Simultaneity and Structural Change in U.S. Meat Demand

by

James Eales and Laurian J. Unnevehr

SIMULTANEITY AND STRUCTURAL CHANGE IN US MEAT DEMAND

James Eales and Laurian J. Unnevehr[1]

Findings of structural change in meat demand, while still contested, are quite common. Earlier findings were for the most part derived from quantity-dependent demand systems: Smallwood et al., in their review of the meat demand literature, report that 14 out of the 17 studies examined used quantity-dependent demand models. Such models are often estimated ignoring potential simultaneity in meat markets. This oversight is due, at least in part, to the desire of researchers to use theoretically consistent models of demand, rather than the ad hoc models most often employed in estimating supply and demand together.

Ignoring the supply side of the market is particularly dangerous for meats, however. Meats are perishable goods, and the red meats are produced with a long biological lag. Thus, of prices and quantities, it seems most likely that it is quantity supplied which may be predetermined for the red meats in particular and quantity-dependent demand models may be inappropriate. Use of such models could lead to spurious identification of structural change in demand. Changes in supply, such as the beef herd liquidation following feed price escalation in the 1970s, could appear as structural change in demand, when none had occurred. Furthermore, any gradual structural change in supply could appear as a shift in demand. For example, increased feed efficiency in broiler production and higher dressed weights for cattle should have shifted the supply curves for these meats outward steadily over time, and may have contributed to the appearance of demand growth unrelated to prices and expenditures.

In this paper we address two questions. First, when estimating a system of demands for U.S. meats, can quantities or prices be taken as predetermined? Second, are findings of structural change in demand, such as the oft found shift in beef demand in the mid-70s, explained by supply side variables? The answers to these two questions are related, because many demand models that have revealed structural change are mis-specified if quantities are predetermined or if prices are endogenous. In such models, supply side changes could show up as structural shifts in demand.

To address the above questions, we employ the AIDS model of Deaton and Muellbauer and the Inverse Almost Ideal Demand System (IAIDS) of Eales and Unnevehr (1991). The IAIDS is similar to the AIDS, except that it is derived from the distance function instead of the cost function. The resulting system of demand equations relate expenditure shares to logarithms of quantities and a quantity index. The IAIDS is the appropriate demand model if quantities are predetermined and prices endogenous.

To test for endogeneity of prices or quantities, the AIDS and IAIDS are each estimated in two ways: first, the right-hand-side (RHS) variables are assumed to be predetermined and

[1] Authors are associate professors in the Department of Rural Economy, University of Alberta and the Department of Agricultural Economics, University of Illinois, respectively.

second, they are assumed to be endogenous. Following Thurman, the two sets of estimates are compared using Hausman's specification test. This allows us to test whether either prices or quantities may be taken as predetermined in U.S. meat demand. Both models are estimated allowing for continuous change in demand and for a one-time shift in the mid-70s. Comparison of results between models which assume predetermined versus endogenous RHS variables will indicate whether supply variables underlie evidence of shifting demand in the estimates.

The Inverse Almost Ideal Demand System

A detailed derivation of the IAIDS model may be found in Eales and Unnevehr (1991). Briefly, one begins by specifying a logarithmic distance function with the same functional form as Deaton and Muellbauer's logarithmic cost function, where quantities take the places of prices. Differentiation with respect to log quantities yields compensated share equations, which may be uncompensated by inverting the distance function and substituting out utility. The resulting system of share equations is:

$$w_i = \alpha_i + \Sigma_j \gamma_{ij} \ln q_j + \beta_i \ln Q \qquad (1)$$

with ln Q given by:

$$\ln Q = \alpha_0 + \Sigma \alpha_j \ln q_j + 0.5 \Sigma_i \Sigma_j \gamma_{ij} \ln q_i \ln q_j \qquad (2)$$

As with the AIDS model, homogeneity and symmetry restrictions involve only the fixed, unknown coefficients and so may be easily tested or imposed. These restrictions are: $\Sigma_i \alpha_i = 1$, $\Sigma_i \gamma_{ij} = 0$, $\Sigma_i \beta_i = 0$ (adding up); $\Sigma_j \gamma_{ij} = 0$ (homogeneity); $\gamma_{ij} = \gamma_{ji}$ (symmetry).

