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Measuring the Impact of Nutritional Awareness on the Demand for Meat Products

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ABSTRACT

This paper extends recent studies of the impact of nutritional information on food demand. A distributed lag of the Brown and Schrader index as well as a broader measure of nutritional information is used within an AIDS model for meats. Both measures show a significant impact on meat demand.

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Measuring the Impact of Nutritional Awareness on the Demand for Meat Products

The study of the role of nutritional information in food demand has become an important area for agricultural economists in recent years. To capture nutritional information in an investigation of factors affecting egg consumption, Brown and Schrader developed an index of cholesterol information over time. Chang and Kinnucan have employed this index in a study of fat and oil consumption in Canada. Capps and Schmitz also utilize this index for meats in the United States using a Rotterdam model.

The purpose of this paper is to estimate the impact of nutritional information on meat items. This paper looks at an alternative specification for the Brown and Schrader (B-S) index. Namely, this information is included within a polynomial distributed lag framework. This framework allows for a more flexible specification of how the nutritional information may impact the demand for these meat items. This method differs notably from the studies above in that the other studies assume an accumulation of knowledge without any decay of that knowledge. It further differs from the work of Capps and Schmitz in that quarterly data are used instead of annual data and that a dynamic AIDS model is used as opposed to a Rotterdam model.

The B-S index is based on information about cholesterol. This index has performed well in the cases reported above. However, the use of this index may not be appropriate as a "global" measure of nutritional information. Many alternative indices could be developed. An alternative index is developed here based on a review conducted by Cronin and Shaw. This Cronin-Shaw (C-S) index is much less elaborate than the B-S index, but looks at a global measure of nutritional awareness over time. This alternative index is used in conjunction with the B-S index.

Model Development

The framework used by Capps and Schmitz provides a beginning for this paper. This framework is based on the work of Basmann in the area of variable preferences. This framework is consistent with the use of nutritional information in a complete demand system. A functional form, however, is not specified by this framework.

Nutritional awareness is akin to advertising in that both provide information about products for consumers. They primarily differ in that advertising normally emphasizes a message of technical or sensual characteristics while nutritional awareness emphasizes a message of how the consumption of the items may affect health. Due to the similarities between advertising and nutritional awareness, it seems appropriate to include the nutritional awareness information in demand systems using the same basic techniques as those which have been used successfully in studying the impacts of advertising on demand. Specifically, the use of distributed lag models may prove to be very helpful in explaining the role of nutritional information on food demand.

In their study of the effects of an Alar scare in apples, van Ravenswaay and Hoehn suggest four possible ways in which Alar can affect the demand for apples. In particular, they offer the hypothesize that "a change in the safety of a product does affect consumers' purchases, but the information is eventually forgotten", (p. 10). This hypothesis gives rise to the use of a distributed lag model. Due to the similarity between information and advertising, and the success of distributed lags in advertising research, such a hypothesis seems plausible.

Baye, Jansen and Lee included a geometric lag structure for advertising within an AIDS model. The geometric lag structure allows for a large initial response with geometrically declining response thereafter. Although this structure may be appropriate in the study of nutrition and food demand, one would not want to limit the response to such a geometric shape. Alternatively, one could use the polynomial distributed lag (PDL) structure developed by Almon. The PDL specification is capable of producing a geometric lag shape as well as other more flexible shapes. This specification allows a gradual response to the information followed by a gradual decline. The presence of this shape can be tested as well as forced or enhanced through the use of head or tail restrictions. The PDL structure is preferred here since it can allow a geometric shape as well as other shapes. The use of a PDL requires the analyst to a priori specify the length of lag and degree of polynomial.

Another alternative, also put forth by van Ravenswaay and Hoehn, is that "the consumers perception of the importance of such information may increase with subsequent announcements", (p. 10). This hypothesis gives rise to the use of a running total or cumulative sum of information. This hypothesis is consistent with the B-S index as used by Brown and Schrader, Capps and Schmitz, and Chang and Kinnucan. This hypothesis is used to model the C-S index in this study.

