# RURAL ECONOMY

**Simultaneity and Structural Change in US Meat Demand**

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Staff Paper 92-03

# STAFF PAPER

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**Abstract**

An inverse of the Almost Ideal Demand System, the IAIDS, is developed in order to test the endogeneity of prices and quantities in the U.S. meat demand system. The IAIDS has all the desirable theoretical properties of the AIDS except aggregation from the micro to the market level. Using annual data, both prices and quantities appear to be endogenous within the entire meat market. Including livestock production costs and technical change indicators as instruments eliminates evidence of a mid-1970s demand change.

**Key Words**: meat demand, structural change, simultaneity, almost ideal demand systems

## SIMULTANEITY AND STRUCTURAL CHANGE IN US MEAT DEMAND

While still contested, findings of structural change in meat demand are common. Most early findings were derived from quantity-dependent demand systems. In their review of 17 meat demand articles, Smallwood et al. report that 14 studies used quantity-dependent demand models. Such models often ignore potential simultaneity in meat prices and quantities. Often, the oversight is due to researchers' desire to use theoretically consistent demand models, rather than the ad hoc ones most often employed when estimating supply and demand together.

Ignoring the supply side of the market is particularly dangerous with meats, however. Meats are perishable, and red meats are produced with a long biological lag. Thus, quantity supplied is likely to be predetermined and quantity-dependent demand models may be inappropriate. Use of such models could lead to a spurious identification of structural demand change. Changes in supply, like the beef herd liquidation following feed price escalation in the 1970s, could appear as structural change in demand, even when none had occurred. Gradual structural change in supply also could appear as a demand shift. For example, increased broiler feed efficiency and higher beef carcass dressed weights probably have shifted supply curves for these meats steadily outward, and may have contributed to an appearance of demand growth unrelated to prices and expenditures.

In the present paper we address two questions. First, when estimating a system of U.S. meat demands, can quantities or prices be taken as predetermined or are both endogenous? 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? Answers to these two questions are related, because many demand models that have revealed structural change are mis-specified if quantities are predetermined or prices are endogenous. In such models, supply-side changes could show up as structural shifts in demand.

To answer these questions, we test the endogeneity of prices and quantities in a meat demand system. It is necessary first to develop a theoretically consistent demand model for markets where quantities are predetermined. Deaton and Muellbauer's AIDS has enjoyed popularity in the modeling of consumer preferences, especially for meats (i.e., Eales and Unnevehr, Moschini and Meilke, Wahl and Hayes). We develop the Inverse Almost Ideal Demand System (IAIDS). The IAIDS is similar to the AIDS, except that it is derived from the distance function instead of the cost function. Both the AIDS and the IAIDS have a budget-share semi-log functional form that provides a theoretically consistent, flexible representation of consumer preferences. This flexibility may help to lessen the impact of the maintained hypotheses on the outcome of the endogeneity tests.

If AIDS-type preferences are assumed, Seemingly Unrelated Regressions (SUR) estimates of the AIDS model are appropriate when prices are predetermined and quantities endogenous. Alternatively, if quantities are predetermined and prices endogenous, the IAIDS is appropriate. If some subset of both prices and quantities are endogenous, then three-stage least squares estimation with instrumental variables characterizing the determinants of supply is the suitable technique for estimating either model.

To test for endogeneity of prices or quantities, we estimate the AIDS and IAIDS in two ways: first, the right-hand-side (RHS) variables observed in meat markets are assumed to be predetermined and 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 demand trends and for a one-time trend shift in the mid-1970s. Whether supply-side variables underlie evidence of shifting demand can be seen by comparing models estimated with and without supply instruments.

**The Inverse Almost Ideal Demand System**

In order to develop an inverse of the AIDS, we start with an alternative representation of preferences, the distance function. It characterizes the amount by which all quantities consumed must be changed proportionally to attain a particular utility level. That is, it gives the proportional "distance" along a ray from the origin by which quantities must be reduced or inflated to reach a particular indifference surface. Given utility function U{q}, the distance function D{u,q} is a scalar giving the amount by which all quantities in the current consumption bundle, q, must be divided to reach the indifference surface defined by u. Thus, distance function D is implicitly defined by U{q/D(u,q)} = u.