As it stands, Equation 1 requires nonlinear estimation. It is convenient to substitute an approximation to the quantity index which does not depend on unknown parameters, such as Stone's quantity index, in order to derive a linear approximation.[2]

Demand estimation yields elasticities. On the inverse side, the sensitivities are typically measured by flexibilities (Houck). An important consideration in the interpretation of inverse demand results is the appropriate analog of the expenditure elasticity. Anderson proposed a compensation technique for inverse demands according to "scale," where a movement from an old to a new consumption bundle is broken up into two pieces: the movement along the indifference surface representing the original utility level (the substitution effect) and then a movement to the new indifference surface, expanding all quantities proportionally (the scale

[2] Obviously, the justification employed for this substitution in the AIDS model, that prices in time-series data are collinear, is not appropriate for the IAIDS model. Quantities do not move together. Thus, the adequacy of the approximation is an empirical question and no generalization can be made for the LA/IAIDS model. Eales and Unnevehr (1991) have shown, however, that the LA/IAIDS provided a good approximation of the IAIDS for quarterly meat demand data.

effect). The distance function measures distance along rays through the origin. Thus, compensation according to the "scale" of consumption for the distance function is the analogue of compensation according to expenditure for the cost function (see: Anderson, or Eales and Unnevehr,1991).

To be consistent with theory, ordinary demand curves must satisfy the homogeneity, Cournot, and Engel aggregation relations. For inverse demands, Anderson shows that similar aggregations hold. That is, if f_{ij}, f_i, and w_i represent cross-price flexibilities, scale flexibilities, and expenditure shares, respectively; then flexibilities must satisfy the following aggregation relations: $\sum_j f_{ij} = f_i$ (homogeneity); $\sum_i w_i f_{ij} = -w_j$ (Cournot); $\sum_i w_i f_i = -1$ (Engel).[3]

Given the scale decomposition of inverse demands, the formulae for the calculation of Marshallian cross-price, expenditure, and compensated or Hicksian elasticities are almost identical to those required for the cross-price, scale, and compensated flexibilities. Derivation and exact formulae for flexibilities from IAIDS models may be found in Eales and Unnevehr (1991).

Flexibilities are less commonly employed in interpretation of results, and therefore deserves some clarification. We found no agreed upon terminology when discussing flexibilities. In what follows, we employ the convention that demand for a commodity is said to be inflexible if a 1% increase in consumption of that commodity leads to a greater than 1% decrease in the marginal value of that commodity in consumption (its normalized price) Likewise, we will refer to commodities with scale flexibilities less (greater) than -1 as scale inflexible (flexible).[4] Commodities are termed gross q-substitutes if their cross-price flexibility is negative, gross q-complements if it is positive (Hicks). An interpretation of scale flexibilities can be made by considering the case of homothetic preferences, i.e. all expenditure elasticities equal to one. In this case, expanding consumption of all commodities by 1%, that is moving out along a ray through the origin, requires no change in relative prices to support the new equilibrium consumption bundle. But, expenditures must increase by 1% to achieve this new bundle. Thus, the normalized prices, price divided by expenditures, will decrease by approximately 1%, and all scale flexibilities must be -1. Necessities and luxuries can then be defined in reference to the base case of homothetic preferences. Scale flexibilities are less than –1 for necessities and greater than -1 for luxuries. At the margin, normalized price is proportional to marginal utility. Therefore, as consumption of all goods increases 1%, the marginal utility of necessities declines more than proportionately (scale flexibility < -1) and the

---

[3] Anderson actually refers to the f_{ij} and f_i as quantity and scale elasticities (δ_{ij} and μ_i in his notation). Choice of the terms price and scale flexibilities is made for its consistency with previous work in the Agricultural Economics literature. There is a misprint in Anderson. The Engel aggregation for inverse demands says that the expenditure share weighted sum of the scale flexibilities is -1.

[4] This definition was motivated, in part, because the matrix of flexibilities is the inverse of the matrix of elasticities (Houck or Anderson). Thus, inelastic demand with an own-price elasticity of -0.5, say, corresponds roughly to inflexible demand with an own-price flexibility of -2.

marginal utility of luxuries declines less than proportionately (scale flexibility > -1).

Estimation Models and Data

The test for endogeneity is similar to that in Thurman. That is, Hausman tests for endogeneity will be used to determine whether prices, quantities, or both are endogenous. In contrast to Thurman's work, these tests will be conducted using a system of meat demands based on theoretically-consistent, flexible functional forms. The flexibility of the AIDS and the IAIDS may help to lessen the impact of the maintained hypotheses on the outcome of the tests.

