**Paper Title**: What is Driving Changes in Consumer Demand for Meats?

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# **What is Driving Changes in Consumer Demand for Meats**?

Abstract

A large household data set is used to estimate the demand for beef, poultry, pork, and fish. Various forms of expenditure allocation models are employed to determine the impacts of prices, demographics, seasonal effects, promotions, and total expenditures on household demand for meat products. A standard output from these models includes the various price and expenditure elasticities. Along with the elasticities, all demand drivers are ranked in terms of their relative importance. Education is shown to have a negative impact on both beef and pork demand. Some policy implications are provided.

**What is Driving Changes in Consumer Demand for Meats?**

Sara Medina and Ronald W. Ward

Meat products have been important to the U.S. economy since early Colonial days. After World War II, as Americans became more affluent, the demand for meats exploded. Today, the U.S. meat industry is the largest component of both the nation's agricultural sector and food marketing industry, employing nearly half a million workers and contributing over $90 billion in annual sales to the Gross National Product (GNP). Within a two-week period 95 percent of U.S. households purchase some quantity of beef, fish, pork or poultry with annual expenditures accounting for 2.2 percent of the typical household income. This value is almost 50 percent less than 25 years ago when consumers were spending 4.3 percent of their income in meat products. Total per capita consumption of beef, pork, poultry and fish increased by 16 pounds over the past decade with the average person increasing his or her total meat consumption by more than 1.5 pounds a year since 1990 (American Meat Institute, Meat Facts). Factors that likely helped meat demand include a strong U.S. economy, rising wages, low inflation and a low unemployment rate. Consumers are also recognizing the nutrient contributions of meat to the diet quality. An understanding of meat demand is important to ensure that convenience and nutrition work together to satisfy household food needs. Over the last decades, there have been substantial shifts in consumption from red to white meat. Changing lifestyles are causing consumers to demand more convenience foods and white meats are often perceived to be healthier than red meats. This is particularly relevant for industry participants and government policy makers, calling possibly for a quality adjustment in production and increased efforts in promotion and marketing.

Using individual consumer household purchasing data, the impact of the major factors influencing consumers demand for competing meat products are determined. These demands are estimated using various forms of expenditure allocation models where the expenditure shares ($w_j$) are estimated showing the relationship of $w_j$ to prices, demographics, seasonal effects, promotions, and total expenditures. Price and expenditure elasticities are calculated and the major demand drivers are ranked in terms of their relative importance. A few implications for the meat industry are set forth.

## Household Purchasing Data

Data used in this analysis is from a household panel database collected by the National Panel Diary Company (NPD, 1998). NPD maintains the household panel where participating households keep eating diaries, documenting their purchasing habits. The female head of the household reports the eating occasions within the home, recording the types of meat products purchased. Specifically, households report the quantities and expenditures on specific meat products purchased in a two-week time period. There are 7520 different households in the data set spanning the period from the last quarter of 1992 through the first quarter of 1998. Demographics are recorded for each household, including income levels, household sizes, ages of females, presence of children in the household, female employment status, female education levels, geographic regions (by state), and market sizes. Variable definitions are presented in Table 1. The full data set includes information on household demographics and the quantities and expenditures of the different households on beef, fish, poultry and pork for a total of 30,611 observations.

NPD maintains a separate panel where consumers are asked to indicate their concerns about health issues. Households respond to the statement that “a person should be concerned about cholesterol and fat” by using a five point scale of degree of concern. A health index was created from these data and incorporated into the meat eatings database. Finally, promotion expenditures on several of the meat types were included in the data set.

## Model Specification

Various empirical demand systems, with alternative specifications and functional forms implied for the utility function, have appeared in the literature since Richard Stone (1954) first estimated a system of demand equations explicitly derived from consumer theory. Among the different expenditure allocation models, the Almost Ideal Demand System (AIDS) model has probably been the most widely used and is adopted for the current analysis. The AIDS model is a functional form that is flexible and consistent with demand theory.

