Estimating Interrelated Demands For Meats Using

New Measures For Ground And Table Cut Beef

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Abstract

Two systems of demand equations for meats are estimated using a traditional and a new measure of ground and table cut beef. The results reject the hypothesis that the elasticities generated by the two data sets are the same. Several tests for model selection are performed. A very slight preference for the ground beef system is indicated by the Bayesian posterior odds ratio. Both the Akaike Information Criteria and the multivariate P-test favor the ground beef model. Theil's residual-variance criterion rejects both models. The results of these tests may possibly suggest the existence of a more ideal data set.

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Numerous studies have estimated consumer price elasticities of demand for food using systems of demand equations. The advantages of using a system approach versus a single equation methodology have been well documented (Barten, 1977). Generally, such studies have aggregated food commodities into relatively broad categories for the purpose of parsimonious estimation. In at least some cases, however, one would expect demand elasticities to vary significantly for the disaggregated components of the broader food categories. For example, Eales and Unnevehr discuss how the disaggregation of the composite poultry food group into poultry products subgroups allows them to identify sources of structural changes in meat demand. Their motivation stems from the idea that an individual subgroup may have a significantly different elasticity than the composite category.

Researchers of beef demand have often used this same motivation for disaggregating beef consumption into at least two subgroups. It seems intuitive to consider the demand for ground beef separate from the demand for table cut beef. Not only are the two commodities significantly different from one another from a consumption perspective, but they are in general produced from different types of beef animals. Freebairn and Rausser note that changes in agricultural policy regarding beef import quotas may cause asymmetric impacts on cattle breeders and those who feed cattle. It addition, Wohlgenant suggests that ground beef may be a better substitute for poultry products than are table cuts of beef. Consequently, aggregate beef demand may be affected by the relative composition of the supply of beef. For example, during the liquidation phase of the cattle cycle, the production of ground beef increases and aggregate beef demand may become more sensitive to changes in poultry prices. Finally, the dramatic growth in the fast food industry cannot be ignored by researchers who are interested in understanding the food marketing system. Much of the output of this industry is in the form of meals which contain ground beef.

In empirical work, the disaggregation of beef demand has been hampered by data availability. While it seems reasonable to estimate the demand for hamburger separate from the demand for table cuts, the traditional approach has been to use estimates of nonfed and fed beef as proxies for hamburger and table cut beef consumption, respectively. From a production perspective, nonfed beef refers to grass fattened steers and heifers as well as cull cows and bulls. Fed beef is the designation used for grain fattened cattle. These particular classifications in consumer demand analysis have been more a function of data availability than of actual consumer behavior. That is, consumers do not generally purchase either "nonfed" or "fed" beef. Rather, the more proper designation is one of ground beef and table cut beef. The label "ground beef" refers to the consumption of hamburger and other processed beef such as sausages, while "table cut beef" refers to all other types of beef consumed such as steaks, roasts, and veal. However, data limitations have frequently forced researchers to use nonfed beef as a proxy for ground beef consumption and fed beef as a proxy for table cuts (e.g. Arzac and Wilkinson, Brester and Marsh, Eales and Unnevehr, Wohlgenant). These designations are only proxies since some nonfed beef, e.g. cull cows and nonfed steers and heifers, is often processed into steaks and roasts, while portions of fed beef carcasses, e.g. trimmings and lower quality cuts, are generally processed into hamburger. Consequently, it seems desirable to use data which provide more accurate measures of the actual production and consumption of ground and table cut beef.

The purpose of this paper is to introduce new data which more accurately reflect the beef market. In addition, the effects of these new data are analyzed in terms of their impacts on estimated demand elasticities for meats in a demand systems model. Two meat demand systems are estimated using the absolute price version of the Rotterdam model in order to evaluate the consequences of the alternative measures of beef consumption. The first system (hereafter referred to as the "nonfed beef system") estimates the demand for nonfed beef, fed beef, pork, poultry, and nonmeats.[1] The second system employs our new measures of ground beef and table cut beef as the components of beef demand and will be referred to as the "ground beef system." Both models assume that meat products are weakly separable from other food and nonfood commodities. The inclusion of the nonmeat equation (and the use of total per capita personal consumption expenditures as the income variable) implies that the elasticity estimates derived from the model are unconditional elasticities and that the system of demand equations is weakly integrable (LaFrance and Hanemann).

The remainder of this paper proceeds as follows: a section describing the data development; a brief discussion of the Rotterdam model; a section that reports the empirical results; a presentation of model selection criteria; and finally, our conclusions.