The dynamic, linear approximation of the AIDS model is estimated:

$$\Delta w_i = \alpha_i + \theta_i D + \Sigma_j \gamma_{ij} \Delta \ln p_j + \beta_i \Delta \ln (x / P^*) \qquad (3)$$

where all variables are in first differences; αs, θs, γs, and βs are unknown coefficients; D is a dummy variable, which is one up through 1975 and zero thereafter; x is total per capita expenditure; and $\Delta \ln P^*$ is a Stone's price index, $\Sigma_j w_j \Delta \ln p_j$.

The estimation equation for the IAIDS is a similar dynamic linear approximation:

$$\Delta w_i = \alpha_i + \theta_i D + \Sigma_j \gamma_{ij} \Delta \ln q_j + \beta_i \Delta \ln Q^* \qquad (4)$$

where αs, θs, γs, and βs, again, represent the coefficients to emphasize the similarities between the two systems (even though they are different from those of the AIDS model) and $\Delta \ln Q^*$ is a Stone's quantity index, $\Sigma_j w_j \Delta \ln q_j$.

Both the AIDS and the IAIDS are estimated twice: first, with iterative Seemingly Unrelated Regressions (SUR); and second, with iterative Three Stage Least Squares (3SLS) using instrumental variables that determine the costs of livestock production. In each case, homogeneity and symmetry have been imposed on the estimates. The first set of estimates is appropriate if the RHS variables are assumed to be predetermined; the second set of estimates is appropriate if they are endogenous. In order to test whether prices, quantities, or both are endogenous, the two sets of estimates are compared using the Hausman specification test. Estimates from the model which is asymptotically efficient under the null hypothesis and inconsistent under the alternative hypothesis (SUR, in this case) are compared to those which are consistent under both the null and alternative hypothesis (3SLS). If the RHS variables are appropriately taken as predetermined, the two sets of estimates should be similar and the Hausman test will be insignificant.

The models include: beef, pork, chicken, non-meat food, all other goods.[5] Annual per

---

[5] LaFrance has pointed out that expenditures in separable demand systems cannot be predetermined. That is, the multi-stage budgeting process does not allow you to assume that meat expenditures are predetermined in a separable system which models only meat demands. By including non-meat food and all other goods our expenditure variable is total per capita

capita consumption of and price indexes for beef, pork, and chicken from 1962 through 1989 are from *Food Consumption, Prices and Expenditure*, 1967-1988 (USDA, 1990) and previous issues. Instruments are required for consistent estimation of systems in which endogeneity of the RHS variables is allowed. Instruments employed consisted of: price of corn (on calendar year basis), three variables to represent changes in technology in beef, pork, and chicken production (average dressed carcass weight for beef; fat removed per 100 pounds of pork carcass; and broiler feed conversion ratios for chicken) all from USDA sources; 90-day Treasury Bill yields, an energy price index, and personal consumption expenditures per capita from *The Economic Report of the President*, 1990.[6] Estimation was done using version 6.2 of the SHAZAM program.

Results

Previous studies by Thurman and by Wahl and Hayes provide some evidence regarding the predeterminedness of chicken price, but not of other meat prices. Thurman, in a study of U.S. broiler demand, found that prices were predetermined by costs of production. Wahl and Hayes examined demand for meats in Japan and found that elasticity estimates differed when prices are taken to be endogenous, compared to those obtained when quantities are assumed endogenous. Wahl and Hayes also found evidence that the price of chicken is predetermined in Japan.

Our study is the first to examine the endogeneity of prices within an entire system of U.S. meat demands. Results of the specification tests are given in table 1.[7] The Hausman statistic for the AIDS model tests whether all prices can be taken as predetermined. Rejection suggests prices are endogenous. Statistics for the IAIDS model, on the other hand, test the predeterminedness of all quantities.

---

consumption expenditures, thus avoiding this problem and not biasing the outcomes of the specification tests.

[6] The inclusion of the technological change variables is to reflect improvements in livestock productivity over time. The pounds of feed used to produce a pound of live broiler have declined (Stillman and Weimar); the dressed weight of cattle has increased as a larger proportion of animals are of higher yield grade (USDA 1988); and the pounds of fat removed from pork carcasses has dropped as hogs have become leaner (Duewer, Bost and Futrell).

[7] Calculation of the Hausman test statistic is complicated by the fact that the difference in covariance matrices for the two sets of coefficients is singular for this case, as well as many others. Hausman and Taylor suggest the use of a generalized inverse for the calculations. We employed the singular value decomposition of the covariance matrix of the difference in coefficients to calculate a Moore-Penrose generalized inverse. The less numerically-stable, eigenvalue decomposition occasionally produced negative chi-squared values.