The distance function possesses properties similar to the cost function: it is linearly homogenous, concave, and nondecreasing in quantities (as opposed to prices); and it is decreasing, rather than increasing, in utility (Diewert). It also has a derivative property similar to the cost function (Deaton, 1979; p. 394): at the optimum, differentiation with respect to the quantity of a particular good yields the compensated inverse demand for that good. Thus, in a manner similar to Deaton and Muellbauer's derivation of the AIDS model (1980), a logarithmic distance function can be specified as:

(1) $\ln D(u,q) = (1-u) \ln a(q) + u \ln b(q)$

To be consistent with theory, the distance function has the same requirements as the cost function (with quantities substituted for prices). Thus the two functions, ln a(q) and ln b(q), may be specified in a manner analogous to that employed in the AIDS:

(2)
$$\ln a(q) = \alpha_0 + \Sigma\, \alpha_j \ln q_j + 0.5\, \Sigma_i\, \Sigma_j\, \gamma_{ij}^* \ln q_i \ln q_j$$
$$\ln b(q) = \beta_0\, \Pi_j\, q_j^{-\beta_j} + \ln a(q)$$

This parameterization yields:[1]

(3) $$\ln D(u,q) = \alpha_0 + \Sigma_j\, \alpha_j \ln q_j + 0.5\, \Sigma_i\, \Sigma_j\, \gamma_{ij}^* \ln q_i \ln q_j + u\; \beta_0\, \Pi_j\, q_j^{-\beta_j}$$

Differentiation yields compensated <u>inverse</u> demands (Deaton, 1979; p 394):

(4) $$\partial \ln D \,/\, \partial \ln q_i = w_i = \alpha_i + \Sigma_j\, \gamma_{ij} \ln q_j - \beta_i\, u\; \beta_0\, \Pi_j\, q_j^{-\beta_j}$$

where: $\gamma_{ij} = 0.5\,(\gamma_{ji}^* + \gamma_{ij}^*)$

Inversion of the distance function at the optimum yields the direct utility function, which may be used to uncompensate the inverse demands (Deaton, 1979; p 393).

(5) $$U(q) = -\ln a(q) \,/\, \{\ln b(q) - \ln a(q)\}$$

Substituting (5) into (4) yields a system of inverse demand functions which will be called the <u>Inverse Almost Ideal Demand System</u> or IAIDS:[2]

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

with ln Q given by:

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

As with the AIDS model; adding up, homogeneity, and symmetry restrictions involve only the fixed, unknown coefficients and so can be easily tested or imposed. The 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). Equation (6) requires nonlinear estimation. To derive a linear approximation, Stone's quantity index, which does not depend on unknown parameters, is substituted for the quantity index.[3]

With inverse demand models, sensitivities are typically measured by flexibilities (Houck). Interpretation of inverse demand results requires an appropriate analog of the expenditure elasticity. Anderson proposed a compensation technique for inverse demands in which a movement from an old to a new consumption bundle is broken up into two pieces: the movement along the indifference surface of the original utility level (substitution effect), and then a movement to the new indifference surface, expanding all quantities proportionally (the scale effect). The distance function measures distance along rays from the origin. Thus, compensation according to the consumption "scale" in the distance function is the analogue of expenditure compensation in the cost function (Anderson; Eales and Unnevehr 1991).

To be consistent with theory, ordinary demand curves must satisfy the homogeneity, Cournot, and Engel aggregation relations. With inverse demands, Anderson shows that similar aggregations hold. 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: $\Sigma_j f_{ij} = f_i$ (homogeneity); $\Sigma_i w_i f_{ij} = -w_j$ (Cournot); $\Sigma_i w_i f_i = -1$ (Engel).

