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CHANGES IN CONSUMER PREFERENCES FOR MEAT IN GREAT BRITAIN:
Non-Parametric and Parametric Analysis.

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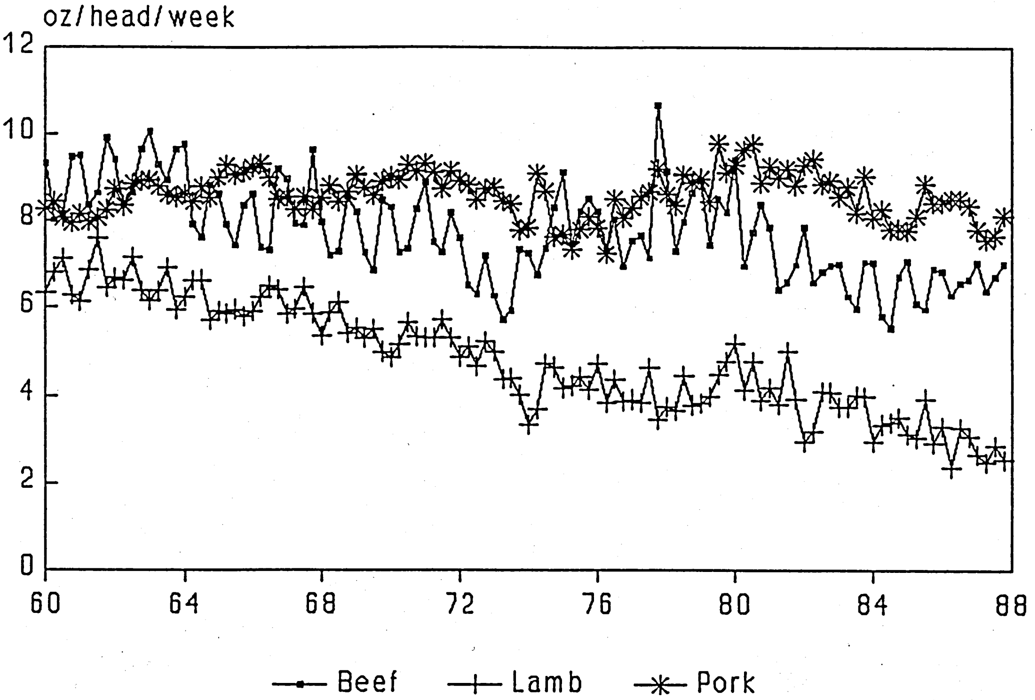
There have been significant shifts in the patterns of meat consumption in Britain over the last 20-30 years, with a decline in the consumption of red meats and a rise in the consumption of chicken and fish. These changes have important implications for the income distribution among livestock producers, and for the design of income support programmes and of environmental policy. From a policy perspective, it is important to distinguish between changes in consumption which are due to changes in economic factors and those which are due to changes in consumer preferences. The former may be counteracted by manipulating relative prices; the latter may call for advertising, education campaigns, and product innovations. The purpose of this study is to investigate whether there are systematic changes in consumption which are not attributable to conventional economic factors, namely prices and budget changes.