Table 1. HAUSMAN TEST RESULTS

Models:	AIDS	IAIDS
Statistic	33.58*	25.06*

Statistic is chi-square with 12 degrees of freedom. 0.05 cut off is 21.03

The results in table 1 suggest that both quantities and prices are endogenous in meat demand systems using annual data. So, while there are production lags in the supply of meats, in annual data both prices and quantities adjust to changing factors in the meat system as a whole.

To examine the issue of endogeneity at the level of the particular livestock industries, the models were re-estimated and tested to see whether each price or quantity could be taken as predetermined. This is done by comparing the 3SLS results when the variable being tested is assumed predetermined against 3SLS results with all RHS variables assumed endogenous. The results are given in table 2.

Table 2. TESTS OF PREDETERMINEDNESS OF PRICES AND QUANTITIES ONE AT A TIME

Variables:	Beef	Pork	Chicken
Quantities	3.43	4.38	19.55*
Prices	27.91*	10.58*	98.18*

Statistics are chi-square with 4 degrees of freedom. 0.05 cut off is 9.49. Rejection implies variable can not be taken as predetermined.

Table 2 shows beef and pork quantity can be taken as predetermined; while all prices and chicken quantities are endogenous. These results accord with the differing lengths of production lags for the meats. Beef quantity, with the longest production lag (2-4 years), is predetermined in annual data and beef price must adjust to clear the market. For pork, with a production lag of 5 to 6 calendar quarters, quantity is also predetermined in annual data. Chicken has a production lag of only weeks, so that both quantities and prices adjust within one year. These findings for chicken do not agree with those of Thurman, who found that chicken quantities adjust to prices that are predetermined by production costs.[8]

Taken together, the results in tables 1 and 2 show that the typical quantity-dependent demand system for meat estimated as a set of seemingly unrelated regressions is likely to produce biased and inconsistent estimates. It is more appropriate to employ 3SLS for model estimation. The question remains as to which RHS variables should be assumed endogenous and which assumed predetermined. While table 2 shows that only chicken quantity is endogenous in an IAIDS model, we are wary of adopting that assumption. Hausman warned against making one-variable-at-a-time tests (as in table 2), because such sequential testing procedures lack power. The results in table 2 are reassuring in that they conform to expectations based on livestock production lags. However, the results in table 1 indicate that, in the meat system as a whole, substitutions in both supply and demand among meats make all prices and quantities endogenous. Thus, the specification tests do not clearly indicate whether the IAIDS or the AIDS model is more appropriate.

It is also difficult to pick either model on purely statistical grounds. The AIDS model resulted in higher R^2s and more significant coefficient estimates (a table of coefficient estimates from the 3SLS models are given in an appendix). However, there appears to be some residual autocorrelation in the beef, pork, and non-meat food equations. The IAIDS model does not appear to suffer from autocorrelation (with the possible exception of the pork equation).

The specification tests do clearly indicate that the 3SLS estimates of either the AIDS or IAIDS are preferred to the SUR estimates. Therefore, it is interesting to see whether accounting for supply-side variables makes a difference in the measurement of consumer behavior. Table 3 shows the elasticities and flexibilities from all four sets of estimates.[9] The estimates from the SUR and the 3SLS are qualitatively similar in most cases. Looking at the flexibilities, it is apparent that all meats are necessities (scale flexibility < -1), in most cases the meats are inflexible with respect to own quantity, and all meats are gross q-substitutes. In the AIDS estimates, all meats are necessities, all except pork are own-price inelastic, and all are p-substitutes. The SUR estimates are similar to those reported by Eales and Unnevehr

---

[8] Thurman's data set included the period of rapid technological change in the broiler industry, when the supply curve may have been shifting outward faster than the demand curve, thus identifying the demand curve in annual data. Our data include more recent years when the rate of improvement in broiler feed efficiency has slowed (Stillman and Weimar).

[9] Green and Alston advocate an entirely different formula, for the calculation of the analogues of the LA/IAIDS flexibilities. We prefer the interpretation of Deaton and Muellbauer. In their American Economic Review article, they state: "However, it must be emphasized that (16) (the LA/AIDS) exists only as an approximation to (15) (the NL/AIDS) and will only be accurate in specific circumstances, albeit widely occurring ones in time-series estimation." (page 317, material in parentheses has been added) Our interpretation, Green and Alston not withstanding, is that the coefficients from the LA/IAIDS should be taken as estimates of the underlying NL/IAIDS coefficients and, therefore, it makes sense to use the formulae for flexibilities implied by the NL/IAIDS model.