The AIDS for a particular household h in share form is given by :

$$(1) \qquad w_{ih} = \alpha_i + \sum_{j=1}^{n} \delta_{ij} \ln(p_{jh}) + \beta_i \ln(m_h / P_h)$$

In equation (1) $w_{ih}$ is the average budget share for the $i^{th}$ commodity in the $h^{th}$ household, $p_{jh}$ is the price of the $j^{th}$ commodity for the $h^{th}$ household, and $m_h$ is the total meat expenditure by the $h^{th}$ household. $P_h$ is a price index defined by:

$$(2) \qquad \ln(P_h) = \alpha_0 + \sum_{k=1}^{n} \alpha_k \ln(p_{kh}) + 1/2 \sum_{k=1}^{n} \sum_{j=1}^{n} \delta_{kj} \ln(p_{kh}) \ln(p_{jh})$$

The AIDS model possesses most of the properties of conventional demand analysis such as adding-up, homogeneity, and symmetry (3). Equation (1) is estimated after substituting (2) into (1).

$$(3) \qquad \sum_{i=1}^{n} \alpha_i = 1, \sum_{i=1}^{n} \delta_{ij} = 0, \sum_{i=1}^{n} \beta_i = 0; \sum_{j} \delta_{ij} = 0, \delta_{ij} = \delta_{ji}$$

Demographics, seasonality, promotion, and health concern variables are incorporated into the AIDS model. Scaling and translating techniques allow the incorporation of these variables into the direct utility function. The incorporation of demographic effects in demand systems dates from Barten (1964), Muellbauer (1977) and Pollak and Wales (1978, 1980, 1981). Pollak and Wales (1981) describe four different procedures for incorporating demographic variables into complete demand systems: demographic translating, demographic scaling, Gorman specification, and the modified Prais-Houthakker procedure. In all of these cases the demand systems describe the allocation of expenditure among a number of consumption categories. Each procedure replaces the original class of demand systems by a related class involving additional parameters and postulates that only these additional parameters depend on the demographic and other variables. Due to simplicity and flexibility reasons this study employs the use of demographic translating to incorporate the different demographic variables into the AIDS model. According to Pollak and Wales (1981), translating allows subsistence parameters of demand systems to depend on the demographic variables.

The Almost Ideal Demand System (AIDS) in share form including demographic, seasonality, health and promotional effects is given by:

(4) $$w_{ih} = \alpha_i + \sum_{r=1}^{3} \Theta_{irh} + \sum_{j=1}^{4} \delta_{ij} \ln(p_{jh}) + \beta_i \ln(m_h / P_h)$$

The price index, $P_h$ is now defined where $1_{ith}$ includes the demographic, seasonality, promotional and health effects:

(5) $$\ln P_h = \alpha_0 + \sum_{k=1}^{4} \left( \alpha_k + \sum_{r=1}^{3} \Theta_{irkh} \right) \ln(p_{kh}) + \frac{1}{2} \sum_{k=1}^{4} \sum_{j=1}^{4} \delta_{kj} \ln(p_{kh}) \ln(p_{jh})$$

The demographic effects including income level, household size, age of female, age and presence of children in the household, female employment level, female education level, census region, market size and seasonality can be expressed as:

(6) $$\begin{aligned} \Theta_{i1h} = {} & \lambda_{i1}(INC_1 - INC_4) + \lambda_{i2}(INC_2 - INC_4) + \lambda_{i3}(INC_3 - INC_4) \\ & + \lambda_{i4}(HSZ_1 - HSZ_4) + \lambda_{i5}(HSZ_2 - HSZ_4) + \lambda_{i6}(HSZ_3 - HSZ_4) \\ & + \lambda_{i7}(AGF_1 - AGF_3) + \lambda_{i8}(AGF_2 - AGF_3) + \lambda_{i9}(CHD_1 - CHD_2) \\ & + \lambda_{i10}(EMF_1 - EMF_3) + \lambda_{i11}(EMF_2 - EMF_3) + \lambda_{i12}(EDF_1 - EDF_3) \\ & + \lambda_{i13}(EDF_2 - EDF_3) + \lambda_{i14}(STA_1 - STA_4) + \lambda_{i15}(STA_2 - STA_4) \\ & + \lambda_{i16}(STA_3 - STA_4) + \lambda_{i17}(MSA_1 - MSA_3) + \lambda_{i18}(MSA_2 - MSA_3) \\ & + \lambda_{i19}(QTR_1 - QTR_4) + \lambda_{i20}(QTR_2 - QTR_4) + \lambda_{i21}(QTR_3 - QTR_4) \end{aligned}$$

where each of the demographic variables is compared to an average household. The different coefficient estimates measure the deviation for each demographic from an average household. Each demographic or similar variable is binary (see Table 1) and is represented by usually two or three dummy variables. When using the dummies the sum of the parameters for a particular variable is set to zero. With this standard method, all coefficients are then expressed relative to the average household over the four seasons.