Data Development

Estimates of the per capita consumption of fed beef are obtained by estimating the number of fed steers and heifers slaughtered annually and their average dressed weights. Multiplication of these components yields carcass weight fed beef production, which is converted to a per capita retail weight equivalent. The difference between the above estimate of fed beef production and total beef and veal consumption, the latter of which is calculated by the USDA, is designated as nonfed beef consumption. This procedure closely follows that of Wohlgenant with the only difference being the methodology employed in the estimation of the average dressed weights of fed steers and fed heifers. For this study, we follow the procedure used by the Western Livestock Marketing Information Project (WLMIP).

The WLMIP reports estimates of ground and processing beef on an annual basis for the years 1970 to the present. They essentially use their own commercial production figures by class of beef animal and the beef and veal import numbers reported by the USDA. The WLMIP assumes that the following fixed proportions of ground beef are obtained from each class of beef animal: cows--90%; bulls--100%; fed cattle--25%; nonfed cattle--45%; imports--80%. These percentages are assumed to be time invariant and are used to estimate carcass weight production of ground beef. Estimates of ground beef production are then converted to per capita retail weight equivalents. The above procedure imposes the unrealistic assumption of fixed proportions of ground beef being produced from each type of animal. It seems reasonable to assume that the proportion of ground beef obtained from each type of carcass responds to economic factors. Nonetheless, this procedure seems to be an improvement over the traditional estimates of ground beef production (i.e. using estimates of nonfed beef production as a proxy) in that it assumes that some ground beef is produced from fed carcasses and that some table cut beef is produced from nonfed carcasses.

We use the WLMIP procedures described above to extend the ground beef production series so as to include the period 1962-1987. Data limitations prevent extension of the series to earlier time periods. The estimated per capita production of ground beef from the above procedure is then subtracted from the annual per capita consumption of all beef and veal (on a retail weight basis) as reported by the USDA (1988). The difference is the estimated annual consumption of table cut beef on a per capita basis. It is important to note that both nonfed and fed beef consumption, as well as ground and table cut beef consumption, total to the same amount, i.e. total beef consumption as derived by the USDA from disappearance data. Consequently, the differences between the series are merely a function of data construction. The upper graph of figure 1 shows the relationship between the nonfed and ground beef data used in this paper. The lower graph illustrates the relationship between fed beef and table cut beef consumption.

The Model

The Rotterdam model is used to evaluate the performance of the alternative measures of beef consumption described above. This specification was chosen because it is based on consumer demand theory, i.e. the model is developed by totally differentiating ordinary demand equations. In addition, the model is linear in parameters and is at least as flexible a functional form as the translog, miniflex Laurent, and AIDS models (Mountain). A detailed development of the Rotterdam model is provided by Theil (1980). The estimable log differential form for discrete time periods of each of the n demand equations in the system is given by:

$$\bar{W}_{it}\Delta \ln Q_{it} = \alpha_i + \beta_i \Delta \ln \bar{X}_t + \sum_{j=1}^{J} \delta_{ij}\Delta \ln P_{jt} + U_{it} \qquad i=1,2,\ldots,n \quad (1)$$

where:

$$\bar{W}_{it} = 1/2(W_{it} + W_{it-1}),$$

$$\Delta \ln \bar{X}_t = \Delta \ln X_t - \sum_{i=1}^{n} \bar{W}_{it}\Delta \ln P_{it},$$

W_i are the expenditure share weights of the ith meat, P_j are retail prices of each meat commodity and one aggregate nonmeat commodity, Q_i are per capita constant dollar expenditures on each meat commodity and one nonmeat commodity, X represents total per capita personal consumption expenditures, and U_{it} is a time-wise independent error term that is contemporaneously correlated across the n equations.

One of the n equations can be deleted from the system for purposes of estimation because of the following nontestable restrictions:

$$\sum_{i=1}^{n} \beta_i = 1; \qquad \sum_{i=1}^{n}\sum_{j=1}^{J} \delta_{ij} = 0. \qquad (2)$$

Empirical Results

The two meat demand systems are estimated using the Iterated Seemingly Unrelated Regressions (ITSUR) option of the <u>SYSNLIN</u> procedure in <u>SAS</u>. The parameter estimates obtained by using ITSUR converge to their maximum likelihood values if the error terms follow a multivariate normal distribution (Judge, et.al.), and are invariant to the choice of the deleted equation (Barten, 1969). The nonmeat equation in each model is deleted for estimation purposes. The parameter estimates for each deleted equation are recoverable via the restrictions imposed by equation (2). Definitions of the variables used in this paper are presented in table 1. Symmetry and homogeneity of degree zero in prices and income are imposed on both models.