Table 3. COMPARISON OF ELASTICITIES AND FLEXIBILITIES*

	AIDS				IAIDS			
	SUR		3SLS		SUR		3SLS	
	elasticity	std err#	elasticity	std err	flexibility	std err	flexibility	std err
Beef								
Beef	-.484	.112	-.340	.171	-1.182	.159	-.983	.237
Pork	.153	.063	.181	.087	-.075	.070	-.114	.092
Chicken	.054	.017	.075	.028	-.077	.056	-.081	.132
Non-meat	.278	.293	.334	.394	-.627	.250	-.742	.312
Other	-.406	.158	-.559	.201	-.005	.262	-.033	.277
Exp/Scale	.404	.233	.309	.265	-1.966	.379	-1.954	.408
Pork								
Beef	.319	.133	.367	.182	-.157	.145	-.233	.189
Pork	-.749	.118	-1.041	.172	-1.035	.110	-.932	.122
Chicken	.069	.028	.011	.042	-.165	.058	-.067	.128
Non-meat	.900	.419	1.315	.493	-.954	.299	-.825	.322
Other	-.886	.240	-1.252	.294	.240	.353	.218	.347
Exp/Scale	.347	.365	.599	.405	-2.071	.519	-1.840	.520
Chicken								
Beef	.297	.095	.405	.150	-.437	.307	-.484	.727
Pork	.182	.072	.029	.111	-.444	.155	-.200	.344
Chicken	-.149	.059	-.127	.081	-1.552	.384	-4.014	.889
Non-meat	-.082	.290	-.052	.357	-1.164	.524	-.462	1.030
Other	-.709	.167	-.800	.198	1.105	.477	1.736	.876
Exp/Scale	.460	.215	.544	.251	-2.493	.697	-3.424	1.286
Non-meat Food								
Beef	.045	.049	.053	.066	-.093	.040	-.112	.051
Pork	.073	.033	.111	.039	-.071	.023	-.063	.025
Chicken	-.003	.009	-.001	.011	-.031	.015	-.004	.031
Non-meat	-.439	.255	-.447	.285	-.725	.118	-.707	.125
Other	-.195	.117	-.188	.125	-.485	.114	-.492	.115
Exp/Scale	.520	.140	.472	.149	-1.405	.160	-1.378	.162
All Other Goods								
Beef	-.034		-.042		.030		.029	
Pork	-.025		-.028		.020		.017	
Chicken	-.008		-.008		.015		.024	
Non-meat	-.137		-.145		-.010		-.016	
Other	-.927		-.916		-.913		-.914	
Exp/Scale	1.132		1.140		-.857		-.861	

* All elasticities and flexibilities are calculated at the sample means.
\# Standard errors are approximate and do not consider variability of the sample mean of the shares or Stone's indexes. Approximation can be found in Mood, et al. p. 181.

(1988) from an AIDS model with annual data.

There are differences, however, between the SUR and the 3SLS estimates for both IAIDS and AIDS. These differences are most pronounced for chicken in the IAIDS model. The 3SLS estimates are more own-price inelastic and own-quantity inflexible and more responsive to changes in expenditures or scale. Given the results in table 2 and the technological changes in broiler production, it is perhaps not surprising that correcting for supply side variables would influence the chicken estimates. Next we consider whether including supply side variables accounts for apparent shifts in demand.

The typical reasons given for shifts in meat demand are increasing health consciousness in consumers (i.e. Chavas) and increased demand for convenience (Eales and Unnevehr 1988). Both of these phenomena should induce a gradual shift in demand, as either information on the ties between cholesterol and increased risk of heart disease disseminates through the population of consumers, or as an increasing proportion of consumers reside in households which are two-income, single person, or headed by women.

Evidence on whether structural change in demand has been continuous or abrupt varies among studies, perhaps due in part to differences in methodology. Eales and Unnevehr (1988) found evidence of continuous growth in chicken demand and continuous decline in beef demand after 1975, and the rates of growth differed before and after 1975. Moschini and Meilke (1989) did extensive testing of potential shifts in US meat demand allowing for more gradual patterns. They found a number of potential paths for such shifts, but the maximum likelihood estimates suggested that the shift most likely occurred abruptly, from 1975 quarter IV to 1976 quarter III, and only affected the constants. Earlier studies by Chavas (1983) and Dahlgran (1987) also indicated that change occurred in the mid 1970s.

