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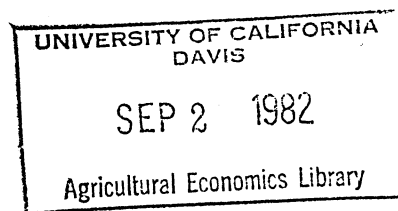
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Structural Shifts in Demand for Meats:
Taste or Quality Changes?^{1/}



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A common problem in demand analysis is how to take into account the effects of quality changes and introduction of new products. Modeling these changes with a time trend does little more than acknowledge the existence of the problem. Furthermore, this approach can lead to erroneous speculation about the permanence of the change, such as taste changes. A case in point is the cause of a recently observed decrease in demand for red meats. Statistical analysis confirms there has been a significant, negative shift in this demand structure not accounted for by relative prices and income. But to attribute this shift to changing tastes and changing health attitudes about red meats may be presumptuous. A competing hypothesis is that this shift is due to substitution of new processed poultry products for processed red meats, particularly processed pork. In recent years, there has been rapid growth in new processed poultry products, especially chicken franks and turkey hams.^{3/} Also, statistical analysis of demand for poultry shows there has been a significant, positive shift in demand not accounted for by relative prices and income.

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^{3/}See the recent paper by Theresa Sun for estimates of growth in demand for chicken franks.

The purpose of this paper is to examine the hypothesis that unexplained structural shifts in demand for meats can be attributed to quality changes in the composition of meats consumed. The next section develops a framework for studying quality changes in commodity demands. The final section uses this framework to determine the relative importance of quality changes in explaining observed structural shifts in demands for beef, pork, and poultry.

Demand Structure with Quantity-Quality Substitution

In the spirit of household production theory, the consumer is viewed as consuming a set of final goods which are produced by commodities purchased on the market (Muth; Stigler and Becker; Deaton and Muellbauer, Chap. 10). In this case, the objects of choice can be thought of as consumption "services" of market goods, where each good is a function of the quantity and quality of the market good purchased (e.g., Rosen).

Let z_j be the j th final good consumed, q_j be the quantity of the j th market good purchased, and s_j be the quality per unit of the j th market good. The utility function is hypothesized to have the weakly separable form

$$(1) \quad u = u(z_1, z_2, \dots, z_n), \text{ where}$$

$$(2) \quad z_j = f_j(q_j, s_j), \text{ for } j = 1, 2, \dots, n.$$

Following Rosen, assume each production function is homogenous of degree one, implying $z_j = q_j f_j(1, s_j)$. Since, in this context, the scaling of s_j is arbitrary, define $s_j \equiv f_j(1, s_j)$. This gives the well-known efficiency units specification

$$(2') \quad z_j = q_j s_j, \text{ for } j = 1, 2, \dots, n.$$

This specification transforms heterogeneous quantity units into homogenous quality units. For example, if q_j represents pounds of meat consumed and s_j denotes number of grams of protein per pound of meat, z_j equals total grams of protein consumed. In general, it is not possible to characterize quality by a single

attribute. s_j is therefore viewed as an index of quality, and is assumed to depend upon a whole set of attributes, i.e.,

$$(3) \quad s_j = g_j(a_{1j}, a_{2j}, \dots, a_{m_j, j}), \text{ for } j = 1, 2, \dots, n,$$

where a_{ij} is the amount of the i th characteristic yielded by one unit of the j th market good. Thus, in the case considered here, the attributes might include such nutritional elements as food energy, protein, iron, etc., as well as one unique attribute provided by each commodity.

Assuming the consumer can vary only the q_j 's (i.e., the s_j 's are parameters to the individual), the problem is to maximize (1) subject to (2') and the budget constraint

$$(4) \quad \sum_j p_j q_j = x,$$

where p_j is the price of the j th good (in general, a "full" price in the sense of Becker -- the sum of market price and implicit time cost), and x is total consumer expenditure or "full" income.

The solutions to this problem are the constant-quality demand functions

$$(5) \quad z_j = z_j(\pi_1, \pi_2, \dots, \pi_n, x), \text{ for } j = 1, 2, \dots, n, \text{ where}$$

$\pi_j = p_j/s_j$ is the shadow price of the j th good. This specification indicates that quality changes can be interpreted as movements along stable demand curves through changes in shadow prices, i.e., an increase in s_j decreases π_j which leads to an increase in z_j . From equation (2'), the derived demand functions for purchased market goods are

$$(6) \quad q_j = \frac{1}{s_j} z_j(\pi_1, \pi_2, \dots, \pi_n, x)$$

$$= q_j(p_1, p_2, \dots, p_n, x; s_1, s_2, \dots, s_n),$$

for $j = 1, 2, \dots, n$. This specification indicates that if we have estimates of the quality indexes, we can incorporate quality changes into the demand model by simply dividing market prices and multiplying quantities by these estimated functions. (Herein lies one value of the efficiency units specification.)