The estimated regression coefficients for the nonfed beef system (with homogeneity and symmetry imposed) are presented in the upper portion of table 2. Most of the coefficients are significant at the .05 level. Curvature restrictions are met in that the substitution matrix (including the nonmeat coefficients which are not reported here) is negative semi-definite. The own-price coefficients are all negative. The income coefficient for nonfed beef is significantly different from zero at approximately the .10 level. Nonfed beef appears to be an inferior good. Fed beef is a complementary good with both pork and poultry which does not conform to a priori expectations. Neither of the two estimates, however, are significantly different from zero.

The lower portion of table 2 reports the regression results for the ground beef system. Again, both homogeneity and symmetry are imposed, and the substitution matrix is negative semi-definite. The diagonal own-price elements are all negative. Ground beef appears to be an inferior good; however, its estimated income coefficient is not statistically different from zero. All commodities are substitutes with the exception of table cut beef and poultry, for which the parameter estimate is significantly different from zero at about the .15 level.

The estimated price and income elasticities for both models along with their t-values are presented in table 3.[2] The elasticities for the nonfed beef system are presented in the upper portion of the table. Contrary to the estimated price coefficients, the cross-price elasticities are not symmetric because they are obtained by dividing the parameter estimates by their respective expenditure share weights. Most of the price elasticities are less than one in absolute value. The two exceptions are the own-price elasticity of nonfed beef and the cross-price elasticity of nonfed beef to fed beef, both of which are relatively price elastic. Note that the own-price elasticity of nonfed beef is much larger than that of fed beef. These results are similar to those of Eales and Unnevehr who used nonfed and fed beef as proxies for hamburger and table cut beef, respectively.

The elasticity estimates for the ground beef system are reported in the lower portion of table 3. The estimated elasticities are all less than one in absolute value. Contrary to the nonfed model, the own-price elasticity for ground beef is inelastic as is the cross-price elasticity of ground beef to table cut beef. The income elasticities for ground beef and table cut beef are now both inelastic; however, the income elasticity estimate for ground beef is not significantly different from zero.

In order to test the null hypothesis that the two sets of regression estimates are not significantly different from one another, the nonfed system is "stacked" on top of the ground beef and table cut beef equations and ITSUR is again employed. The ITSUR procedure is appropriate because the two measures of ground and table cut beef consumption used in this analysis are not independent. Recall that both series sum to the total beef consumption reported by the USDA. Note that the two models have the pork and poultry equation in common. Given that the dependent variables for the pork and poultry equations are identical, it is not possible to use all eight equations in an ITSUR framework since the covariance matrix of error terms would not be of full rank. Thus the stacked ITSUR method employed on the six remaining equations assumes that the parameter estimates of the pork and poultry equations are equal in both models. The estimates reported in table 2 lend support to this assumption. The parameters for the nonfed and fed beef equations were restricted to be equal to those of the ground and table cut equations. The likelihood ratio test statistic for these restrictions is 24.94. The difference in the number of parametric restrictions between the "unrestricted" and "restricted" models is six. Given that the chi-squared critical value for six degrees of freedom at the .05 level is 12.59, the null hypothesis that the restrictions are correct is strongly rejected.[3] Consequently, we reject the hypothesis that the parameter estimates for the income and beef price variables are the same between the two models.[4]

Model Selection

While the two sets of demand estimates are different from one another, we are left to decide which set is correct. There exist a myriad of approaches to the problem of model selection. Unfortunately, no single procedure dominates in all cases. Therefore, we undertake several approaches.

A Bayesian approach to this problem considers from which of the demand estimates the data were most likely generated. The choice is made based upon the posterior odds ratio, which is the product of the prior odds ratio and the likelihood ratio (Zellner). If we assume diffuse (equally likely) priors for each model, then the posterior odds ratio is simply the likelihood ratio. The posterior odds ratio for the ground beef model relative to the nonfed beef model is calculated to be 1.04. Consequently, the odds are only slightly in favor of the conclusion that the ground beef demand system is more likely to have generated the data.