The polynomial distributed lag (PDL) model involves the use of current and lagged values of at least one of the exogenous variables. The weights associated with the structural coefficients are assumed to follow a polynomial shape of a given degree. The resulting structural model is not estimated directly. Rather, a reduced-form for this relationship is estimated. The structural coefficients depend on both the length of lag of the particular exogenous variable and the degree of polynomial used.

The linearized, dynamic PDL/AIDS model used in study can be expressed as

$$w_{it} = \left(\alpha_i^* + \zeta_i w_{i,t-1} + \sum_{k=1}^{3} \tau_{ik} S_{kt} + \sum_{d=0}^{D} \delta_{id} R_{dt} + \nu_i C_t\right) + \sum_{j=1}^{N} \gamma_{ij} \ln P_{jt} + \beta_i \ln\left(\frac{X}{P^*}\right)_t + \varepsilon_{it}, \tag{1}$$

where w_i is the budget share for good i ($w_i = P_i Q_i / X$), P_j is the price of good j, N is the number of goods in the model, X is the total expenditure on these N goods, and

$$\ln P_t^* = \sum_{j=1}^{N} w_{j,t-1} \ln P_{jt} \tag{2}$$

Stone's Approximation is used in (2) to linearize the AIDS model. Lagged budget shares are also used in (2) to avoid simultaneity between this approximation and the dependent variable.

The intercept term is augmented to include seasonality (S), the cumulative index developed from the work of Cronin and Shaw (C), the PDL structure (R), and dynamics (w_{t-1}). Seasonality is included in the model by use of intercept shifters for the second, third, and fourth quarters.

The R_{dt} variables represent the linear relationships derived for the PDL model. These variables are calculated by

$$\begin{aligned} R_{0t} &= r_t + r_{t-1} + r_{t-2} + \dots + r_{t-L}\text{, and} \\ R_{dt} &= r_{t-1} + 2^d r_{t-2} + 3^d r_{t-3} + \dots + L^d r_{t-L} \;\forall\; d=[1\dots D] \end{aligned} \tag{3}$$

where L is the length of lag, D is the degree of polynomial desired, and r_t is the B-S index in period t. The structural coefficients can be retrieved from the estimated δs estimated in the reduced-form model above. These coefficients are retrieved by

$$\omega_{im} = \delta_{0i} + \delta_{1i}m + \delta_{2i}m^2 + \ldots + \delta_{Di}m^D \tag{4}$$

To maintain the integrability conditions necessary to guarantee the existence of an underlying utility function, it is necessary to impose the classical restrictions on the demand system. Homogeneity requires that

$$\sum_{j=1}^{N} \gamma_{ij} = 0, \quad \forall\, i = [1 \ldots N], \tag{5}$$

while Slutsky symmetry requires that

$$\gamma_{ij} = \gamma_{ji}, \quad \forall\, i,j \; ; \; (i \neq j). \tag{6}$$

In the static model, the presence of adding up requires that one equation be dropped from the system. This deletion is done to avoid a singular variance-covariance matrix. In the dynamic case, the inclusion of the lagged budget share avoids the singular variance-covariance matrix. In this case, all N equations are estimated. In addition to the homogeneity and Slutsky symmetry conditions above, adding up requires that

$$\sum_{i=1}^{N} \gamma_{ij}=0, \quad \sum_{i=1}^{N} \beta_i=0, \quad \sum_{i=1}^{N} \left(\alpha_i^* + \zeta_i O_i\right) = 1 \;, \tag{7}$$

where O_i represents all variables in the model except prices and expenditure. These restrictions can be simplified. The combination of homogeneity and Slutsky symmetry guarantee that the γs will sum to zero, and the complete demand system structure will automatically require that all the remaining coefficients will sum to one. Thus, the only remaining requirement for the adding up restriction is that the βs must sum to zero.