The health effects can be expressed by the cholesterol concern expressed by the households where PRCHL represents the percentage of households that completely or moderately agree with cholesterol concern:

(7) $$\Theta_{i2h} = \varepsilon_i PRCHL$$

Promotional and advertising effects are introduced as shown in equation (8). Square roots of the promotion and leading national advertisers variables are used in the assumption that these impacts increase at a decreasing rate with PROM representing quarterly expenditures on beef promotions, LNA#PK advertising expenditures in pork, LNA#PL advertising expenditures in chicken and LNA#TK advertising expenditures in turkey. This specification is preliminary and can be adjusted according to other functional forms:

(8) $$\Theta_{i3h} = \gamma_{i1} PROM^{.5} + \gamma_{i2}(LNA\#PK)^{.5} + \gamma_{i3}(LNA\#PL + LNA\#TK)^{.5}$$

## Econometrics Estimates

Equation (4) estimates for beef, poultry, and pork are reported in Table 2. Estimates for fish are not reported since they are predetermined from the adding up, homogeneity and symmetry conditions (equation 3). For convenience, the t-values instead of the standard errors are reported. At the bottom of the table, the number of observations used in the final estimation is 30,611 and the likelihood value is shown. The panel data used in this study consists of time series observations on each of several cross section units. Pooling cross sectional and time series data in the model should not present a problem given that household differences are captured with demographics and seasonality. Also, the number of time units changes across households since every household does not consistently reports each period.

Using the R-square as a quasi-measure of goodness-of-fit, this statistic shows the amount of variation explained to be approximately four, seven and five percent for the beef, poultry and pork expenditure equations respectively. While a higher goodness-of-fit would be preferred, these low values are typical when using large pooled data sets. The majority of the *'s are significant, indicating relationships between budget shares and prices. In all cases, unit percentage increases in own prices yield percentage increases in budget shares, while unit percentage increases in cross prices yield percentage decreases in budget shares. Comparing the own price effects with the significant cross price effects, they are quite similar in magnitude. All the cross price effects are significant, except the ones between beef and pork and between beef and fish.

With respect to the impact of the different demographic variables on the budget shares, the empirical results, with some exceptions, conform to a priori expectations and the majority of the demographic coefficients are statistically significant. Incorporation of the demographic effects into the AIDS model was estimated according to equation (6). As noted earlier, for each of the different demographics the sum of the coefficients was set to zero. Looking for example at the income effect on beef budget shares, the effect of households with an income less than $25,000 a year is above that for a household with an average income level. Households with an income level between $25,000 and $50,000 a year is close to that of the average household and not significant. Other demographics are discussed later.

**Price Elasticities**

Compensated own price and cross price elasticities and expenditure elasticities of demand are presented in Table 3. Expenditure elasticities measure the change in the demand for the four different meat products as the allocation of the household expenditures among these meat products change. All expenditure elasticities are calculated at the mean values. While each elasticity will change when moving away from the mean prices and the average household, interestingly poultry loses relative to the other meats when the total meat expenditures increase. Fish shows the largest relative gain (or loss if expenditures decline).

All own-price elasticities reported are negative varying from -.49 for fish to -.65 for pork. Net of expenditure effects, pork is more sensitive to own price changes in comparison to any of the other three meat products. Using the cross price elasticities, there is little substitutability between fish and the other three meat products, while beef shows the highest degrees of substitutability with the other products. The effect of an increase in the price of beef on the quantity of pork purchased by the household is about three times higher than the effect of an increase in the price of poultry (i.e., comparing $e_{31}$=.411 to $e_{32}$=.143). The degree of substitutability of beef on fish ($e_{41}$=.393) in comparison with fish on beef ($e_{14}$=.083) is about 4.5 times higher.