Given the scale decomposition of inverse demands, formulae for calculating Marshallian cross-price, expenditure, and compensated or Hicksian elasticities are almost identical to those required for the cross-price, scale, and compensated flexibilities. For comparison, these formulae are given in table 1 (complete derivation of the IAIDS flexibilities is given in Eales and Unnevehr 1991).

Flexibilities are less commonly employed in interpreting results, and we found no agreed-upon terminology. In the following, 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 consumption value of that commodity (its normalized price). Likewise, we will refer to commodities with scale flexibilities less (greater) than -1 as scale inflexible (flexible). 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, where all expenditure elasticities equal one. In this case, expanding consumption of all commodities by 1%, or moving out along a ray from the origin, requires no change in relative prices but expenditures must increase by 1% to achieve the new bundle. Thus, the normalized prices (divided by expenditures) will decrease by 1% and all scale flexibilities must be -1. Necessities and luxuries then can 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 $< -1$; i.e. $= -2.0$) and the marginal utility of luxuries declines less than proportionately (scale flexibility $> -1$; i.e. $= -0.5$).

Table 1. FORMULAE FOR AIDS ELASTICITIES AND IAIDS FLEXIBILITIES

| | AIDS | IAIDS |
|---|---|---|
| Own & Cross Price | $\epsilon_{ij} = -\delta_{ij} + \{ \gamma_{ij} - \beta_i ( w_j - \beta_j \ln (x/P) ) \} / w_i$ | $f_{ij} = -\delta_{ij} + \{ \gamma_{ij} + \beta_i ( w_j - \beta_j \ln Q ) \} / w_i$ |
| Expenditure or Scale | $\epsilon_i = 1 + \beta_i / w_i$ | $f_i = -1 + \beta_i / w_i$ |
| Compensated | $\epsilon_{ij}^* = \epsilon_{ij} + w_j \epsilon_i$ | $f_{ij}^* = f_{ij} - w_j f_i$ |

In the table, $\epsilon$s are elasticities; fs are flexibilities; ws are expenditure shares; $\delta_{ij}$ is the Kronecker delta; x is total expenditure; P and Q are the price and quantity indices; and $\beta$s and $\gamma$s are parameters.

## Estimation Models and Data

Our test for endogeneity is similar to that in Thurman. Hausman tests for endogeneity will be used to determine whether prices, quantities, or both are endogenous. In contrast to Thurman's work, our tests will be conducted using a system of meat demands based on theoretically-consistent, flexible functional forms. Flexibility of the AIDS and the IAIDS should reduce the impact of the maintained hypotheses on the test outcomes.

The first-differenced, linear approximation of the AIDS model is estimated as:

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

where all variables are in first differences; $\alpha$s, $\theta$s, $\gamma$s, and $\beta$s are unknown coefficients; D is a dummy variable (one through 1975 and zero thereafter); x is total per-capita expenditure; and $\Delta \ln P^* = \Sigma_j w_j \Delta \ln p_j$ is a Stone's price index, where $w_j$ is lagged one period to avoid simultaneity problems.[4]

The estimation equation for the IAIDS is a similar first-differenced linear approximation:

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

with terms defined as before.

Green and Alston have shown that the AIDS price elasticity formula in table 1 is inappropriate when the linear approximation is used. Therefore, Chalfant's (1987) formula is employed in calculating price elasticities and the analog to Chalfant's formula is used to calculate flexibilities:

(10)
$$\epsilon_{ij} = -\delta_{ij} + \{ \gamma_{ij} - \beta_i w_j \} / w_i$$
$$f_{ij} = -\delta_{ij} + \{ \gamma_{ij} + \beta_i w_j \} / w_i$$

Both the AIDS and IAIDS are estimated twice. In all cases, homogeneity and symmetry are imposed on the estimates. The AIDS model is first estimated with iterative Seemingly Unrelated Regressions (SUR), which is appropriate if prices are predetermined. Second, the AIDS is reestimated with iterative Three Stage Least Squares (3SLS) in which instrumental variables are used to reflect livestock production costs. Even if meat quantities are predetermined, estimation of the IAIDS model must reflect the endogeneity of non-meat food and all other goods' quantities. Thus, the IAIDS model is estimated first using 3SLS and instruments including a time trend, price of other foods, and total per capita expenditures (to reflect quantities of non-meat foods and all other goods, and the quantity index); and meat quantities (as they are assumed predetermined). This first estimation is not appropriate if meat quantities are endogenous. The second estimation of the IAIDS model uses 3SLS in which livestock production costs replace meat quantities in the instruments.