The form of the demand functions in (6) allows us to determine directly the impact of quality changes on demand for purchased goods. In terms of changes in the product attributes in (3), these effects are

$$(7a) \quad \frac{\partial \log q_j}{\partial a_{ij}} = - (1 + e_{z_j, \pi_j}) \frac{\partial \log g_j}{\partial a_{ij}} \quad \text{and}$$

$$(7b) \quad \frac{\partial \log q_j}{\partial a_{ik}} = - e_{z_j, \pi_k} \frac{\partial \log g_k}{\partial a_{ik}} \quad \text{for } j \neq k,$$

where $e_{z_j, \pi_k} = \partial \log z_j / \partial \log \pi_k$. There are two opposing effects of a change in own-quality of the good caused by a change in a_{ij} . A change in a_{ij} that increases s_j decreases π_j , and this induces the individual to consume more of the constant-quality commodity, z_j . However, an increase in s_j also decreases the marginal rate of substitution of q_j for other goods at each level of z_j . This implies the individual will substitute quality for quantity by purchasing proportionately less of the commodity. Indeed, it is entirely possible that this effect can offset the direct price effect from a change in s_j so that q_j decreases when s_j increases. For the efficiency units specification, this occurs when the own-price elasticity of demand for z_j is relatively inelastic, equation (7a). The effect of a change in a_{ik} on demand for q_j depends on the sign of the cross-price elasticity of z_j with respect to π_k , equation (7b). If the two goods are gross substitutes, a change in a_{ik} that increases s_k decreases demand for q_j . Conversely, if the two goods are gross complements, an increase in s_k increases demand for good j .

The elasticities in (7a) and (7b) are derived assuming quality has no effect on prices. To the extent that quality changes are reflected in prices these elasticities will either under-or over-state the total effect. It turns out, however, that these elasticities are still valid when used to calculate demand changes not accounted for by changes in relative prices and changes in income. To see this, consider the total differentials of the demand functions with and without adjustments for quality changes:

$$(8) \quad d\log q_j = \sum_k e_{q_j, p_k} d\log p_k + e_{q_j, x} d\log x \text{ and}$$

$$(9) \quad d\log q_j^* = \sum_k e_{z_j, \pi_k} d\log \pi_k + e_{z_j, x} d\log x - d\log s_j.$$

Assuming these elasticities are the same,^{4/} i.e.,

$e_{jk} = e_{q_j, p_k} = e_{z_j, p_k}$ and $e_j = e_{q_j, x} = e_{z_j, x}$, subtracting (8) from (9) gives

the difference due to quality changes,

$$d\log q_j^* - d\log q_j = \sum_k e_{jk} (d\log \pi_k - d\log p_k) - d\log s_j,$$

or since $d\log \pi_k = d\log p_k - d\log s_k$ and $d\log s_k = \sum_i (\partial \log g_k / \partial a_{ik}) da_{ik}$,

$$(10) \quad d\log q_j^* - d\log q_j = - (1 + e_{jj}) \sum_i (\partial \log g_j / \partial a_{ij}) da_{ij} \\ - \sum_{j \neq k} e_{jk} \sum_i (\partial \log g_k / \partial a_{ik}) da_{ik}.$$

Thus, the elasticities in (7a) and (7b) show the marginal effects of product attributes on demand changes not accounted for by changes in relative prices and income.

Note that the derivative, $\partial \log g_j / \partial a_{ij}$, can be interpreted as the proportionate change in the price paid for an additional unit of the i th attribute of the j th good. This follows from the fact that when prices fully reflect quality changes, any change in the j th market price, dp_j , can be decomposed into two components (see Adelman and Griliches, p. 539):

^{4/} Since, in general, price changes are not orthogonal to quality changes, some provision must be made for time related changes due to quality changes when estimating the demand elasticities in (8). In the absence of a comprehensive measure of quality change, one could follow the usual procedure of including trend or dummy variables in the regression equations to account for structural shifts over time.