**Ranking Demand Shifters**

Table 1 set forth major demographic and other variables expected to impact the demand for the four meat types while Table 2 provided the estimated coefficients for these variables. Using equation 6 each demographic was represented with a number of binary variables using the restriction that the sum of the coefficients for each demographic equal zero. This procedure is useful in that the impact from changing any combination of demographics can be expressed relative to the average consumer. For example, suppose the quantity demand for beef ($q_1$) if derived from the AIDS model, then for the average consumer let the quantity be $q^0$. Consider any particular demographic variable over the range from the lowest to highest value, the new quantity is express as $q^j$ where j=1,2,.. depending on the number of binary variables needed to reflect a specific demographic factor. Each $q^j$ is expressed relative to $q^0$ or $R^1=( q^j / q^0 )$. For example, let R=.95, then for the lowest value of the demographic, demand is five percent less than that of the average household. These R values are comparable within a particular demographic as well as across demographics since in every case they are relative to the same base, the average household. Finally, for a demographic variable it is useful to show the range of impact from the lowest to highest values of the demographic where $?_1=R^3-R^1$ assuming three discrete variables for a particular demographic factor. These ranges are then subsequently ranked across the demographics from those having the most negative effects to those with the most positive impact on each meat type. Figures 1a-1d provide these rankings across nine demand shifts and for each meat type.

While some of these results are preliminary they do provide insight into the relative importance of the major exogenous variables included in the AIDS model. Space does not permit discussing each variable so only a couple of the more interesting ones are considered. Education of the female head of the household ranged from high school (lowest range) to post graduate (highest range). In Figures 1a and 1c, education is shown to have the largest negative impact on both beef and pork demand where for beef the range is -.15. That is, after indexing to the average household there is a 15 percent spread between the impact of education on beef demand with the demand declining with increasing education levels. For pork this spread is almost -.20. Comparing these ranges to poultry and fish, the results are just the opposite with both showing a range above +.20. Clearly the most pronounced shift from beef and pork to poultry and fish is attributed to educational differences.

A result somewhat contrary to expectations is seen with the female employment status. One argument often suggested is that with an increase employment there is a greater demand for convenience. Hence the expectation is that the demand for less convenient products should decline as employment increases. Figures 1a and 1c show both beef and pork to increase with the employment status and poultry to decline while the effects on fish are close to zero. The beef results in particularly are contrary to what has been seen in another study by Ward using a different panel data set. Household size provides another interesting result in that both beef and poultry demand increases with larger households while pork and fish demand declines. Given the preliminary nature of the AIDS estimates we emphasize that the conclusions suggested with Figures 1a-1d could change as the model is refined.

While each results could be discussed in detail, the most important consideration to take from Figures 1a-1d is that the demographics and other factors can be put into perspective to show what is really driving the demand for each meat product and the direction of change. It provides a ready tool for predicting change and to identify where markets should be targets if an industry wants to address negative effects. For example, the beef industry should possibly target higher educated households if they want to reduce the negative effect from higher education.

**Implications and Conclusion**

Considerable advances have been made in both the collection of data about consumer purchasing and the ability to quantify the demand. In this paper, a large data set detailing the purchasing of meat products has been used for estimating the demand for beef, poultry, pork, and fish. AIDS models were estimated and used to calculate price and expenditure elasticities and the effects of fundamental differences in the households.

Uses of demand analysis range from evaluation to forecasting with both being important. Models such as shown here are particularly useful for sorting out what really causes the demand for products to differ both over time and across commodities. Having a precise empirical measure of what is driving consumers purchasing decisions is fundamental to make long term risk management decisions. As shown in the last section, the impacts can be expressed by ranking the demand drivers. Space limited a full discussion, yet it is clear that demographics such as education are particularly important. Such comparisons point to household profiles that can be targeted when particularly strong negative effects are seen. While industries cannot change demographics, they may influence purchasing behavior among these variables.

At this point, we emphasize that the results are preliminary since there is a full range of alternative estimates that must be explored. One of particular interest is to estimate separate models across incomes instead of including the binary income variables in the model as used in these estimates. This would be less restrictive allowing of the constraining expenditure levels inheritant in the AIDS model to change with higher income levels. These alternatives are being currently explored.