Akaike (1973, 1981) suggests another methodology to model selection which considers the competing goals of accuracy in estimation and the most logical approximation to reality. The Akaike Information Criteria (AIC) is a statistic that combines a measure of the precision of parameter estimates and a rule which rewards parametric parsimony of the model. One variant of the AIC proposes that the log likelihood be used as the primary measure of the goodness of fit of a model. Of course, the likelihood is itself determined by the data. The logarithm of the likelihood will be an unbiased estimator of the expected log likelihood of the model with respect to future observations (Judge, et.al.). The expectation is taken with respect to the distribution of present and future observations. Thus, the AIC may be written as;

$$\text{AIC} = -2\ln(\text{maximum likelihood}) + 2K \,, \tag{3}$$

where K equals the number of estimated model parameters. Akaike (1978) proposes that, given the model parameters, equation (3) is asymptotically a reasonable definition of the likelihood of a model. For purposes of model selection, the decision criteria is to choose the model which has the smallest associated AIC statistic.

The AIC for the nonfed model is calculated to be -1,524.2, while that for the ground model is -1,591.8. Therefore, the ground model specification is chosen if the decision is based solely on the AIC statistic.

Theil (1971) proposes the use of a residual-variance criterion for the purpose of model selection. It can be shown that, on average, the residual-variance estimator of the incorrect specification exceeds that of the correct specification. This approach, however, requires that the dependent variables in each model be the same. Recall that the pork and poultry dependent variables are the same for both models, and that the sum of the nonfed and fed beef dependent variables are equal to the sum of the ground and table cut beef dependent variables. The exploitation of this latter condition allows for the dependent variables of the ground model to be transformed so as to be identical to those of the nonfed model (and vice versa).

Let Y represent the matrix of per capita constant dollar expenditures on all beef, pork, and poultry for all time periods, and Y_1 represent the matrix of per capita constant dollar expenditures for nonfed beef, fed beef, pork, and poultry. Then the relationship between Y and Y_1 can be represented by:

$$\Delta \ln Y_1 = \Delta \ln Y + A, \qquad (4)$$

where,

$$A = \mathrm{diag}(\Delta \ln Y_{1i} - \Delta \ln Y_i) \ , \qquad i = 1, \ \ldots.,n. \qquad (5)$$

The matrix A is the matrix of weights use to transform the total consumption of beef and veal into its nonfed and fed components. Note that the elements of A are equal to zero for the pork and poultry dependent variables (i.e. for i = 3 and 4).

The left-hand-side (LHS) variables of the nonfed beef model can be written as:

$$w_1 \Delta \ln Y_1 = w_1 \Delta \ln Y + w_1 A; \quad w_1 = diag(w_{1i}) \tag{6}$$

where w_{1i} represent the expenditure share weights.

In a like fashion, the relationship between Y and Y_2, where Y_2 is the matrix of per capita constant dollar expenditures for ground beef, table cut beef, pork, and poultry can be represented by:

$$\Delta \ln Y_2 = \Delta \ln Y + B, \tag{7}$$

where,

$$B = diag(\Delta \ln Y_{2i} - \Delta \ln Y_i) , \qquad i = 1, \ldots, n. \tag{8}$$

The matrix B is the matrix of weights use to transform the total consumption of beef and veal into its ground and table cut components. Once again, note that the elements of B are equal to zero for the pork and poultry dependent variables (i.e. for i = 3 and 4).

The LHS variables of the ground beef model can be written as:

$$w_2 \Delta \ln Y_2 = w_2 \Delta \ln Y + w_2 B; \quad w_2 = diag(w_{2i}) \tag{9}$$

where w_{2i} represent the expenditure share weights. Equation (9) can be rewritten as:

$$w_2 \Delta \ln Y_2 = w_2 (w_1^{-1} w_1) \Delta \ln Y + w_2 B. \tag{10}$$

Solving equation (6) for $w_1 \Delta \ln Y$, and substituting it into equation (10) yields:

$$w_2 \Delta \ln Y_2 = w_2 w_1^{-1}(w_1 \Delta \ln Y_1 - w_1 A) + w_2 B \quad (11a)$$

$$= w_2 w_1^{-1}(w_1 \Delta \ln Y_1) + w_2 B - w_1 A \quad (11b)$$

$$= w_2 w_1^{-1}(w_1 \Delta \ln Y_1) + w_2 (B - A), \quad (11c)$$

or, to simplify notation,

$$Y_2^* = w_2 w_1^{-1} Y_1^* + w_2 (B - A), \quad (12)$$

Note that the predicted values of the dependent variables for the nonfed model can be written as:

$$\hat{Y}_1^* = X_1 \hat{\beta}_1 , \quad (13)$$

while those for the ground model are provided by:

$$\hat{Y}_2^* = X_2 \hat{\beta}_2 . \quad (14)$$

Equating the predicted values from equation (12) with equation (14) yields:

$$w_2 w_1^{-1} \hat{Y}_1^* + w_2 (B - A) = X_2 \hat{\beta}_2 , \quad (15)$$

or,

$$\hat{Y}_1^* = w_2 w_1^{-1} X_2 \hat{\beta}_2 + w_2 (B - A) . \quad (16)$$

Equation (16) represents the transformed ground beef model such that the dependent variables are the same as that for the nonfed beef model. Consequently, the residual-variance criterion can be applied to the two models upon the calculation of residuals which result from the predicted values suggested by equations (13) and (14). The determinants of the covariance matrices of the two models are calculated, and the residual-variance criterion suggests that the correct model will have the smaller determinant. The values of the determinants of the covariance matrices for the nonfed and transformed ground beef models are 7.9×10^{-28} and 9.1×10^{-24}, respectively. Therefore, the nonfed model is chosen as being correct when compared to the transformed ground beef model.

As Theil notes, the residual-variance criterion does not work when neither specification is correct. Thus, one should consider the decision criteria under the assumption that the ground model is the null hypothesis, and compare its covariance matrix to that of the transformed nonfed model. In this case, we find that the values of the determinants of the covariance matrices of the ground and transformed nonfed models are 5.3×10^{-29} and 1.9×10^{-22}, respectively. Consequently, we now choose the ground model over the transformed model. Theil suggests that such contradictions are not uncommon, and that the residual-variance criterion for model selection is far from being a perfect instrument.

Davidson and MacKinnon propose a multivariate P-test as another criterion to be used for nonnested model selection. Two models are nonnested if neither can be obtained from the other via the imposition of parametric constraints. The goal is to test whether one model, say H_o, could have generated the data by evaluating an alternative nonnested model, say H_1, to see if the latter is consistent with the former. This test is based on an artificial linear regression and is referred to as the P_1-test. Once again, the test needs to be performed with the dependent variables of the two models being identical.

If we consider the nonfed model as the null hypothesis, and follow the transformations and notation described above, the artificial regression for the P_1-test becomes:

$$Y_1^* - \hat{Y}_1^* = X_1\beta_1 \theta + \alpha H + e , \tag{17}$$

where $\hat{Y}_1^*$ represents the predicted values of the nonfed model as calculated by equation (13).[5] The matrix H is calculated by taking the differences between the predicted values for the ground and nonfed models, (i.e. equations (16) and (13), respectively) and then premultiplying the resulting matrix by $\Sigma_o\Sigma_1^{-1}$ where Σ_o is the estimated covariance matrix of residuals from the nonfed model (which is the null hypothesis) and Σ_1 is the estimate of the covariance matrix from the transformed ground model (the alternative hypothesis). Equation (17) is then estimated by Seemingly Unrelated Regression (SUR) under the assumption that Σ_o is the contemporaneous matrix for e (Chalfant). The matrix α is of dimension nx1, where n is the number of equations in the demand system. Upon setting each element of α to be equal, the ratio of the estimate of the single remaining α to its standard deviation converges in distribution to N(0,1). Consequently, the P_1-test consists of a t-test to determine if the estimate of α is significantly different from zero. If it is, then the hypothesis that H_o is the correct specification is rejected because the predictions of the alternative hypothesis add to the explanatory power of the system.

With the nonfed model specification as the maintained hypothesis, the estimate of α is 1.48 with a t-value of 4.59. Therefore, we reject the null hypothesis.

Judge, et.al note that many of these types of tests for model selection are dependent upon the choice of reference hypothesis. Thus, conclusions as to the correct model may not be symmetric with respect to the chosen reference hypotheses. Consequently, it is necessary to consider the P_1-test with the null hypothesis being that the ground model is correct. This reverses the roles of the two models. In this case, the value of α is estimated to be 6.66. The t-value, however, is only 0.76 which indicates that the null hypothesis that the ground model is the correct specification cannot be rejected.

Davidson and MacKinnon note that care should be exercised when drawing inferences from the test in small samples since the P_1-test is asymptotic. Chalfant and Finkelshtain examine the small sample properties of the P_1-test and find that it is biased towards rejection, but has good power even in small samples. With these caveats in mind, we conclude that the P_1-test favors the ground beef specification.

Conclusions

Nonfed beef production has historically been used as a proxy for ground beef consumption in demand analysis. An alternative measure for ground beef production is derived using a methodology proposed by the WLMIP. Demand elasticity estimates derived from the absolute price version of the Rotterdam model are found to be significantly different for the two data sets. In particular, the price elasticity estimates for hamburger and table cuts of beef are dramatically influenced by the choice of data.