The first estimates (without supply-side instruments) are appropriate if the RHS meat variables are assumed predetermined; the second estimates (with supply-side instruments) are appropriate if the RHS meat variables are endogenous. In order to test whether meat prices (quantities) are endogenous, the two sets of AIDS (IAIDS) estimates are compared using the Hausman specification test. AIDS or IAIDS estimates without supply-side instruments are from the model which is asymptotically efficient under the null hypothesis and inconsistent under the alternative hypothesis. These estimates are compared to the second estimates with supply side instruments, which are consistent under both the null and alternative hypothesis. If the RHS meat variables are appropriately taken as predetermined for a particular model, the two estimates are similar and the Hausman test is insignificant.

The models include beef, pork, chicken, non-meat food, and all other goods.[5] Data are annual per capita consumption and price indexes from 1962 through 1989. Instruments employed to represent RHS meat variables include: price of corn (on calendar year basis), three variables to represent technological change in meat production (average beef carcass dressed weight; pork carcass fat removed per 100 pounds; and broiler feed conversion ratio), 90-day Treasury Bill yields, an energy price index, meat-packing wages, price of other foods, personal consumption expenditures per capita, and a time trend.[6] All data are from USDA sources and all variables except the time trend are first differences of logs. Estimation was carried out with version 6.2 of the SHAZAM program (White).

## Results

Previous studies (Thurman; Wahl and Hayes) provide evidence regarding the predeterminedness of chicken price but not of other meat prices. Thurman found that prices were predetermined by costs of production in U.S. broiler markets. Wahl and Hayes compared Japanese meat demand elasticities when prices are taken as endogenous to those obtained when quantities are assumed endogenous. Wahl and Hayes found evidence that chicken price is predetermined in Japan. Our study is the first to test the endogeneity of prices within a U.S. meat demand system.

The Hausman statistic of the AIDS (IAIDS) model tests whether all prices (quantities) can be taken as predetermined. Rejecting the AIDS (IAIDS) suggests prices (quantities) are endogenous. Specification test results in table 2 suggest that both quantities and prices are endogenous in meat demand systems using annual data. While there are production lags in the supply of meats, both annual prices and quantities adjust to changing factors within the entire meat system.

To examine endogeneity in each meat product market, the models are re-estimated and tested to see whether each individual price or quantity can be taken as predetermined. Each specification test is a comparison of the 3SLS results in which the respective variable is assumed predetermined, against 3SLS results in which all RHS meat variables are assumed endogenous.

Results in table 3 show beef quantity can be taken as predetermined; all prices and pork and chicken quantities are endogenous. These results accord with the differing production lags among the meats. Beef has the longest production lag (2-4 years). Thus, beef quantity is predetermined in annual data and beef price must adjust to clear the market. As the pork production lag is about 5 calendar quarters, some quantity adjustment occurs within one year. Chicken has a production lag of only weeks, so that both quantities and prices adjust within one year. Our findings for chicken do not agree with those of Thurman, who found that chicken quantities adjust to prices that are predetermined by production costs.[7]

Results in tables 2 and 3 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. The question remains as to which RHS meat variables should be assumed endogenous and which assumed predetermined. Hausman warned against making one-variable-at-a-time tests,

Table 2. HAUSMAN TEST RESULTS

| Models: | AIDS | IAIDS |
|---|---|---|
| Statistic | 46.02* | 39.08* |

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

Table 3. TESTS OF PREDETERMINEDNESS OF PRICES

AND QUANTITIES, ONE AT A TIME

| Variables: | Beef | Pork | Chicken |
|---|---|---|---|
| Quantities | 6.93 | 12.06* | 17.20* |
| Prices | 13.93* | 13.42* | 43.33* |

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

Rejection implies variable cannot be taken as predetermined.