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Table 1. Variable definitions for NPD household meat consumption data.

| Type of variable | Variable | Range | Number of household (percentage) |
|---|---|---|---|
| Demographics: income (dollars) | $INC_1$ | 0 to $24,999 | 2500 (33.25%) |
| | $INC_2$ | $25,000 to $49,999 | 2713 (36.08%) |
| | $INC_3$ | $50,000 to $74,999 | 1376 (18.30%) |
| | $INC_4$ | over $75,000 | 931 (12.38%) |
| Demographics: household size(number of people) | $HSZ_1$ | 1 | 1072 (14.26%) |
| | $HSZ_2$ | 2 | 2210 (29.39%) |
| | $HSZ_3$ | 3 | 1482 (19.71%) |
| | $HSZ_4$ | 4 plus | 2756 (36.65%) |
| Demographics: age of female (years) | $AGF_1$ | 29 and under | 1318 (19.27%) |
| | $AGF_2$ | 30 to 49 | 3788 (55.39%) |
| | $AGF_3$ | over 50 | 1733 (25.34%) |
| Demographics: age and presence of children (years) | $CHD_1$ | presence of children under 18 | 3740 (49.73%) |
| | $CHD_2$ | no children under 18 | 3780 (50.27%) |
| Demographics: female employment level (hours) | $EMF_1$ | unemployed | 2771 (40.52%) |
| | $EMF_2$ | 0 to 30 | 908 (13.28%) |
| | $EMF_3$ | over 30 | 3160 (46.21%) |
| Demographics: female education level | $EDF_1$ | high school | 2924 (42.75%) |
| | $EDF_2$ | college | 3359 (49.12%) |
| | $EDF_3$ | post college graduate | 556 (8.13%) |
| Demographics: census region | $STA_1$ | east | 1459 (19.40%) |
| | $STA_2$ | central | 1780 (23.67%) |
| | $STA_3$ | south | 2711 (36.05%) |
| | $STA_4$ | west | 1570 (20.88%) |
| Demographics: market size(number of people) | $MSA_1$ | 0 to 49,999 | 1650 (21.94%) |
| | $MSA_2$ | 50,000 to 249,999 | 698 (9.28%) |
| | $MSA_3$ | over 250,000 | 5172 (68.78%) |
| Seasonality (quarters) | $QTR_1$ | January-March | 1927 (25.62%) |
| | $QTR_2$ | April-June | 1959 (26.05%) |
| | $QTR_3$ | July-September | 1606 (21.36%) |
| | $QTR_4$ | October-December | 2028 (26.97%) |

Table 4. Preliminary AIDS estimates for meat products (not using Stone's index approximation)