Two additional restrictions known as head and tail restrictions are often used with a PDL. A head restriction constrains the information (r) included in the PDL to have no impact in the time period before its release. Thus a change in r cannot be anticipated. A tail restriction constrains this information to have no impact after L periods have passed. Either, both or neither of these restrictions may be used as needed for the particular modeling application. The head restriction requires that

$$\omega_{-1i} \equiv \sum_{d=0}^{D} (-1)^d \delta_{di} = 0, \tag{8}$$

while the tail restriction requires

$$\omega_{L+1,i} \equiv \sum_{d=0}^{D} (L+1)^d \delta_{di} = 0. \tag{9}$$

The elasticity formulas for the PDL/AIDS model remain unchanged from the formulas for the AIDS family (Green and Alston). In this case, the linear approximation with lagged budget shares is used to estimate the AIDS model. The elasticity formulas for this specification are given by

$$\begin{aligned} \epsilon_{ij} &= -\ddot{\delta}_{ij} + \frac{\gamma_{ij} - \beta_i w_j}{w_i}, \\ \epsilon_{ij}^* &= \epsilon_{ij} + w_j \eta_i, \textit{ and} \\ \eta_i &= 1 + \frac{\beta_i}{w_i}, \end{aligned} \tag{10}$$

for the uncompensated, compensated, and expenditure elasticities, respectively. The coefficient $\ddot{\delta}_{ij}$ represents the Kronecker delta (equals 1 if i equals j and 0 otherwise). An approximation to the variance for these elasticities may also be calculated (Chalfant). The variance for these elasticities are calculated by

$$\begin{aligned} VAR(\epsilon_{ij}) &= \frac{1}{w_i^2} VAR(\gamma_{ij}) + \frac{w_j^2}{w_i^2} VAR(\beta_i) - \frac{2w_j}{w_i^2} COV(\gamma_{ij}, \beta_i), \\ VAR(\epsilon_{ij}^*) &= \frac{1}{w_i^2} VAR(\gamma_{ij}), \textit{ and} \\ VAR(\eta_i) &= \frac{1}{w_i^2} VAR(\beta_i). \end{aligned} \tag{11}$$

These values represent only approximations to the true variances. Thus only an asymptotic t-value may be calculated.

Elasticity calculations can also be derived for the nutritional information included in the model. Prices and expenditure are exogenous variables in the AIDS model. The dependent variable in the AIDS model is budget share, not quantity. Thus it is necessary to multiply the coefficient by (X/P_i) to obtain the partial of quantity. Recognizing this relationship, the elasticity formula is then readily obtained by

$$\frac{\partial Q_i}{\partial C}\frac{\bar{C}}{\bar{Q}_i} = \frac{\nu_i \bar{X}}{\bar{P}_i}\frac{\bar{C}}{\bar{Q}_i} = \frac{\nu_i \bar{C}}{\bar{w}_i} \tag{12}$$

The PDL model provides more alternatives for elasticity measures. Because of the dynamic structure of the PDL, one may talk about short-run, interim, cumulative, and long-run measures of elasticities. Each of these formulas have a similar nature to the formula derived above. These formulas are however based on the structural coefficients calculated in (4). These formula are given by

$$\begin{aligned} SR &= \omega_{0i}\frac{\bar{r}}{\bar{w}_i} & INT_k &= \omega_{ki}\frac{\bar{r}}{\bar{w}_i} \\ CUM_K &= \sum_{l=0}^{K}\omega_{li}\frac{\bar{r}}{\bar{w}_i} & LR &= \sum_{l=0}^{L}\omega_{li}\frac{\bar{r}}{\bar{w}_i} \end{aligned} \tag{13}$$

Data

This model is estimated for four meat items. These items include beef, fish, poultry, and pork. Data for these items are taken from various Department of Agriculture and Department of Commerce sources. Quarterly data are used for the years from 1968 through 1988. Quarterly fish consumption data are not directly available. Thus, monthly disappearance data are generated from various Department of Commerce data sources. These data are then used to weight the annual consumption data which are available from the Department of Agriculture (see Schmitz for more detail).