Table 4. COMPARISON OF ELASTICITIES AND FLEXIBILITIES[1]

| | AIDS | | | | IAIDS | | | |
|---|---|---|---|---|---|---|---|---|
| | Without Supply Instruments | | With Supply Instruments | | Without Supply Instruments | | With Supply Instruments | |
| | Elasticity | Standard error[2] | Elasticity | Standard error | Flexibility | Standard error | Flexibility | Standard error |
| | | | | Beef | | | | |
| Own-Price | -.573 | .074 | -.850 | .223 | -1.234 | .179 | -1.189 | .255 |
| Expenditure/Scale | .402 | .219 | .791 | .432 | -2.117 | .639 | -1.284 | .507 |
| | | | | Pork | | | | |
| Own-Price | -.801 | .083 | -1.234 | .278 | -1.053 | .147 | -.879 | .164 |
| Expenditure/Scale | .350 | .348 | 1.281 | .824 | -2.410 | .911 | -.912 | .668 |
| | | | | Chicken | | | | |
| Own-Price | -.162 | .055 | -.233 | .098 | -1.334 | .477 | -2.257 | .800 |
| Expenditure/Scale | .459 | .211 | .693 | .349 | -2.374 | .978 | -1.832 | .947 |

1. All elasticities and flexibilities are calculated at the sample means.

2. 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.

because such sequential testing procedures lack power. The table 3 results are reassuring because they conform to expectations based on livestock production lags. However, the table 2 results indicate that substitutions among meats in both supply and demand make all prices and quantities endogenous in the entire meat market. Thus, the specification tests do not clearly indicate whether the IAIDS or the AIDS model is the more appropriate.

Our specification tests do indicate clearly that the 3SLS estimates of either the AIDS or IAIDS models which employ livestock production cost instruments are preferable to those that do not. Therefore, it is interesting to see whether including supply-side instruments alters measurements of consumer behavior. Table 4 shows the AIDS own-price and expenditure elasticities and the IAIDS own-price and scale flexibilities (complete results are in appendix table A2). Estimates with and without supply-side instruments are qualitatively similar to one another: all meats (except pork) are necessities and are own-price inelastic or inflexible. However, the magnitudes of the estimates differ depending upon whether the supply-side instruments are included. All meat demands from AIDS estimates which account for the supply side are both more own-price elastic and more income elastic than are those from estimates which do not account for the supply side. The IAIDS estimates show the expected inverse pattern: all meats are more own-price flexible and scale flexible when supply-side instruments are used. Taking account of the endogeneity of both prices and quantities in estimation clearly alters the results.

Next we consider whether including supply instruments removes estimated demand shifts. Growing health consciousness among consumers (Chavas) or increased demand for convenience (Eales and Unnevehr 1988) are typical explanations of meat demand shifts.

These phenomena should induce gradual demand shifts as health information disseminates through the population, or as more consumers reside in two-income, single person, or female-headed households. Whether structural demand change is found to be continuous or abrupt varies among studies, perhaps due in part to methodological differences. Eales and Unnevehr (1988) found continuous growth in chicken demand and decline in beef demand, and the rates of growth and decay differed before and after 1975. Moschini and Meilke tested the nature of U.S. meat demand and found several potential shift patterns. However, their estimates suggested the shift likely occurred abruptly between 1975 quarter IV to 1976 quarter III, and affected only the constants. Earlier studies by Chavas (1983) and Dahlgran (1987) also indicated that demand change occurred in the mid 1970s.

In the first-difference forms of the models estimated here, a significant constant term indicates a trend in demand. In order to test for a change in the trend, the AIDS and IAIDS models are estimated with an intercept dummy allowing a one-time shift between 1975 and 1976. To test the overall significance of the constants and dummies in the system, a Wald test is used. Asymptotically it is distributed chi-square with degrees of freedom given in table 5.