| | **Beef** | | **Poultry** | | **Pork** | |
|---|---|---|---|---|---|---|
| | Coefficient Estimates | Coefficients t-values* | Coefficient Estimates | Coefficients t-values* | Coefficient Estimates | Coefficients t-values* |
| "$_{i}$ | .377993 | 6.62830 | .684945 | 12.9615 | .144697 | 3.12062 |
| 8$_{i1}$ | .017242 | 5.71336 | -.012795 | -4.48602 | .00681395 | 2.81857 |
| 8$_{i2}$ | -.00222175 | -.860131 | .00529702 | 2.16531 | -.000583620 | -.282045 |
| 8$_{i3}$ | .00522427 | 1.70954 | -.00502138 | -1.73609 | .000986696 | .402986 |
| 8$_{i4}$ | -.017565 | -3.93008 | .00452511 | 1.06755 | -.00262710 | -.733791 |
| 8$_{i5}$ | -.00266466 | -.885448 | -.010010 | -3.50539 | .00931117 | 3.86275 |
| 8$_{i6}$ | .00986490 | 3.12189 | -.00448598 | -1.49661 | .00257657 | 1.01770 |
| 8$_{i7}$ | .015270 | 4.23934 | .000830402 | .244246 | -.027019 | -9.35463 |
| 8$_{i8}$ | -.000419772 | -.162320 | .00601141 | 2.45604 | -.000946475 | -.456507 |
| 8$_{i9}$ | -.00930626 | -3.39015 | .00140142 | .538689 | .000045457 | .020664 |
| 8$_{i10}$ | -.00649369 | -2.75436 | .014309 | 6.39956 | -.00701161 | -3.71131 |
| 8$_{i11}$ | -.000606484 | -.198308 | .00208163 | .717968 | -.00110250 | -.449943 |
| 8$_{i12}$ | .030368 | 10.8335 | -.039266 | -14.7591 | .020386 | 9.08044 |
| 8$_{i13}$ | -.000517173 | -.196131 | .00358032 | 1.43111 | -.00224004 | -1.06081 |
| 8$_{i14}$ | -.033374 | -11.7853 | .027764 | 10.3474 | -.00627657 | -2.76679 |
| 8$_{i15}$ | .00325567 | 1.19078 | -.020194 | -7.80015 | .033225 | 15.1657 |
| 8$_{i16}$ | .00848009 | 3.47422 | -.00096270 | -.415848 | -.00703262 | -3.59543 |
| 8$_{i17}$ | .010266 | 3.60132 | -.00408628 | -1.51163 | .00741975 | 3.24718 |
| 8$_{i18}$ | .00784488 | 2.15853 | -.014479 | -4.20127 | .00587231 | 2.01606 |
| 8$_{i23}$ | -.000179688 | -.055294 | -.011221 | -3.63943 | -.00751614 | -2.88599 |
| 8$_{i24}$ | .014730 | 5.01050 | -.016731 | -6.00627 | .00321842 | 1.36616 |
| 8$_{i25}$ | .028798 | 9.38243 | -.012139 | -4.17506 | -.013757 | -5.59048 |
| ,$_{i1}$ | -.120543 | -2.57730 | -.00222224 | -.050124 | .167878 | 4.48707 |
| ($_{i1}$ | .00235060 | .439423 | -.00610485 | -1.20311 | .00192166 | .448345 |
| ($_{i2}$ | .0000714414 | .307598 | -.000131007 | -.594446 | .000059619 | .320426 |
| ($_{i3}$ | .000715979 | 3.79565 | -.000231665 | -1.29506 | -.000461675 | -3.05612 |
| *$_{i1}$ | .019470 | 4.15083 | -.020190 | -6.85722 | .00214173 | .673981 |
| *$_{i2}$ | -.020190 | -6.85722 | .039193 | 11.6187 | -.028938 | -11.7673 |
| $d_{i3}$ | .00214173 | .673981 | -.028938 | -11.7673 | .027519 | 7.27438 |
| $d_{i4}$ | -.00594382 | -1.21303 | -.016518 | -3.63576 | -.016085 | -4.07688 |
| ß$_{i}$ | .010406 | 6.35532 | -.047910 | -31.6116 | .015786 | 12.0260 |

Number of observations = 30611 Log likelihood = 16818.1 *Table t at 5% =1.96
R-Sq (equation 1)=.035634 R-Sq (equation 2)=.069407 R-Sq (equation 3)=.046091

Table 3. Preliminary Expenditure and Compensated price Elasticities for the AIDS model.

| Meat Products | Expenditure Elasticities | Compensated Elasticities | | | |
|---|---|---|---|---|---|
| | | Beef (1) | Poultry (2) | Pork (3) | Fish (4) |
| Beef | 1.02611 | -.55153 | .23663 | .22024 | .083318 |
| Poultry | .83589 | .32279 | -.54459 | .10188 | .029313 |
| Pork | 1.07413 | .41161 | .14285 | -.65241 | .025816 |
| Fish | 1.22497 | .39291 | .35479 | .22188 | -.48958 |