These price data are in index form. Thus representative prices are needed to generate the expenditure variable as well as the budget shares. Representative prices for beef, pork and poultry are also obtained from the Department of Agriculture. However, relevant fish prices are not available. A value of $4.00 per pound is used for fish.

This study includes two measures of nutritional information. The first is the index by Brown and Schrader. The data for this index is published with their work. Data for the period beyond their published data have been obtained from these authors as well. Brown and Schrader use a cumulative sum of the articles with a two quarter lag. In adapting their index to the PDL specification in this paper, the number of articles published in the given period is used in lieu of the cumulative number of articles they used. Furthermore, since the lag structure is built in to the PDL, the two period lag discussed by Brown and Schrader is also removed.

An alternative measure of nutritional awareness is developed here as well. The B-S index considers cholesterol information. This constraint may potentially be a limitation in this empirical analysis. Thus a more "global" measure is needed. Cronin and Shaw review ten major articles in the development of the link between nutrition and health. An index is developed which cumulatively counts the release of these ten articles. Thus the article counts from 0 to 10 over this period, with the first release in 1977. Before 1977, this index remains at zero, but increases to 1 in 1977. Later publications result in an increase to 3 in 1979, 5 in 1980, 6 in 1982, 7 in 1984, 8 in 1985, and final 10 in 1988. Descriptive statistics for the remaining variables are given in Table 1. The average quarterly *per capita* expenditure on meat products over this period is $88.56. Mean prices are highest for beef and fish with fish being much more variable. The poultry price is the lowest and least variable of the meat groups. Beef enjoys the largest mean consumption level while fish has the smallest level of consumption. The consumption levels of poultry and fish are, however, much more variable than consumption of beef and pork. Poultry products have shown substantial increases in consumption relative to other meats since the mid-1970s.

Results

Coefficient estimates and summary statistics for this model appear in Table 2. In the polynomial distributed lag model, a lag length of 6 periods with a second degree polynomial is used and remains the same across equations. R-squares range between 0.84 for pork and 0.93 for both beef and poultry. The Durbin h statistic indicates a serial correlation problem in poultry, however the runs test does not indicate such a problem. Thus no correction for serial correlation is employed.

All of the own-price coefficients are statistically significant as well as most of the cross-price coefficients ($\alpha = 0.10$). The lagged budget shares range from 0.25 to 0.30 and are significant for each equation. The expenditure term is also significant for each equation except fish. Seasonality plays a significant role in explaining the demand for each of these items based on results from the F-tests. In pairwise comparisons, each meat shows significant deviation from its first quarter consumption in every quarter. Beef consumption is highest in the first quarter while poultry consumption is lowest in this quarter. Fish and pork consumption is highest and lowest, respectively, in the third quarter.

The focus of this study is on the nutritional variables. A F-test performed on these variables indicate that both of these measures are statistically significant. Thus, both of these measures are important. Furthermore, the F-tests indicate that these two variables combined have significant impacts on each item in the model. F-tests have also been performed to determine the applicability of head and tail restrictions. On the basis of these tests, we are unable to reject either of these restrictions. Thus head and tail restrictions have been imposed on this model.

Both the C-S index and the PDL indicate significant decreases in beef consumption which are offset by significant increases in poultry consumption. However these indices differ in

Table 1. Descriptive Statistics for Selected Meat Items

NAME	OBS.	MEAN	ST. DEV.	VAR.	MIN.	MAX.	C.V.
P_{beef}	84	216.64	67.87	4606.20	102.74	306.03	0.3128
P_{pork}	84	151.67	45.65	2083.80	76.02	223.93	0.3010
P_{poult}	84	93.06	22.23	494.15	55.74	134.67	0.2389
P_{fish}	84	215.39	98.74	9749.40	78.24	403.57	0.4584
Q_{beef}	84	20.91	1.62	2.61	17.60	25.10	0.0775
Q_{pork}	84	15.13	1.33	1.78	11.30	17.90	0.0879
Q_{poult}	84	14.54	2.86	8.17	9.70	21.60	0.1967
Q_{fish}	84	3.20	0.92	0.84	2.03	5.54	0.2875
EXPEND($)	84	88.65	27.82	773.95	40.66	140.49	0.3138