In accordance with earlier studies (Moschini and Meilke; Eales and Unnevehr 1988) the AIDS results without the supply instruments support both a trend and a shift in the trend in 1975. These changes consist of continuous chicken demand growth throughout the sample period and a beef demand decline after 1975 (appendix table A1). The IAIDS estimates also support a trend change after 1975. However, the 3SLS estimates which incorporate supply-

Table 5. TESTS FOR CHANGE IN DEMAND

| | Trend | | 1975 Shift in Trend | |
|---|---|---|---|---|
| Models: | AIDS | IAIDS | AIDS | IAIDS |
| Without Supply Instruments | 28.91* | 4.66 | 18.08* | 10.74* |
| With Supply Instruments | 11.52* | 8.43 | 8.59 | 6.96 |

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

side instruments are more appropriate because of potential endogeneity of the RHS meat variables. When these instruments are included in estimation, neither model supports significant demand trend shifts in the mid 1970s (table 5). Only the AIDS model provides evidence of significant demand trends. Changes in supply-side variables explain much of the apparent mid-1970s shift in beef and chicken demand.

## Summary and Conclusions

We started with the observation that livestock supply shifts might induce apparent demand shifts in quantity-dependent meat demand models. In order to test this hypothesis, an inverse form of the AIDS model was derived from the distance function. The inverse AIDS possesses the desirable theoretical properties of the AIDS model except aggregation from the micro to the market level. Anderson's scale compensation was used to derive and interpret flexibilities from the IAIDS. In any demand application where observation suggests quantities are predetermined and prices endogenous, the IAIDS provides an alternative that is consistent with theory and with the price discovery process.

We did not assume exogenous meat prices, but tested the endogeneity of meat prices and quantities as RHS variables in a demand system. Both the AIDS and the IAIDS were estimated with and without instruments for meat supplies. Instrumental variables included livestock production cost determinants and technological change indicators. Following Thurman, the Hausman specification test was used to see whether meat prices or quantities could be taken as predetermined.

Comparison of IAIDS and AIDS results provides answers to two questions. First, can prices be taken as predetermined in meat demand systems? The answer appears to be no. Prices and quantities are both endogenous in the meat demand system as a whole; however, tests of individual variables indicate that beef quantity could be predetermined. Including supply-side instruments gives more elastic estimates of own-price and expenditure elasticities (and the inverse for flexibilities) in comparison to estimates without supply-side instruments. Thus, the typical demand model in which prices are assumed predetermined is misspecified; this could influence parameter estimates, including findings of structural change in demand.

Our second question was: is the abrupt demand shift, particularly the post-1975 beef decline, an artifact of supply-side shocks manifesting themselves through endogenous prices? The answer is a qualified yes. The significant post-1975 demand change disappears when models are corrected for endogenous right-hand-side meat variables. Furthermore, there is no significant demand trend or change in trend in the IAIDS model estimated with supply-side instruments. These results do not conclusively reject the possibility of structural demand change, however, as the AIDS model estimated with supply-side instruments shows significant trends in demand throughout the sample period.

Our findings agree with a small but growing literature questioning the mid-1970s structural change in meat demand. Using a partially inverted Rotterdam model, Dahlgran found demand changes in the 1970s were not permanent, but "most likely the result of changing supply conditions interacting with stable meat demands" (p.162). Using non-parametric techniques, Chalfant and Alston found that demand patterns did not support structural change. More recently, Alston and Chalfant employed simulation to show that the AIDS model is likely to produce evidence of demand shifts, even when no shifts are built into the data.

Structural change findings are slippery at best; the search persists because independent evidence indicates changing consumer attitudes (i.e. National Livestock and Meat Board). We hoped here only to raise for consideration the more complex dynamics of simultaneous supply and demand shifts. However, we have not explicitly modelled the supply side and our results are only indicative. Sorting out impacts on the meat market of structural changes in both supply and demand is surely worthy of further investigation.

## Bibliography


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

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

Chalfant, J. "A Globally Flexible, Almost Ideal Demand System." *Journal of Business & Economic Statistics* 5(1987): 233-242.