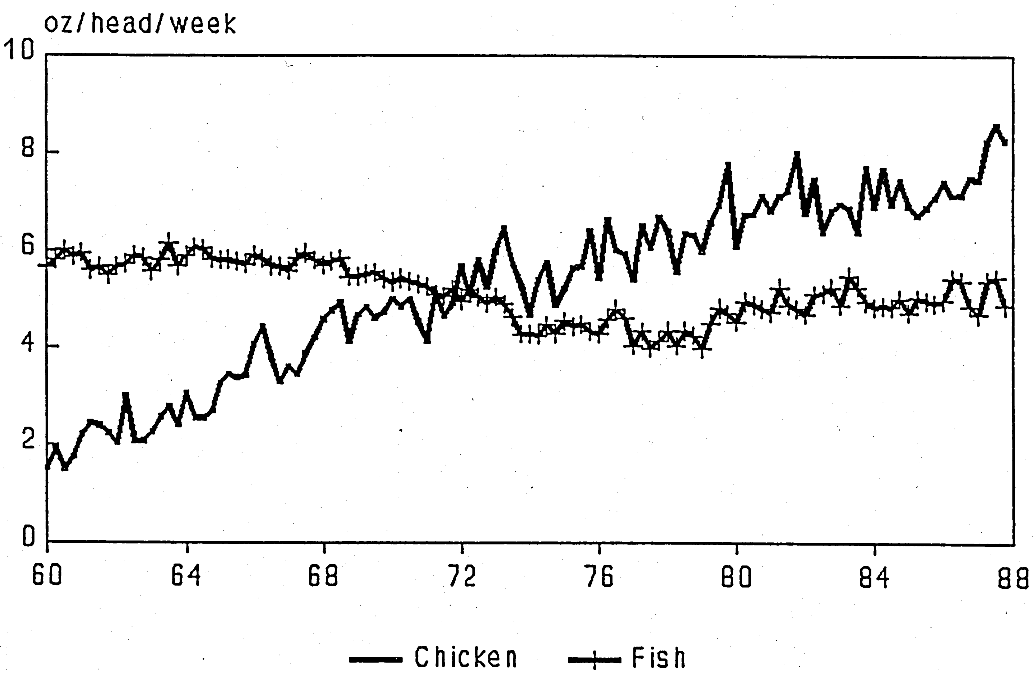
The household budget surveys conducted annually by the National Food Survey provide the data base for our analysis. The changing pattern of meat demand is evident from the consumption data depicted in Figure 1. The most striking changes are the secular rise in chicken consumption and the secular decline in lamb consumption over the sample period. For the other products the changes in demand have been less marked. For pork, a sustained decline in consumption has been only a recent phenomenon; over the whole sample period consumption has been maintained at a constant level, with cyclical fluctuations. The downward trend in beef consumption which occurred at the beginning of the period was reversed from 1973 to 1980. The consumption of fish declined quite steadily until the mid-1970s, since when consumption has picked up.

A popular explanation for these observed changes in meat demand is that dietary concerns, particularly increased health consciousness, have prompted a shift in consumer preferences. Of course this conclusion cannot be inferred from these figures alone, since some or all of the observed variations in demand may be explained by changes in relative prices and consumer expenditure. It is the purpose of this study to decompose the observed variation in meat and fish consumption into those changes which are due to economic factors and those which may be attributable to shifts in consumer preferences.

Most economists have been reluctant to engage in the analysis of taste change, even though the most casual empiricism suggests that changes in tastes are quite frequent and can be considerable. Friedman considered it a matter of division of labour: "The economist has little to say about the formation of wants; this is the province of the psychologist. The economist's task is to trace the consequences of any given set of wants. The legitimacy of and justification for this abstraction must rest ultimately ... on the light that is shed and the power to predict that is yielded by the abstraction." (1962,p.13).

Figure 1: Meat Consumption





The validity of Friedman's approach rests on its power to predict. It is therefore not surprising that a significant challenge has come from applied demand analysts, whose search for better empirical models has led them to explore ways of incorporating tastes. Typically, it is assumed either that tastes changes are in response to external information and so the model includes some exogenous demand shifters or that current tastes are influenced by past decisions in which case a dynamic model with some form of endogenous taste formation is constructed[2].

Our sympathies lie with the applied demand analysts. But for completeness, two alternative approaches should be noted. There is the "radical" view (Gintis, 1974) that tastes are endogenous to the whole economic system and are conditioned not only by prices and quantities but by employment, availability of consumption goods, social institutions etc. How applied work is to be conducted at this level of generality is not clear. On the other hand, Stigler and Becker (1977), still within the neoclassical tradition, argue that tastes are in fact constant over time and over individuals. In their approach the utility function is defined not in terms of market goods but in terms of "basic variables" such as nourishment, comfort, etc., which are produced in the household from inputs of market goods and time. Consumers' preferences are stable but the constraints they face change through time, with changes in the shadow prices of household resources or the household technology. However, as Deaton and Muellbauer (1980a,p.244) point out, "when the intervening variables are not observable, there may be little cutting edge to the distinction between preferences and constraints.."

The analysis reported in this paper is conducted along two interrelated lines of enquiry. Firstly, we focus on non-parametric methods of testing whether meat demands have shifted because of changes in tastes. The advantage of this approach, which emerges from the "revealed preference" theory of demand, is that the stability of consumer preferences can be investigated without identifying explicitly a system of demand equations. As the test results are somewhat inconclusive, and as some may doubt the power of the tests, we proceed to estimate static and dynamic demand systems in order to ascertain whether models which incorporate systematic demand shifters unrelated to price and expenditure changes, provide a better explanation of observed changes in meat consumption.