Table 2. Coefficients and Summary Statistics for the PDL/AIDS Model

	Beef	Fish	Poultry	Pork
Const	0.25415*	-0.05247	0.04598	0.46523*
	(0.06630)	(0.06114)	(0.04022)	(0.05633)
Beef	0.06212*	-0.02042*	-0.04586*	0.00416
	(0.01633)	(0.01162)	(0.00885)	(0.00957)
Fish	-0.02042*	0.04539*	-0.01079	-0.01418*
	(0.01162)	(0.01392)	(0.00776)	(0.00847)
Poultry	-0.04586*	-0.01079	0.08093*	-0.02428*
	(0.00885)	(0.00776)	(0.00988)	(0.00743)
Pork	0.00416	-0.01418*	-0.02428*	0.03430*
	(0.00957)	(0.00847)	(0.00743)	(0.01009)
Expend	0.01655*	0.01050	0.01209*	-0.03914*
	(0.00883)	(0.00857)	(0.00594)	(0.00663)
Q2	-0.01937*	0.02072*	0.01407*	-0.01551*
	(0.00335)	(0.00281)	(0.00227)	(0.00209)
Q3	-0.02835*	0.03469*	0.01173*	-0.01741*
	(0.00324)	(0.00331)	(0.00222)	(0.00243)
Q4	-0.02792*	-0.01328*	0.02844*	0.01413*
	(0.00311)	(0.00386)	(0.00209)	(0.00272)
L(w)	0.29200*	0.25169*	0.28479*	0.28229*
	(0.05767)	(0.06086)	(0.05674)	(0.06432)
PDL(0)	-0.00011*	0.00008*	0.00006*	-0.00002
	(0.00004)	(0.00003)	(0.00002)	(0.00003)
PDL(1)	-0.00009*	0.00007*	0.00005*	-0.00002
	(0.00004)	(0.00003)	(0.00002)	(0.00002)
PDL(2)	0.00002*	-0.00001*	-0.00001*	0.00000
	(0.00001)	(0.00000)	(0.00000)	(0.00000)
C-S	-0.00607*	-0.00038	0.00366*	0.00295*
	(0.00096)	(0.00084)	(0.00058)	(0.00071)
R-Square	0.9338	0.8979	0.9305	0.8421
RUNS	-0.8019	0.2410	-0.6148*	-1.7182
Durbin-h	1.7496	-1.2970	2.0307*	1.6628

respects to the other two items. The C-S index indicates a significant increase in pork consumption with an insignificant decreases in fish consumption. Alternatively, this B-S index shows a significant increase in fish consumption, but an insignificant decrease for pork.

Price, expenditure and income elasticities for this model are given in Table 3. The income elasticities are obtained by multiplying the expenditure elasticity by 0.67. This conversion factor is estimated by regressing *per capita* disposable income on *per capita* expenditures for meat items. Price elasticities with t-values greater than 2 are identified by (*). The variance for each of the income elasticities is obtained by assuming that the adjustment factor is constant. By doing so, the variance is the same as for the expenditure elasticity. Similar t tests are preformed for the income elasticity, however, this test uses 1 instead of 0. Income elasticities that have t-values greater than two are also identified by the (*).

All of the own-price elasticities in this model are negative, however, the elasticities for fish are not significant. Marshallian estimates for beef and pork are -0.9, poultry is -0.5, and fish is -0.4. Income elasticities range from 0.57 for pork to 0.77 for fish. All of these are significantly less than one. Thus all of these goods can be labeled as normal goods. The Hicksian cross-price elasticities are all positive, however the cross-price elasticities involving fish are not significant. Thus beef, pork and poultry are considered to be substitutes for each other while fish is considered to be independent.