Chalfant, J., and J. Alston. "Accounting for Changes in Tastes." *Journal of Political Economy* 96(1988): 391-410.

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

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. *A Revision of Demand Theory.* Oxford: Oxford University Press, 1956.

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

King, J. "Lean Beef Making an Impact in the Marketplace", *Farmline*, IX(1988): 10-11.

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

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.

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.

## ENDNOTES

1. The following logarithmic distance function is not the dual of the AIDS logarithmic cost function. To our knowledge, no closed-form solution for the dual of the AIDS log-cost function exists.

2. It has recently come to our attention that a model similar to the one developed here has been developed independently by Moschini and Vissa.

3. The justification for this substitution in the AIDS model (that time-series prices are collinear) is not appropriate for the IAIDS model. Quantities do not move together. Thus the adequacy of the approximation is an empirical question. Eales and Unnevehr (1991) have shown that the LA/IAIDS provided a good approximation of the IAIDS for quarterly meat demand data.

4. After differencing, Stone's price index is actually $\Delta$ ( $\Sigma_j$ $w_j$ ln $p_j$ ); but with a $w_j$ lagged one period, this leads to the loss of two degrees of freedom. The formula in the text was adopted to save one of those degrees of freedom. The correlation between the two forms of the differenced Stone's price index is 0.998 in our sample. In the IAIDS model, the correlation between the two forms of the differenced Stone quantity index is 0.963. Use of either form produces no qualitative differences in the results given below.

5. Including categories all-other-goods and non-meat food categories required calculating their corresponding quantities and a non-meat food price. The ratio of non-food expenditures to the non-food CPI is used as the quantity of all other goods. The non-meat food quantity is food quantity (ratio of food expenditures to food CPI) minus the sum of the meat quantities. Non-meat food price is then the ratio of non-meat food expenditures to the non-meat food quantity.

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

7. 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, during which the rate of improvement in broiler feed efficiency has slowed (Stillman and Weimar).

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 | -.281 | -.210 | -1.628* | 2.000* | -2.636* | .074 | -.065 | .431 | 2.089 | .027 |
| | (.648) | (.247) | (.362) | (.807) | (.765) | (1.127) | (.049) | (.038) | | | |
| Pork | -.281 | .106 | -.084 | -.922* | 1.181* | -1.121 | .013 | -.031 | .391 | 2.566 | .013 |
| | (.247) | (.158) | (.170) | (.387) | (.455) | (.694) | (.026) | (.021) | | | |
| Chicken | -.209 | -.084 | -.151 | -.037 | 1.840* | -1.218 | -.017 | .039 | .151 | 2.114 | .005 |
| | (.362) | (.170) | (.446) | (.496) | (.498) | (.647) | (.027) | (.023) | | | |
| Non-meat Food | -1.628* | -.922* | -.037 | 5.663* | -3.075 | -6.063* | .141 | -.083 | .436 | 2.042 | .159 |
| | (.807) | (.387) | (.496) | (1.816) | (1.780) | (2.597) | (.100) | (.080) | | | |

| AIDS | Beef | Pork | Chick | Non-meat | Other | Expend | D | Con | $R^2$ | DW | mean share |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Beef | 1.443* | .383 | .158* | -.838 | -1.146* | -1.910* | .080* | -.048* | .703 | 3.249 | .027 |
| | (.394) | (.206) | (.069) | (.712) | (.523) | (.734) | (.032) | (.027) | | | |
| Pork | .383 | -.087 | .000 | 1.262* | -1.560* | -.535 | -.011 | -.014 | .499 | 2.534 | .013 |
| | (.206) | (.200) | (.049) | (.524) | (.378) | (.541) | (.022) | (.020) | | | |
| Chicken | .158* | .000 | .433* | -.237 | -.354* | -.229 | -.006 | .014* | .923 | 2.136 | .005 |
| | (.069) | (.049) | (.039) | (.145) | (.096) | (.126) | (.005) | (.005) | | | |
| Non-meat Food | -.838 | 1.263* | -.237 | 1.060 | -1.247 | -8.452* | -.027 | .037 | .341 | 2.560 | .159 |
| | (.712) | (.525) | (.145) | (2.398) | (1.930) | (2.387) | (.103) | (.085) | | | |

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.