In the first difference forms of the models estimated here, a significant constant term indicates continuous change in demand. In order to test for a shift in the AIDS and IAIDS models estimated here, they are estimated with an intercept dummy allowing a one-time shift between 1975 and 1976. The estimates for the constants and the dummies from the different models are in table 4. The SUR constants show results similar to those reported in 1988 by Eales and Unnevehr: beef demand declines significantly after 1975 in both the AIDS and the IAIDS, and chicken demand grows continuously in the AIDS model. However, the 3SLS models, which remove the influence of supply side shifts, show less significance in the constants. In the IAIDS estimated by 3SLS, none of the constants or dummies is significant. Thus, most of the apparent outward shift of chicken demand and inward shift of beef demand could be the result of mis-specification and not accounting for supply side shifts.

Table 4. SUR AND 3SLS SHIFT RESULTS*

	AIDS Constant	AIDS Shift	IAIDS Constant	IAIDS Shift
SUR				
Beef	-0.062*	0.089*	-0.084*	0.101*
	(0.023)	(0.028)	(0.033)	(0.041)
Pork	-0.003	-0.013	-0.019	0.002
	(0.017)	(0.021)	(0.021)	(0.025)
Chicken	0.015*	-0.007	0.003	-0.005
	(0.004)	(0.005)	(0.012)	(0.014)
Non-meat Food	0.010	-0.015	-0.054	0.116
	(0.080)	(0.098)	(0.078)	(0.096)

	AIDS Constant	AIDS Shift	IAIDS Constant	IAIDS Shift
3SLS: All RHS Variables Endogenous				
Beef	-0.048	0.080*	-0.065	0.074
	(0.027)	(0.031)	(0.038)	(0.049)
Pork	-0.014	-0.011	-0.031	0.013
	(0.020)	(0.022)	(0.021)	(0.026)
Chicken	0.014*	-0.006	0.039	-0.017
	(0.005)	(0.005)	(0.023)	(0.027)
Non-meat Food	0.037	-0.027	-0.083	0.141
	(0.085)	(0.102)	(0.080)	(0.100)

* Coefficients and standard errors have been multiplied by 100. Interpretation - Dummy is one up through 1975 and zero thereafter. Thus, post-1975, exogenous demand shifts are due to the constant. Prior to 1976, it is the sum of the constant and the shift which is relevant. Actually, this is important. A little thought will suggest that it is impossible to estimate a one-time shift "consistently." One never gets anymore information on the shift even as $T \to \infty$. By specifying the dummy in the way that we have, its effect on the asymptotics goes to zero. Thus, the Hausman test statistics are valid.

To test the overall significance of the dummies in the system, a Wald test is used. Asymptotically, it is distributed chi-square with 4 degrees of freedom. Results are given in table 5.

Table 5. SHIFT TEST RESULTS

Models:	AIDS	IAIDS
SUR	18.06*	10.74*
3SLS	9.21	6.64

Statistics are chi-square with 4 degrees of freedom. 0.05 cut off is 9.49.

In accordance with earlier studies (Moschini and Mielke; Eales and Unnevehr 1988) the SUR results for the AIDS model support a shift in demand in 1975. However, the 3SLS estimates of either the AIDS or the IAIDS models are more appropriate because they account for the potential endogeneity of the RHS variables. The 3SLS results for either system in table 5 do not support the findings of significant shifts in demand in the mid 1970s. Taken together, the results in Tables 4 and 5 indicate that supply side shifts may explain much of the apparent shifts in beef and chicken demand.

Summary and Conclusions

This paper started from the observation that supply side shifts in the livestock industries may account for apparent demand shifts found in quantity-dependent meat demand models. In order to investigate this issue, an inverse form of the AIDS model of Deaton and Muellbauer was employed. This inverse AIDS possesses all of the desirable theoretical properties of the AIDS model, with the exception of aggregation from the micro to the market level.[10] Anderson's scale compensation was used to show how flexibilities from the IAIDS may be interpreted. In any demand application where it is appropriate to assume that quantities are predetermined and prices are endogenous, the IAIDS provides an alternative that is both consistent with theory and with observations of the price discovery process.

In this paper, however, we did not assume endogeneity of prices, but rather test the endogeneity of prices and quantities as RHS variables in a system of meat demands. Both the AIDS and the IAIDS were estimated by SUR and by 3SLS. For the latter, instrumental variables included the determinants of livestock production costs and changes in livestock production technology. Following Thurman, the Hausman specification test was used to see which variables could be taken as predetermined.