Table 3. Price, Expenditure, and Income Elasticities for Meat Items

Elasticity	Beef	Fish	Poultry	Pork	Beef	Fish	Poultry	Pork
PRICES	(UnCompensated)				(Compensated)			
Beef	-0.89*	-0.04	-0.09*	-0.00	-0.37*	0.03	0.07*	0.27*
Fish	-0.34	-0.40	-0.17	-0.23	0.24	-0.32	0.01	0.07
Poultry	-0.34*	-0.08	-0.49*	-0.18*	0.21*	0.01	-0.32*	0.10*
Pork	0.09	-0.04	-0.07	-0.83*	0.53*	0.02	0.06*	-0.61*
EXPENDITURES	(Expenditure)				(Income)			
	1.03	1.14	1.08	0.85	0.69*	0.77*	0.72*	0.57*

Elasticities can also be generated for the nutritional information. The structural parameters for the PDL as well as the elasticity calculations for the two measures of nutritional information are presented in Table 4. The C-S index is entered in a static fashion thus no distinction is made between short-run and long-run. However, the PDL is dynamic in nature. Thus short-run, cumulative, and long-run elasticities are presented.

The C-S index has a small impact on the consumption of these items. Elasticities for this variable remain below 0.01 in absolute value. Despite the small magnitude of these elasticities, this variable does have significant impacts. The B-S index in the PDL formulation offers much larger impacts on these meat items. Fish is affected most by this information. A one percent increase in the B-S index results in a 0.5 percent increase in the short-run and a long-run increase of nearly 6 percent. This impact is exaggerated by the small budget share for fish products.

Table 4. Structural Coefficients, Short-run, Cumulative, and Long-run Elasticities for the PDL and Elasticities for the C-S Index

	Beef	Fish	Poultry	Pork
Structural Coefficients				
ω_0	-0.000111	0.000083	0.000055	-0.000022
ω_1	-0.000190	0.000142	0.000095	-0.000037
ω_2	-0.000237	0.000178	0.000118	-0.000046
ω_3	-0.000253	0.000189	0.000126	-0.000049
ω_4	-0.000237	0.000178	0.000118	-0.000046
ω_5	-0.000190	0.000142	0.000095	-0.000037
ω_6	-0.000111	0.000083	0.000055	-0.000022
Elasticities				
SR	-0.097	0.498	0.160	-0.037
C_1	-0.265	1.351	0.434	-0.101
C_2	-0.473	2.418	0.777	-0.181
C_3	-0.696	3.556	1.143	-0.267
C_4	-0.905	4.623	1.486	-0.347
C_5	-1.072	5.476	1.760	-0.411
LR	-1.169	5.974	1.920	-0.448
C-S	-0.0100	-0.0001	0.0018	0.0025

Beef and poultry are also affected heavily. The same one percent increase in information results in a 0.1 percent decrease in beef consumption and a 0.16 percent increase in poultry consumption in the short-run. In the long-run, this increase results in a 1.2 percent decrease in beef consumption and a 1.9 percent increase in poultry consumption, *ceteris paribus*. A one percent increase in the B-S index is equivalent to five articles.

Conclusions

Nutritional information as measured in this article has significant impacts on the demand for meat products. The consumer has been flooded with information about nutrition and diet from many sources. The response of the consumer can have not only significant but also sizable responses. For three of the four items, the long-run elasticities from the PDL portion of the model offer larger elasticities than do price or income.

Considerable work is still needed in this area of research. Several areas of research must still be undertaken. First of all, better data sources are needed. The B-S index offers a good source of data about cholesterol. But as shown here with the C-S index, cholesterol may not be the only variable of concern. The C-S index offers generality but little else. Other measures could be constructed using the methodology of the B-S index, but for other nutrients. This construction would allow the analyst to determine which nutrients are important enough to consider within the demand system.

Secondly, results from this model ignore any interaction which may occur in earlier budgeting stages. These results look at substitution among these items. It most notably ignores any movement to increased or decreased consumption of meats as a group resulting from nutritional awareness.

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