Four approaches to model selection are considered. The Bayesian posterior odds ratio is very nearly equal to one if diffuse priors are assumed. Consequently, both models are almost equally likely to have generated the data. The ground model is selected if the decision criteria is based upon the AIC statistic. Contradictory results are obtained via the use of Theil's residual-variance criterion. That is, neither model is chosen as being superior. However, Davidson and MacKinnon's multivariate P-test favors the ground beef model.

Based on these results, it would appear that the ground beef data are superior to the nonfed beef data. Nonfed and fed beef production are at best proxies for the consumption of hamburger and table cut beef. The WLMIP procedure for estimating the production of ground beef is intuitively appealing in that consideration is given as to the composition of the actual production of ground beef.

However, the ambiguous test results of Theil's residual-variance criterion probably indicates that both data sets are subject to some measurement error. Indeed, rejection of both models by Theil's test suggests that there may exist a more ideal set of data than either of those presented in this paper. As previously noted, our ground beef data are constructed with the unrealistic assumption that fixed proportions of nonfed and fed beef are processed into ground beef. This data could possibly be improved by allowing these proportions to be time variant. Extending the ground beef data in this manner may yield further improvements in estimated demand elasticities for ground and table cut beef.

Footnotes

1. The use of the term "nonmeats" is somewhat of a misnomer. The variable actually represents all other consumption items except beef, pork, and poultry. Consequently, some meats are included in the nonmeat equation, e.g. fish, mutton, and purchased wild game.

2. The t-values for the elasticity estimates are the same as those for their respective parameter estimates. To illustrate, let ϵ_{ij} be the elasticity estimates and w_i be the mean share weight for the ith commodity. In the Rotterdam model, $\epsilon_{ij}=\delta_{ij}/w_i$. So, $\mathrm{Var}(\epsilon_{ij}) = (1/w_i^2)\mathrm{Var}(\delta_{ij})$. Then, the t-value$(\epsilon_{ij}) = \epsilon_{ij}/\{\mathrm{Var}(\delta_{ij}/w_i)\}^{1/2} = \{\delta_{ij}/w_i\}/\{\mathrm{Var}(\delta_{ij})\}^{1/2}/w_i = \delta_{ij}/\{\mathrm{Var}(\delta_{ij})\}^{1/2}$, which is the same as the t-value for δ_{ij} if one assumes that the w_i's are constants.

3. This procedure was also reversed by "stacking" the four equations from the ground beef model on top of the nonfed and fed beef equations from the nonfed model. ITSUR was again used to test the hypothesis that the beef and income parameter estimates between the first two and last two equations were identical. The likelihood ratio test statistic is 33.77, so the hypothesis is again strongly rejected.

4. The Rotterdam and Almost Ideal Demand System (AID) models appear to be the two most popular choices of functional forms for estimating systems of demand equations. The nonfed and ground models were both estimated using the AID model to see if the differences in the elasticity estimates between the two data sets were merely a product of the choice of functional form. All of the elasticity estimates from the AID models were very similar to those of the Rotterdam models.

5. Note that the P_1-test involves regressing the residuals of the maintained model specification on the regressors of the original model and one new variable in each of the equations. This new variable is the difference between the predicted values of the alternative and maintained specifications. For models which are nonlinear in parameters, the original regressors must be replaced with the derivatives of the maintained model with respect to the parameters.

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Table 1. Definition of Variables.

Variable	Definition
Dependent:	
QNF	Weighted first differences of the natural logarithm of per capita constant dollar expenditures (1967) on nonfed beef.
QFD	Weighted first differences of the natural logarithm of per capita constant dollar expenditures (1967) on fed beef.
QPK	Weighted first differences of the natural logarithm of per capita constant dollar expenditures (1967) on pork.
QPY	Weighted first differences of the natural logarithm of per capita constant dollar expenditures (1967) on poultry.
QGB	Weighted first differences of the natural logarithm of per capita constant dollar expenditures (1967) on ground beef.
QTC	Weighted first differences of the natural logarithm of per capita constant dollar expenditures (1967) on table cut beef
Independent:	
INCOMEN	Income in the nonfed beef model. Calculated as the difference between the first differences of the natural logarithm of per capita personal consumption expenditures and the sum of the shares weighted price variables of the nonfed model.
INCOMEG	Income in the ground beef model. Calculated as the difference between the first differences of the natural logarithm of per capita personal consumption expenditures and the sum of the shares weighted price variables of the ground model.
PNF	First differences of the natural logarithm of the price index of nonfed beef deflated by the price index of nonmeats (for the nonfed model), 1967=100.
PFD	First differences of the natural logarithm of the price index of fed beef deflated by the price index of nonmeats (for the nonfed model), 1967=100.
PPK	First differences of the natural logarithm of the price index of pork deflated by the price index of nonmeats (for the nonfed model), 1967=100.
PPY	First differences of the natural logarithm of the price index of poultry deflated by the price index of nonmeats (for the nonfed model), 1967=100.