[10] We are unaware of any results pertaining to consistent aggregation on the primal side.

The comparison of the IAIDS and AIDS results allowed us to address two questions. First, can prices be taken as predetermined in meat demand systems? To this the answer appears to be no. The findings indicate that prices and quantities are both endogenous for the meat demand system as a whole; however tests of individual variables indicated that beef and pork quantities may be predetermined. In this application, accounting for supply side variables alters the estimates of elasticities and flexibilities, particularly for chicken. Thus, the typical demand model estimated assuming prices are predetermined is mis-specified, and findings of structural change in demand could reflect supply side shifts.

Our second question was: is the finding of a demand shift, particularly the post-1975 decline for beef, an artifact of shocks to the supply side manifesting themselves through endogenous prices? The answer is a qualified yes. Correcting both the AIDS and the IAIDS models for potentially endogenous right-hand-side variables reduces the significance of the post-1975 change in demand. Furthermore, there is no evidence of significant structural change in the IAIDS model estimated by 3SLS. When supply side shifts are accounted for, evidence of structural change in meat demand is no longer compelling.

We must end with a cautionary note. Chalfant and Alston employed simulation and showed that the AIDS model was likely to produce evidence of demand shifts, even when no such shifts were built into the data. Our SUR estimates of the IAIDS may be subject to similar pitfalls. Findings of structural change are slippery at best, but the search persists in part because of independent evidence of changing consumer attitudes (i.e. National Livestock and Meat Board). By pursuing the above investigation, we hope to raise up for consideration the more complex dynamics occurring as both supply and demand of livestock products shifts. However, we have not explicitly modelled the supply side and our results are only indicative. Sorting out the impact of structural changes in both supply and demand on meat market equilibria is surely worthy of further investigation.

Bibliography

Anderson, R.W., 1980, Some Theory of Inverse Demand for Applied Demand Analysis. *European Economic Review* 14, 281-290.

Barten, A.P. and L.J. Bettendorf, Price Formation of Fish: An Application of an Inverse Demand System, *European Economic Review* 33, 1509-1525.

Chavas, J.P. "Structural Change in the Demand for Meat". *American Journal of Agricultural Economics*. 65(1983): 148-53.

Chalfant, J. and J. Alston. "Can We Take the Con Out of Meat Demand Studies." *Western Journal of Agricultural Economics*. 16(1991): 36-48.

Dahlgran, R.A. "Complete Flexibility Systems and the Stationarity of U.S. Meat Demands", *Western Journal of Agricultural Economics*. 12(1987): 152-163.

Deaton, A. "The Distance Function in Consumer Behavior with applications to Index Numbers and Optimal Taxation." *Review of Economic Studies* 46(1979): 391-405.

Deaton, A. and J. Muellbauer. "An Almost Ideal Demand System." *American Economic Review.* 70(1980): 312-326.

Diewert, W.E. "Duality Approaches to Microeconomic Theory." in *Handbook of Mathematical Economics*. Vol II. edited by K.J. Arrow and M.D. Intriligator. Amsterdam: North Holland, 1982.

Duewer, L.A., K. Bost, and G. Futrell, "Revisions in Conversion Factors for Pork Consumption Series." *Livestock and Poultry Situation and Outlook*. USDA/ERS, January 1991.

Eales, J.S. and L.J. Unnevehr. "Demand for Beef and Chicken Products: Separability and Structural Change", *American Journal of Agricultural Economics*. 70(1987):521-532,.

Eales, J. S., and L. J. Unnevehr. "The Inverse Almost Ideal Demand System." *Proceedings of the NCR-134 Conference on Applied Commodity Price Analysis, Forecasting, and Market Risk Management*. (1991): 402-17.

Green, R. and J.M. Alston. "Elasticities in AIDS Models." *American Journal of Agricultural Economics.* 72(1990): 442-5.

Hausman, J. A. "Specification Tests in Econometrics." *Econometrica.* 46(1978): 1251-1271.

Hausman, J.A. and W.E. Taylor. "A Generalized Specification Test." *Economic Letters*. 8(1981): 239-45.

Hicks, J.R., 1956, *A Revision of Demand Theory* (Oxford University Press, Oxford).

Houck, J.P., 1965, The Relationship of Direct Price Flexibilities to Direct Price Elasticities, *Journal of Farm Economics* 47, 301-21.

LaFrance, J. T. "When is Expenditure 'Exogenous' in Separable Demand Models?" *Western Journal of Agricultural Economics*. 16(1991): 49-62.