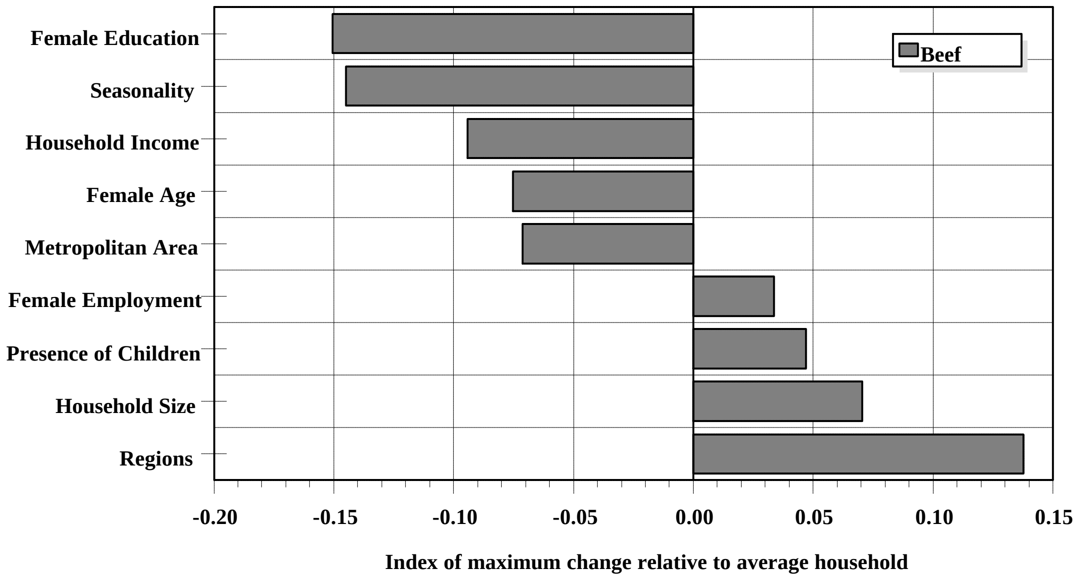


Figure 1a. Ranking of the exogenous variables on meat demand using the AIDS model.

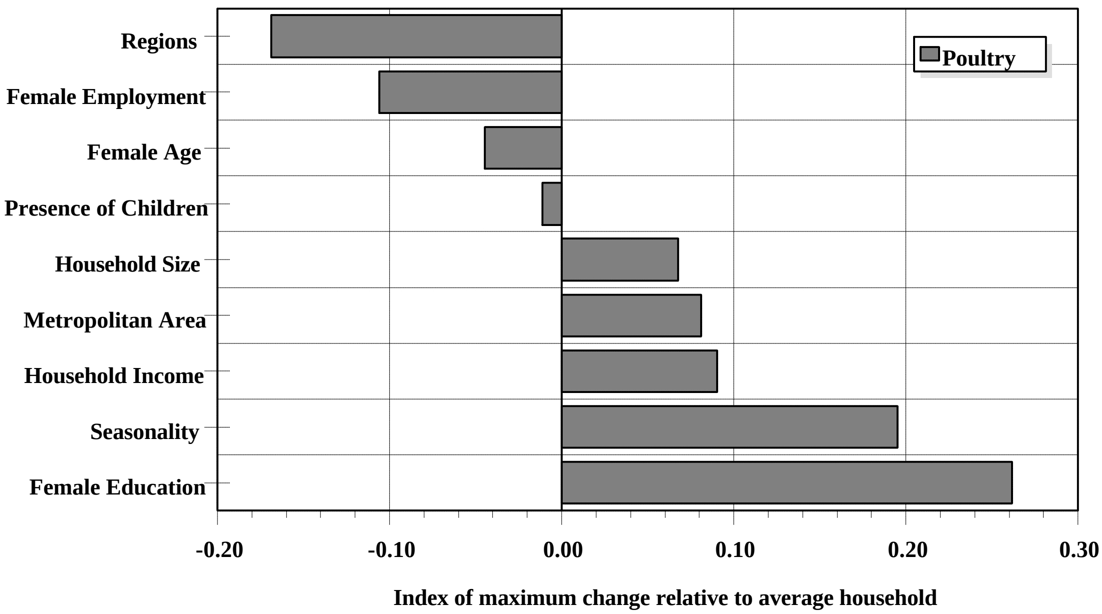


Figure 1b. Ranking of the exogenous variables on meat demand using the AIDS model.

