators (Sposito, et al.). Koenker and Bassett demonstrated that the LAV estimator has asymptotic properties in various cases.

The problem of computational complexity in implementing the LAV procedure has been reduced since Charnes, Cooper, and Ferguson showed that LAV estimation is essentially a linear programming problem. Recenty, IMSL (International Mathematical and Statistical Libraries) and SAS (Statistical Analysis System) have incorporated the LAV estimation capability into their software subroutines.

The LAV procedure is particularly advantageous in the case of data outliers and heavy tailed error distributions (Rice and White) as opposed to OLS where the sum of squared deviations is minimized. Outliers and heavy tailed error distributions are given reduced weights by the LAV method. It is this characteristic of the LAV technique which can provide information concerning structural shifts.

Barnett and Lewis cite several reasons for data outliers. First, outliers may be due to human error and ignorance. This source can be traced to measurement error and execution error. Second, structural changes may produce data outliers. Third, exogenous changes can cause data shifts in the variable(s) under consideration.

Excluding human error, outliers are due to the latter two sources. Since the LAV procedures place less weight on outliers and data shifts, significant differences between OLS and LAV parameter estimates are indicative of structural and/or exogenous changes.

Estimated Models

Demand equations for beef, pork, and chicken were estimated by OLS and LAV for the time period 1960–1978. These demand equations are price dependent and homogeneous of degree zero in prices and income (Heien). Degree zero homogeneity is preserved by deflating all prices and income by a consumer price index for nondurables less food. The demand equations, in terms of dependent and independent variables, are estimated separately under both estimation techniques.

The structural equations for beef, pork, and broiler demand are:[1]

(1.2) RBEEFP = f(BEEFCON, RINC, PORKCON, VEALCON, CHICCON)

(1.3) RPORKP = g(PORKCON, RINC, BEEFCON, CHICCON)

(1.4) RCHICP = h(CHICCON, RINC, BEEFCON, PORKCON)

where

RBEEFP = retail beef and veal price index (1967 = 1.0) deflated by PCNDF,

RPORKP = retail pork price index (1967 = 1.0) deflated by PCNDF,

RCHICP = retail frying chicken price index (1967 = 1.0)

RINC = per capita personal consumption expenditures on nondurable goods and services deflated by PCNDF,

PCNDF = consumer price index for nondurables less food (1967 = 1.0),

BEEFCON = per capita beef consumption (pounds),

PORKCON = per capita pork consumption (pounds),

VEALCON[2] = per capita veal production (pounds), and

CHICCON = per capita chicken consumption (pounds).

[1] Data on quantities and retail prices for beef, pork and veal were obtained from the USDA/ESS, *Livestock and Meat Situation* reports. The data for chicken were collected from the USDA/ESS, *Poultry and Egg Situation* reports. Annual data for personal consumption expenditures on nondurable goods and services were obtained from U.S. Department of Commerce, *Survey of Current Business* (various issues). Consumption quantities and expenditures are in per capita terms while retail prices and per capita personal consumption expenditures are deflated by the consumer price index for nondurables less food.

Results

The estimated OLS equations are shown in Table 1. All estimated coefficients have the expected signs and most variables are statistically significant at the 10% level. The Durbin-Watson (D.W.) statistic for the pork price equation indicates potential serial correlation. However, the Cochrane-Orcutt generalized least squares technique estimated a statistically insignificant rho value.

The corresponding LAV results are shown in Table 2. Price flexibilities for both the LAV and OLS models are found in Table 3. Comparisons of price forecasts for 1979 and 1980 are shown in Table 4. Generally, the LAV forecasts are more robust than OLS price forecasts.

The demand structure for beef, pork and chicken is defined by the set of parameters and form of the functions f, g and h in equations (1.2), (1.3) and (1.4). The LAV technique can be used as a screen for demand data. Differences in the intercept terms and explanatory variable coefficients for the OLS and LAV estimated equations are indicative of data shifts and outliers affecting demand structure.