Table A2. COMPARISON OF ELASTICITIES AND FLEXIBILITIES[1]

| | AIDS | | | | IAIDS | | | |
|---|---|---|---|---|---|---|---|---|
| | SUR | | 3SLS | | SUR | | 3SLS | |
| | Elasticity | Standard error[2] | Elasticity | Standard error | Flexibility | Standard error | Flexibility | Standard error |
| | | | | Beef | | | | |
| Beef | -.573 | .074 | -.850 | .223 | -1.234 | .179 | -1.189 | .255 |
| Pork | .106 | .040 | -.045 | .132 | -.088 | .093 | -.040 | .112 |
| Chicken | .040 | .013 | .070 | .033 | -.093 | .063 | -.168 | .105 |
| Non-meat Food | -.135 | .177 | .644 | .539 | .029 | 1.158 | -.351 | .860 |
| Other | .159 | .214 | -.609 | .582 | -.731 | 1.234 | .464 | .817 |
| Exp/Scale | .402 | .219 | .791 | .432 | -2.117 | .639 | -1.284 | .507 |
| | | | | Pork | | | | |
| Beef | .221 | .084 | -.107 | .279 | -.190 | .196 | -.073 | .235 |
| Pork | -.801 | .083 | -1.234 | .278 | -1.053 | .147 | -.879 | .164 |
| Chicken | .053 | .020 | .013 | .048 | -.174 | .065 | -.093 | .106 |
| Non-meat Food | .445 | .270 | 1.694 | .920 | -.842 | .672 | -.928 | .709 |
| Other | -.269 | .341 | -1.645 | 1.087 | -.152 | .934 | 1.061 | .757 |
| Exp/Scale | .350 | .348 | 1.281 | .824 | -2.410 | .911 | -.912 | .668 |
| | | | | Chicken | | | | |
| Beef | .216 | .074 | .385 | .185 | -.518 | .352 | -.939 | .583 |
| Pork | .140 | .055 | .041 | .127 | -.461 | .173 | -.258 | .279 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Chicken | -.162 | .055 | -.233 | .098 | -1.334 | .477 | -2.257 | .800 |
| Non-meat Food | -.454 | .205 | -.381 | .428 | -5.607 | 5.284 | -2.544 | 4.278 |
| Other | -.199 | .225 | -.505 | .473 | 5.546 | 5.211 | 4.167 | 3.817 |
| Exp/Scale | .459 | .211 | .693 | .349 | -2.374 | .978 | -1.832 | .947 |
| | | | | Non-meat Food | | | | |
| Beef | -.026 | .032 | .129 | .104 | .014 | .207 | -.072 | .148 |
| Pork | .035 | .023 | .156 | .085 | -.062 | .056 | -.088 | .058 |
| Chicken | -.015 | .007 | -.009 | .015 | -.173 | .168 | -.079 | .134 |
| Non-meat Food | -.771 | .135 | -1.197 | .371 | .648 | 5.186 | -.413 | 1.413 |
| Other | .258 | .151 | .769 | .432 | -2.200 | 5.132 | -1.035 | 1.259 |
| Exp/Scale | .518 | .137 | .153 | .310 | -1.772 | .381 | -1.687 | .197 |
| | | | | All Other Goods | | | | |
| Beef | -.015 | | -.032 | | .012 | | .028 | |
| Pork | -.015 | | -.026 | | .019 | | .019 | |
| Chicken | -.005 | | -.006 | | .043 | | .031 | |
| Non-meat Food | -.046 | | -.009 | | -.284 | | -.075 | |
| Other | -1.052 | | -1.103 | | -.563 | | -.851 | |
| Exp/Scale | 1.132 | | 1.175 | | -.773 | | -.848 | |

1. All elasticities and flexibilities are calculated at the sample means.

2. 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.