$$dp_j = dp_j' + \sum_i (\partial p_j / \partial a_{ij}) da_{ij},$$

where dp_j' is the price change that would have occurred in the absence of quality changes, and the second term on the right-hand side is the price change due solely to quality changes. In terms of the model presented here, $p_j = s_j \pi_j$ and $dp_j' = s_j d\pi_j$. Therefore, the price change attributable solely to quality changes is

$$\pi_j ds_j = \pi_j \sum_i (\partial g_j / \partial a_{ij}) da_{ij},$$

or in terms of proportionate price changes,

$$(11) \quad d\log \hat{p}_j = \sum_i (\partial \log g_j / \partial a_{ij}) da_{ij}$$

where $d\log \hat{p}_j = d\log p_j - d\log p_j' = d\log s_j$. This means that if we have cross-section data on product attributes, these data can be used to estimate implicit prices. These implicit prices with information on changes in quantities of attributes, da_{ij} , and demand elasticities then can be used to decompose changes in product demand attributable to quality changes, equation (10).

Application to Quality Changes in Demand for Meats

This section uses the framework developed in the previous section to examine quality changes in annual consumer demands for beef, pork, and poultry. The demand elasticities, table 1, were derived from parameter values of the absolute price version of the Rotterdam model, estimated with data over the period 1947-79. These elasticities are conditional, rather than total, elasticities because the income variable is meat expenditures per capita rather than total consumer expenditures per capita. Justification for this conditional demand specification is that meats are weakly separable from other commodities (e.g., George and King). The fact that these are conditional estimates explains why

many of the cross-price demand elasticities are negative, rather than positive as we would normally expect. That is, because the income variable is meat expenditures, the income effects from price changes are large enough to make the cross-price elasticities of beef and pork negative instead of positive. Intercepts were included in the Rotterdam model to reflect time related changes not accounted for by relative prices and income. Average annual proportionate changes in demand implied by these intercept values are reported in the last column in Table 1.

The set of product attributes chosen for this analysis are the nutritional elements: food energy, protein, carbohydrate, phosphorus, iron, riboflavin, and ascorbic acid. Proportionate implicit prices of the nutritional elements were derived from the estimates provided by Ladd and Suvannunt, equation (9) in Table 3.^{5/} Their estimates were divided by the 1970 average prices of each meat product (beef = 104¢, pork = 79¢, poultry = 40¢, and fish = 94¢) to obtain the proportionate implicit prices in equation (11). Finally, changes in amounts of nutrient elements per pound of each meat product were derived from the 1981 issue of Food Consumption, Prices, and Expenditures.^{6/}

^{5/}Data on potassium (one of the nutrient elements used by Ladd and Suvannunt) are not available. Thus this element was not included in the set of product attributes. Also, Ladd and Suvannunt's parameter estimates were used to derive proportionate implicit prices for fish, even though fish was not included in the set of commodities they analyzed.

^{6/}Nutrient elements are reported only for red meats as a group, rather than for beef and pork separately. The nutrient amounts per pound of each of these commodities were assumed to be the same as nutrients per pound of all red meat.

Percent changes in meat prices attributable to quality changes are shown in Table 2. These price changes are net of quality price changes for fish. This is because quality is a relative measure, i.e., the demand functions in (6) are invariant to proportional changes in quality. Note that these price changes show considerable variation, suggesting quality changes have had an impact on demand for meats.

The quality elasticities, derived from equation (7) and the demand elasticities in Table 1, were multiplied by the price changes in Table 2 to obtain demand changes attributable to quality changes, Table 3. Table 4 shows percent changes in meat demands not accounted for by relative prices and income. The results indicate that, from 1970 through 1980 quality changes accounted for about one-half of the unexplained increase in demand for poultry, and about one-third of the unexplained decrease in demand for red meats (beef and pork).

Demand changes attributable to quality changes have been most persistent since 1978. From 1978 through 1980, relative qualities of all three meats declined continuously. Since all quality elasticities of beef and pork are positive, equation (10) predicts a continual decline in demand for these meats over this period. On the other hand, all the quality elasticities of poultry are negative. Thus, the model predicts a continual increase in demand for poultry due to quality decreases. The logic of these predictions, as discussed above, is that quantity and own-quality move in the same direction when demand is relatively price elastic (beef and pork), but move in the opposite direction when demand is relatively price inelastic (poultry). Also, demand and cross-quality changes move in the same direction when the commodities are gross complements (beef and pork), but move in the opposite direction when the goods are gross substitutes (poultry). In sum, the decompositions for 1978-80 tend to support the hypothesis of negative demand shifts for red meats and positive

demand shifts for poultry due to quality changes. Since 1978, negative relative quality changes in the composition of meats consumed have apparently led to a substitution of poultry for red meats.