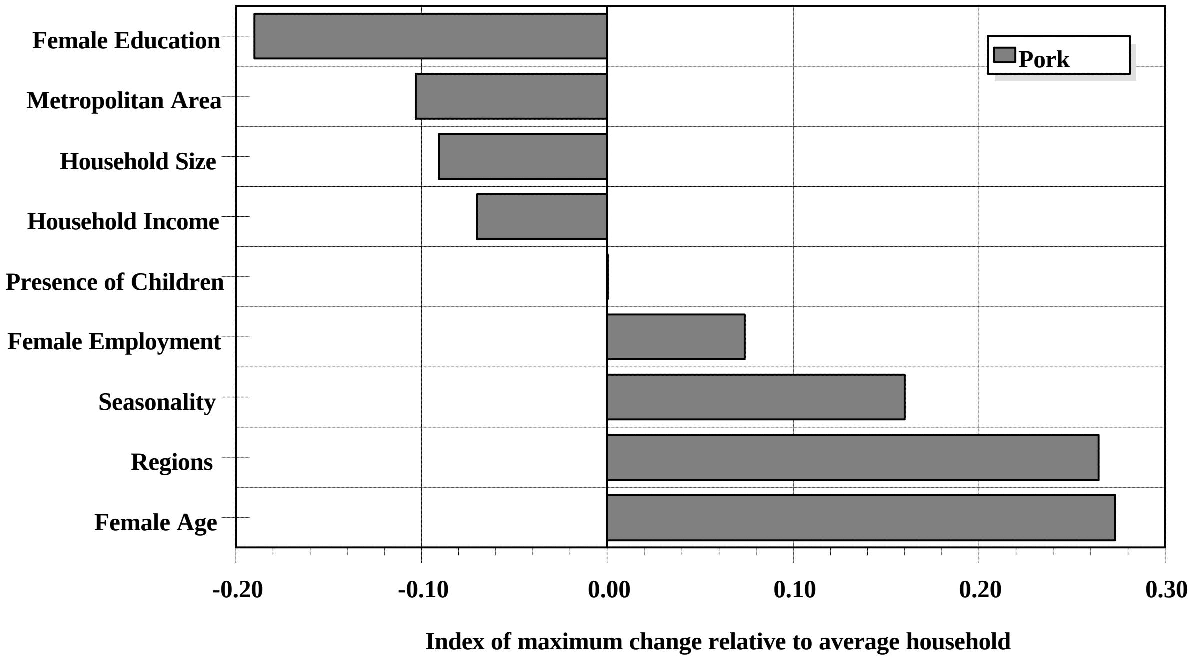


Figure 1c. Ranking of the exogenous variables on meat demand using the AIDS model.

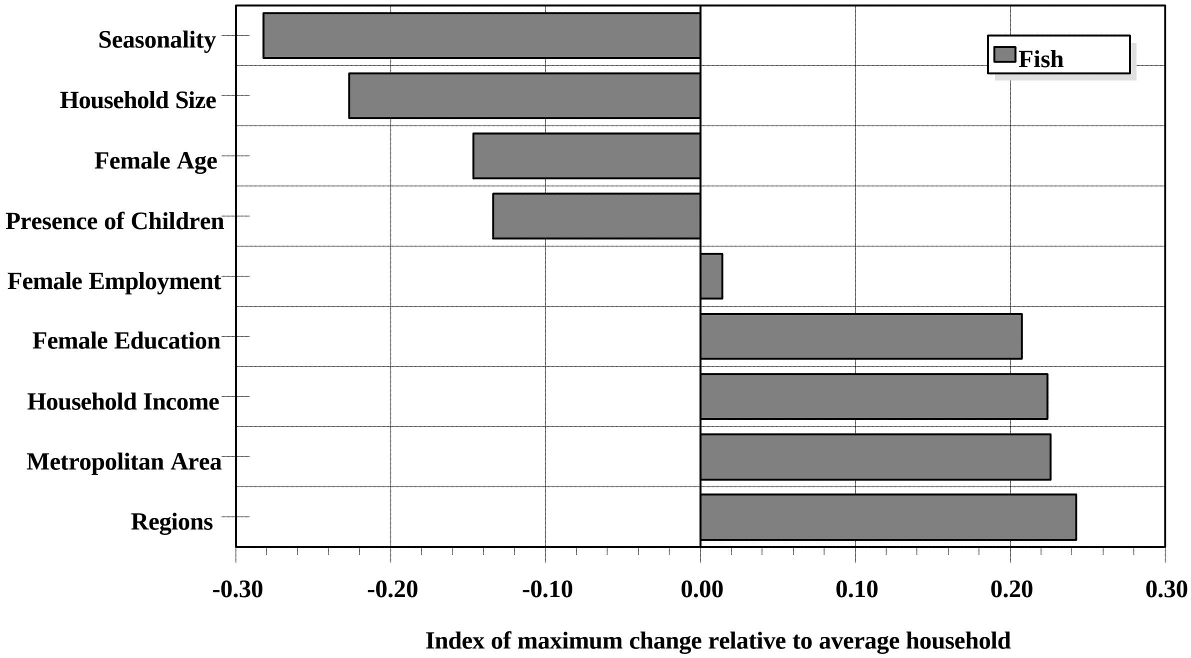


Figure 1d. Ranking of the exogenous variables on meat demand using the AIDS model.