A t-test was performed for each pairwise set of coefficients and intercept terms. Statistical difference at the 30% level was found for the intercept term in the beef demand equation. For the chicken demand equation, the inter-

Table 1. OLS Regression Results for Beef, Pork and Chicken Demand, 1960–1978

	Intercept	BEEFCON	PORKCON	CHICCON	VEALCON	RINC	R^2	F-Statistic	Durbin-Watson Statistic
RBEEFP	2.4045	−0.0068	−0.0064	−0.0180	−0.0893	0.3414	0.95	49.40	2.14
	(11.11)[a]	(−5.12)	(−3.93)	(−2.78)	(−10.10)	(3.88)			
RPORKP	2.0752	−0.0033	−0.0159	−0.0032		0.2392	0.91	36.17	1.62
	(6.22)	(−1.25)	(−5.54)	(−0.26)		(1.35)			
RCHICP	2.0784	−0.0070	−0.0062	−0.0274		0.4772	0.72	9.18	1.87
	(5.52)	(−2.33)	(−1.91)	(−1.98)		(2.39)			

[a] Numbers in parentheses are t-statistics.

Table 2. LAV Results for Beef, Pork, and Broiler Demand, 1960–1978

RBEEFP = 2.1723 − 0.0056 * BEEFCON + 0.3438 * RINC − 0.0051 * PORKCON − 0.0184 * CHICCON − 0.0838 * VEALCON

RPORKP = 1.9954 − 0.0157 * PORKCON + 0.2625 * RINC − 0.0022 * BEEFCON − 0.0065 * CHICCON

RCHICP = 1.7120 − 0.0344 * CHICCON + 0.5018 * RINC − 0.0038 * BEEFCON − 0.0037 * PORKCON

cept showed statistical difference at the 10% level and variable BEEFCON was statistically different between OLS and LAV results at the 30% level. There was no difference detected in the pork demand equation. These results indicate possible structural change affecting the demands for beef and chicken and not pork demand. This is similar to Chavas' function of structural change in the late-1970's affecting beef and chicken demand and absence of structural change in pork demand.

Conclusions

In the case of commodity modeling with outliers, the use of the LAV procedure should be considered as a viable alternative to ordinary least squares. Also, when both techniques are used, comparisons of parameter differences can filter out abnormalities in the underlying data distribution which could suggest structural change. Results from this study indicate parameter changes occurring in both beef and chicken demands and not in pork demand. In the case of beef, structural shift is likely and can be explained as stemming largely from changing dietary habits, i.e., consumers opting to eat less beef and more poultry. As a consequence of chicken becoming a more staple food item in consumers' consumption patterns, this alters the structure of chicken demand and is reflected by a more inelastic demand (as shown by the larger flexibility estimate for LAV than OLS in Table 3).

In the case of annual data, oftentimes the number of observations are too few to permit subdividing the time period into shorter time segments. Instead, quarterly or monthly OLS and LAV demand equations could be estimated and compared. In this case, an alternative specification will be required to account

[2] Veal production was used since veal consumption data were not available. Historically, veal trade and stock levels have been small as compared to consumption and production.

Table 3. Own Price, Cross Price, and Income Flexibilities Evaluated at the Means

	BEEF	PORK	CHICKEN	VEAL	INCOME
OLS					
Beef	−0.71	−0.41	−0.57	−0.31	0.73
Pork	−0.35	−1.04	−0.10		0.52
Chicken	−0.74	−0.41	−0.87		1.04
LAV					
Beef	−0.59	−0.33	−0.58	−0.29	0.74
Pork	−0.23	−1.03	−0.21	—	0.57
Chicken	−0.40	−0.24	−1.10	—	1.09

Table 4. Single Equation Forecasts for 1979 and 1980

	1979 Predicted	1979 Actual	Percent Deviation From Actual (%)	1980 Predicted	1980 Actual	Percent Deviation From Actual (%)
OLS						
Beef	2.414	2.558	5.63	2.734	2.703	1.15
Pork	2.327	2.164	7.53	2.496	2.091	19.37
Chicken	1.981	1.788	10.79	2.147	1.899	13.06
LAV						
Beef	2.381	2.558	6.91	2.702	2.703	0.04
Pork	2.251	2.164	4.02	2.398	2.091	14.68
Chicken	1.754	1.788	1.90	1.890	1.899	0.47

for such factors as seasonality in monthly and quarterly data.

The existence of structural change is often difficult to assess because structural change may not be differentiable from an exogenous shift, i.e., a special event like war, depression, oil embargo, etc. Moreover, structural change and exogenous shifts are not always mutually exclusive. At this time, research on structural change is unable to unequivocally make this distinction. Further research in this area is warranted.

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