Revealed Preference

The investigation of the data set begins with some non-parametric tests to determine whether the data are consistent with the hypothesis of stable preferences. More specifically, these check whether the data are consistent with the axioms of revealed preference theory.

If the consumer chooses a bundle of goods (a) although an alternative bundle of goods (b) is obtainable with the same budget outlay, the consumer is revealing a preference of bundle a over bundle b. In conventional jargon, a is "revealed preferred" to b (or aRb). The theory of revealed preference then posits two consistency conditions on consumer choice.

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[2] See, for example, Pollak (1978) and Phlips (1983).

The Weak Axiom states that if **a** is revealed preferred to **b**, then **b** cannot then be revealed preferred to **a**. In other words, bundle **b** will only be chosen when it is cheaper than **a** (bundle **a** is not obtainable with the same outlay). The second consistency condition concerns transitivity of consumer choices. The Strong Axiom states that if **a** is revealed preferred to **b** and **b** is revealed preferred to a third bundle **c**, then bundle **c** cannot be revealed preferred to bundle **a**.

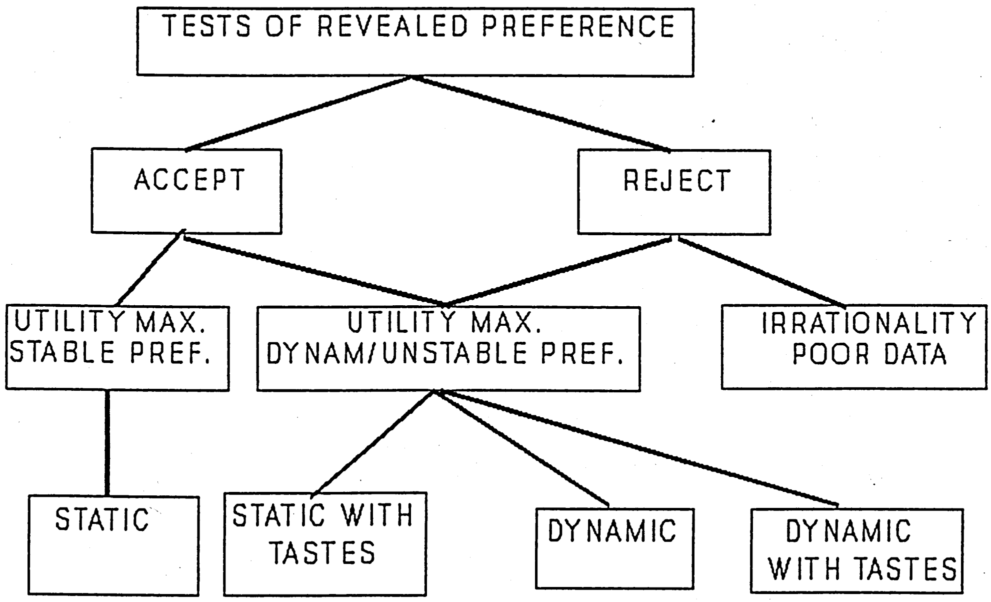
If consumer choices satisfy the Strong Axiom, then they are consistent with the hypothesis that the consumer acts "as if" maximising a stable, well-behaved utility function. Hence, if no violations to this axiom are uncovered in the data, it should be possible to find a stable demand system which fully explains consumption patterns in terms of price and income changes. It would also be permissible to impose the "general restrictions" of neoclassical demand theory (specifically, symmetry and homogeneity) on the demand system. A search for violations of the Strong Axiom thus provides a test of structural change in consumer preferences. The results of the test must however be interpreted with care.

If the Strong Axiom is violated, the data are inconsistent with stable preferences; a static, neoclassical demand system is inappropriate. This rejection of conventional demand theory may be due to a number of factors (Figure 2) including:
(i) poor theory. Consumers do not maximise utility. For example, they may be irrational.
(ii) poor data. The theory holds (for the individual consumer, choosing from the complete range of individual commodities) but not at the level of aggregation of the data set.
(iii) consumer preferences are unstable. The consumer maximises utility but the restrictions of orthodox theory hold only in the long run; in the short run, the consumer is in disequilibrium. Alternatively, the parameters of the utility function shift over time as tastes change.