Limitations of this analysis are that: (a) the implicit prices of nutrients derived from Ladd and Suvannunt hold throughout the period analyzed, (b) the implicit prices for red meats and poultry are valid also for fish, and (c) the same demand elasticities can be used to compare demand changes with and without quality changes. These limitations can be remedied, in part, by re-estimating the hedonic prices for each commodity with cross-section data for more recent years (or with pooled time-series and cross-section data). With this set of parameter values one could then estimate the constant-quality demand functions, (5), and use these parameter estimates directly to decompose changes in demand attributable to quality. Despite these shortcomings, the results suggest that the framework developed here can be useful in studying quality changes in commodity demands -- even when some of the relevant information is lacking.

Table 1. Demand Elasticities for Meat Products

Product	Elasticity with Respect to				Meat Expend.	Percent Change Due to Time	
	Price of Beef	Price of Pork	Price of Poultry	Price of Fish			
Beef	-1.03	-0.05	-0.07	-0.12	1.28	0.25	(0.82)
Pork	-0.07	-1.04	-0.03	-0.09	1.22	-1.57	(-3.11)
Poultry	0.23	0.21	-0.58	-0.09	0.22	1.62	(2.97)
Expend. Shares	0.50	0.26	0.12	0.12			

Notes and Sources: Estimates are uncompensated elasticities derived from absolute price version of Rotterdam model. Symmetry and homogeneity restrictions were imposed on the system. (They were tested and not rejected.) Uncompensated price elasticities derived from Slutsky equation, $e_{ij} = e_{ij}^* - w_j e_i$, where e_{ij}^* is the compensated elasticity of product i with respect to price j and w_j is the expenditure share of product j as a proportion of meat expenditures. The values in the last column are average proportionate changes in demands due to trend. (Values in parentheses are t -values.) Quantities and meat expenditures are in per capita turns. Per capita quantities were obtained from Food Consumption, Prices, and Expenditures. Retail prices indexes were obtained from Monthly Labor Review. Meat expenditures and expenditure shares were derived from these data and per capita expenditures for these commodities in 1965 reported in Livestock and Meat Situation and George and King.

Table 2. Percent Changes in Relative Meat Prices Attributable to Quality Changes, 1970-80

Year	Product		
	Beef	Pork	Poultry
1970	-1.09	-1.27	1.69
1971	-0.07	-0.18	-1.47
1972	-2.33	-2.01	-7.42
1973	3.83	3.7	5.91
1974	1.64	-1.66	-3.06
1975	1.24	1.74	-1.87
1976	-0.19	-0.03	4.94
1977	0.04	0.1	-0.38
1978	-2.97	-3.44	-1.16
1979	-1.25	-1.07	-1.17
1980	-3.00	-2.93	-3.5

Note: Price changes are net of quality price changes for fish. Price changes are calculated according to equation (11). The implicit prices were derived from Ladd and Suvannunt. Changes in nutrient elements per pound are from Food Consumption, Prices, and Expenditures.

Table 3. Percent Change in Meat Demands Attributable to Quality Changes, 1970-80.

Year	Product		
	Beef	Pork	Poultry
1970	0.02	-0.08	-0.19
1971	-0.11	-0.06	0.67
1972	-0.69	-0.47	4.07
1973	0.71	0.59	-4.14
1974	-0.35	-0.27	2.01
1975	-0.01	0.10	0.13
1976	0.34	0.13	-2.02
1977	-0.02	0.0	0.13
1978	-0.34	-0.38	1.89
1979	-0.17	-0.17	1.00
1980	-0.48	-0.43	2.78
Total	-1.1	-1.04	6.38

Note: Relative changes are calculated according to equation (10). The quality elasticities, (7), were estimated from the demand elasticities in Table 1.

Table 4. Percent Change in Meat Demands Not Accounted for By Relative Prices and Income, 1970-80.

Year	Product		
	Beef	Pork	Poultry
1970	-1.36	0.88	0.46
1971	0.81	-2.92	-1.27
1972	0.68	-3.35	-1.56
1973	-3.51	3.57	3.41
1974	1.21	-0.45	-2.74
1975	1.62	-3.73	-0.78
1976	-3.04	0.77	4.08
1977	-2.44	-1.06	5.21
1978	-3.31	-4.74	0.36
1979	4.02	7.22	3.97
1980	0.68	0.81	2.47
Total	-4.62	-2.97	13.64

Note: These calculations are percent changes in demand not predicted by relative price and income changes. The elasticities used in obtaining the predicted values are in Table 1.

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