Mood, A.M., F.A. Graybill, D.C. Boes. *Introduction to the Theory of Statistics* 3rd Edition. New York: McGraw-Hill, 1974.

Moschini, G. and K. D. Meilke. "Modeling the Pattern of Structural Change in US Meat Demand." *American Journal of Agricultural Economics.* 71(1989):253-261.

Moschini, G. and A. Vissa, 1991, A Linear Inverse Demand System, Journal Paper No. U-14444, Iowa Agriculture and Home Economics Experiment Station, Project No. 2875.

National Livestock and Meat Board, "Survey Shows Life-styles affect Meat Consumption", *Meat Briefings*, 1988.

Smallwood, D.M., R.C. Haidacher, and J.R. Blaylock, "A Review of the Research Literature on Meat Demand", in *The Economics of Meat Demand*, R.C.Buse, Ed. (1989): 93-124.

Stillman, R.P. and M.R. Weimar. "Impact of Different Cost Assumptions on Long Term Projections for the Broiler Industry." *Livestock and Poultry Situation and Outlook*. ERS/USDA, LPS-44, November 1990.

Thurman, W. "Endogeneity Testing in a Supply and Demand Framework." *Review of Economics and Statistics*. 68(1986): 638-646.

Thurman, W. "The Poultry Market: Demand Stability and Industry Structure." *American Journal of Agricultural Economics*. 69(1987): 30-37.

U.S.D.A. "Lean Beef Making an Impact in the Marketplace", *Farmline*, Volume IX, No. 9, September 1988.

U.S.D.A. *Feed Situation.* Washington D.C., bi-monthly, selected issues.

U.S.D.A. *Food Consumption, Prices, and Expenditures.* Washington D.C., annual, selected issues.

U.S.D.A. *Livestock and Poultry Situation and Outlook.* Washington D.C., bi-monthly, selected issues.

U.S. Government Printing Office, *Economic Report of the President*. Washington D.C., annual, selected issues.

Wahl, T.I. and D.J. Hayes. "Demand System Estimation with Upward-Sloping Supply." *Canadian Journal of Agricultural Economics*. 38(1990): 107-22.

White, K.J. "A General Computer Program for Econometric Methods- SHAZAM." *Econometrica*. 47(1978): 239-40.

Table A1. 3SLS ESTIMATES OF THE IAIDS MODEL[1]

IAIDS	Beef	Pork	Chick	Non-meat	Other	Scale	D	Con	R^2	DW	mean share
Beef	.119 (.648)	-.281 (.247)	-.210 (.362)	-1.628* (.807)	2.000* (.765)	-2.636* (1.127)	.074 (.049)	-.065 (.038)	.431	2.089	.027
Pork	-.281 (.247)	.106 (.158)	-.084 (.170)	-.922* (.387)	1.181* (.455)	-1.121 (.694)	.013 (.026)	-.031 (.021)	.391	2.566	.013
Chicken	-.209 (.362)	-.084 (.170)	-.151 (.446)	-.037 (.496)	1.840* (.498)	-1.218 (.647)	-.017 (.027)	.039 (.023)	.151	2.114	.005
Non-meat Food	-1.628* (.807)	-.922* (.387)	-.037 (.496)	5.663* (1.816)	-3.075 (1.780)	-6.063* (2.597)	.141 (.100)	-.083 (.080)	.436	2.042	.159
AIDS	**Beef**	**Pork**	**Chick**	**Non-meat**	**Other**	**Expend**	**D**	**Con**	**R^2**	**DW**	**mean share**
Beef	1.443* (.394)	.383 (.206)	.158* (.069)	-.838 (.712)	-1.146* (.523)	-1.910* (.734)	.080* (.032)	-.048* (.027)	.703	3.249	.027
Pork	.383 (.206)	-.087 (.200)	.000 (.049)	1.262* (.524)	-1.560* (.378)	-.535 (.541)	-.011 (.022)	-.014 (.020)	.499	2.534	.013
Chicken	.158* (.069)	.000 (.049)	.433* (.039)	-.237 (.145)	-.354* (.096)	-.229 (.126)	-.006 (.005)	.014* (.005)	.923	2.136	.005
Non-meat Food	-.838 (.712)	1.263* (.525)	-.237 (.145)	1.060 (2.398)	-1.247 (1.930)	-8.452* (2.387)	-.027 (.103)	.037 (.085)	.341	2.560	.159

1. All coefficients and stand errors are multiplied by 100 for ease the presentation.
* Ratio of coefficient to its standard error is greater than two in absolute value.