If there are no violations of the Strong Axiom, the data are consistent with the neoclassical theory of consumer behaviour. In principle, a well-behaved preference map can be constructed which accords with the observed consumption pattern. This does not, however, preclude the possibility that changes in preferences have occurred. As is usually the case, acceptance of the hypothesis is a weaker statement than rejection. It is possible that the consumer's preference map has changed in such a manner that, for the particular configuration of price and budget changes, violations of the Strong Axiom are undetected.

For the non-parametric tests quarterly data, covering the period 1960(1) to 1987(4), are drawn from the National Food Surveys. They comprise quantities (oz. per person per week), expenditure (pence per person per week), and average prices paid of 5 "meat" products: beef and veal; mutton and lamb; pork,bacon and ham; chicken; and fish. The tests must be viewed as conditional on the level of aggregation at which the analysis is conducted. Specifically, it is assumed a) that meat expenditure may be handled in isolation from all other types of expenditure (weak separability), and b) that the data expressed in per caput terms refer to "the representative consumer".

Figure 2: ANALYSIS TREE



The test procedure and results are presented in detail in Appendix 1. In terms of the Weak Axiom, 6 violations (from a possible 6216), involving 8 sample observations are found. With respect to the Strong Axiom, there are 51 violations but only a further 6 data points are involved. However, visual inspection suggests that the extent of the violations may not be significant[3]. If the data were known to be error free, any violation would be sufficient to reject unambiguously the Strong Axiom of Revealed Preference. However, if there is measurement error, then this may be the cause of perceived violations. The question then arises as to whether the violations are 'small' in a formal sense, relative to the possible degree of measurement error. Varian (1985) has proposed a method for identifying the maximum bound on the standard error with which the data must be measured for the violations to be accepted as statistically significant. Applying Varian's approach in the current case (see Appendix 1), one would have to believe the data were measured with a standard error of less than 0.32% in order to reject the null hypothesis of utility maximisation. This implies that we should be able to identify a well-behaved demand system which fits the data, and it is to this that we now turn.

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[3]Chalfant and Alston (1988) find similar 'small' violations when they apply non-parametric tests to meat consumption data from the USA and Australia.

Orthodox Demand Systems: AIDS

We begin by estimating the Almost Ideal Demand System (AIDS), developed by Deaton and Muellbauer (1980b):

$$Y_{it} = \Sigma_j \beta_{ij}.LX_{jt} + \beta_{i0}.LI_t + v_t \qquad i,j=1..n \qquad (1)$$

where $Y_{it} = W_{it} - W_{it-4}$
W_{it} = Expenditure share on commodity i
$LX_{jt} = \ln(P_{jt})-\ln(P_{jt-4})$
P_{jt} = Price of commodity j
$LI_t = \ln(TE_t/PI_t)-\ln(TE_{t-4}/PI_{t-4})$
TE_t = Total Expenditure
$PI_t = \Sigma_j W_j^{\sim}.\ln(P_{jt})$
$W_j^{\sim}$ = average expenditure share

To remove seasonal variation in the data, all variables have been fourth differenced. As a consequence, equation (1) differs from the conventional specification in that it does not contain an intercept. The general restrictions of demand theory can be easily imposed as follows: homogeneity implies $\Sigma_j \beta_{ij}=0$ and symmetry $\beta_{ij} = \beta_{ji}$

The demand system is estimated over the period, 1961(2) to 1987(4). Because the system "adds up" (i.e. the dependent variables, budget shares, sum to unity), one equation is redundant. In keeping with common practice, an equation is arbitrarily deleted and a systems estimator (FIML) applied to the remaining set of equations.

On the basis of a Likelihood Ratio (LR) test (details are to be found in Appendix 2, Table A1), we fail to reject the restrictions of homogeneity and symmetry[4]. Hence, it would appear that we have indeed discovered a demand system which both fits the data and accords with the requirements of a stable set of consumer preferences.

"Dynamic" Demand Systems

For the empiricist, these results beg the question: can a better fit of the data be achieved with alternative specifications of equation (1) which also conform to orthodox demand theory? It turns out that the answer is unequivocally yes. This has been established by (i) developing a dynamic generalisation of the model and (ii) allowing for systematic shifts in the structural relationship over time, which could be attributed to changes in tastes. To adopt the empiricist's stance is, in effect, to treat acceptance of the Strong Axiom as a necessary but not a sufficient condition for tastes to be stable, and then to explore the implications of that interpretation. This approach was also taken by Thurman (1987), who found no violations of the axioms, but went on to identify considerable parametric evidence of structural change.