Table 1. (continued)

Variable	Definition
Independent:	
PGB	First differences of the natural logarithm of the price index of ground beef deflated by the price index of nonmeats (for the nonfed model), 1967=100.
PTC	First differences of the natural logarithm of the price index of table cut beef deflated by the price index of nonmeats (for the nonfed model), 1967=100.

Sources: Price and Income data are from USDA "Food Consumption, Prices and Expenditures," various issues.
Quantity data construction is described in the text.

Table 2. Estimated Regression Coefficients of the Nonfed and Ground Beef Systems of Meat Demand Equations.

Dependent Variables for the Nonfed System	Independent Regressors for the Nonfed System[a]				
	PNF	PFD	PPK	PPY	INCOMEN
QNF	-.0138 (-3.53)	.0095 (1.81)	.0036 (2.93)	.0014 (1.84)	-.0109 (-1.80)
QFD		-.0188 (-2.33)	-.0007 (-0.37)	-.0007 (-0.61)	.0035 (3.29)
QPK			-.0105 (-12.06)	.0007 (2.06)	.0041 (0.89)
QPY				-.0024 (-5.50)	.0032 (2.49)

Dependent Variables for the Ground System	Independent Regressors for the Ground System[a]				
	PGB	PTC	PPK	PPY	INCOMEG
QGB	-.0060 (-5.93)	.0019 (1.41)	.0020 (3.43)	.0017 (3.67)	-.0014 (-0.44)
QTC		-.0137 (-6.10)	-.0017 (-1.80)	-.0011 (-1.61)	.0154 (2.49)
QPK			-.0110 (-11.22)	.0008 (2.19)	.0048 (0.98)
QPY				-.0025 (-5.53)	.0030 (2.42)

[a] Numbers in parenthesis are the t-values for the parameter estimates.

Table 3. Estimated Compensated Price and Income Elasticities for the Nonfed and Ground Beef Systems of Meat Demand Equations.

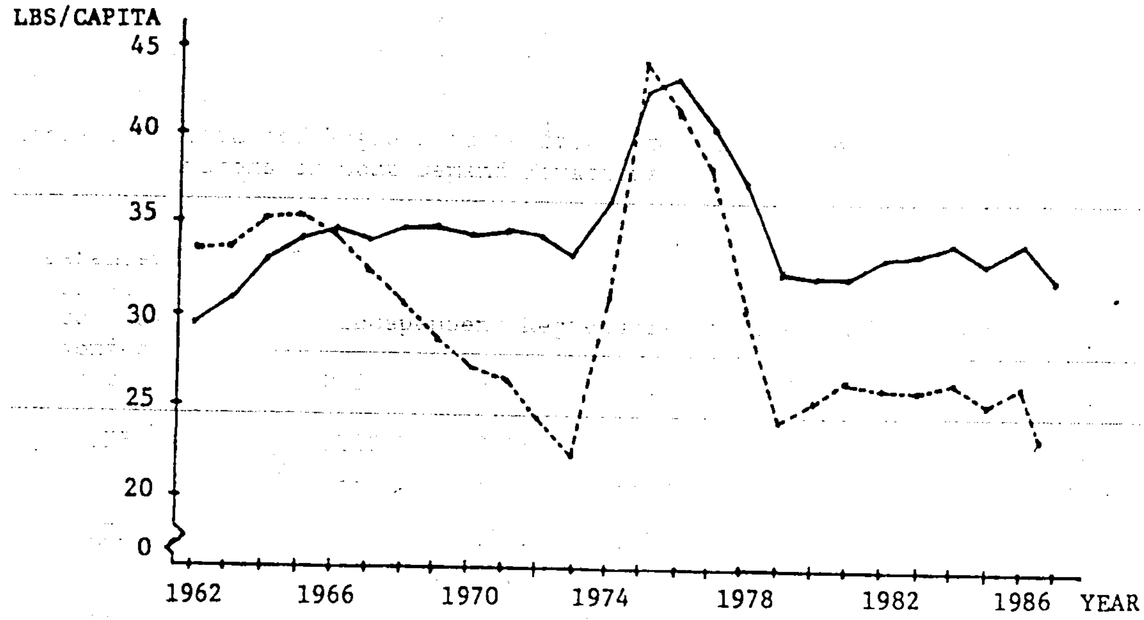
Nonfed Beef System[a]

Elasticity of the Quantity of:	With Respect to the Price of: Nonfed Beef	Fed Beef	Pork	Poultry	With Respect to: Income
Nonfed Beef	-2.324 (-3.53)	1.605 (1.81)	.611 (2.93)	.240 (1.84)	-1.846 (-1.80)
Fed Beef	.481 (1.81)	-.955 (-2.33)	-.036 (-0.37)	-.034 (-.061)	1.801 (3.29)
Pork	.260 (2.93)	-.052 (-0.37)	-.756 (-12.06)	.051 (2.06)	.296 (0.89)
Poultry	.215 (1.84)	-.102 (-0.61)	.108 (2.06)	-.370 (-5.50)	.479 (2.49)

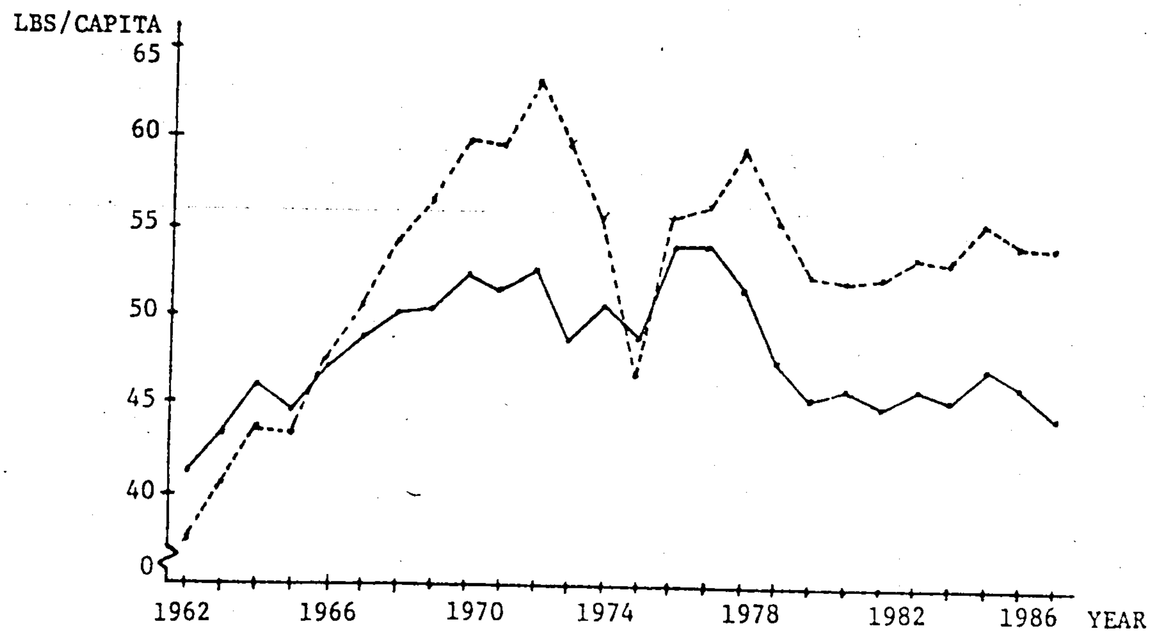
Ground Beef System[a]

Elasticity of the Quantity of:	With Respect to the Price of: Ground Beef	Table Cut Beef	Pork	Poultry	With Respect to: Income
Ground Beef	-.882 (-5.93)	.286 (1.41)	.301 (3.43)	.254 (3.67)	-.206 (-0.44)
Table Cut Beef	.105 (1.41)	-.743 (-6.10)	.093 (1.80)	-.058 (-1.61)	.835 (2.49)
Pork	.147 (3.43)	.124 (1.80)	-.790 (-11.22)	.055 (2.19)	.346 (0.98)
Poultry	.261 (3.67)	-.162 (-1.61)	.117 (2.19)	-.378 (-5.53)	.458 (2.42)

[a] Numbers in parenthesis are the t-values for the elasticity estimates.



LEGEND: GROUND BEEF = SOLID LINE
NONFED BEEF = DOTTED LINE



LEGEND: TABLE CUT BEEF = SOLID LINE
FED BEEF = DOTTED LINE

FIGURE 1. Comparison of Per Capita Consumption of Ground Beef to Nonfed Beef and Table Cut Beef to Fed Beef; 1962-1987.