[4] To be more precise, the data reject the imposition of homogeneity alone. Symmetry and homogeneity together, as the theory requires, are accepted.

Previous parametric analyses of structural change in demand systems has taken one of 3 routes:
(a) splitting the data set into sub-groups and testing for structural stability of the parameters (Martin and Porter, 1985;Anderson and Blundell, 1982). This requires either a search over all possible points of structural break, or an a priori belief of the point at which the structural change occurs. It also suggests that the change is abrupt.
(b) allowing for systematic and stochastic variation in the parameter values over time, using techniques such as the Kalman filter (e.g. Chavas, 1983).
c) explicitly allowing for systematic structural change in parameters by incorporating time trends. This can either imply continuous change (e.g. Eales and Unnevehr, 1988; Martin and Porter, 1985) or use the switching regression technique, which allows for periods of structural stability followed an interval of change, followed by further stability (e.g. Moschini and Meilke, 1989). The latter includes as a limiting case the one-time-only shift in demand curves implied by (a) when all parameters in the system are subject to change.

In the empirical work that follows, approach (c) is used. A criticism of previous applications is that any change in tastes can only be in one direction. If the data cover a sufficiently long period this may be an inappropriate restriction. This is overcome here by allowing taste changes to follow a quadratic form, giving the possibility of a reversal in taste formation. It is also possible to allow tastes changes to alter the price/income elasticities, by including interaction terms between the trend and the explanatory variables (e.g. Moschini and Meilke, 1989; Thurman, 1987) but the complexity of the dynamic specification precluded this as a general feature of the model. Instead, tastes act simply as demand shifters (some experimentation with varying income elasticities was undertaken but did not yield significant improvements in fit; see Appendix 2). Given that the model is estimated in fourth differences, a quadratic intercept shifter in the levels model implies the addition of a constant and trend in the estimating equations of the standard AIDS model:

$$Y_{it} = \alpha_{i1} + \alpha_{i2}.T + \Sigma_j \beta_{ij}.LX_{jt} + \beta_{i0}.LI_t + v_t \qquad i,j=1..n \qquad (2)$$

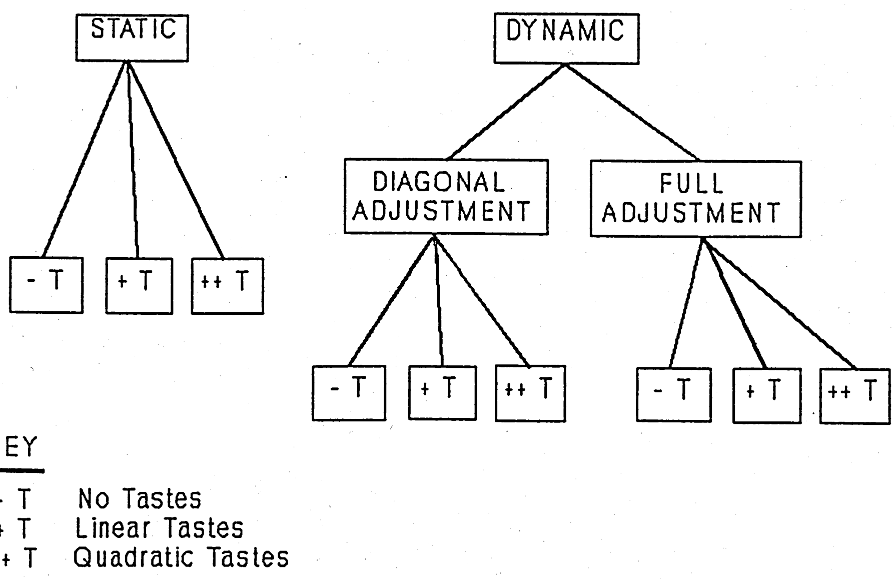
where T = Time trend, of value 1 in 1960:1, with increments of 1 in each quarter.

Following Anderson and Blundell (1982) the dynamic AIDS model assumes that in the short run budget shares adjust in response to changes in prices and expenditure so as to restore the system to a steady state equilibrium, characterised by a demand system such as (2) above. The dynamic model can be represented as follows:

$$Y_{it} = Y_{it-1} - \Sigma_k \delta_{ik}.\{ Y_{kt-1} - (\alpha_{i1} + \alpha_{i2}.t + \Sigma_j \beta_{kj}.LX_{jt-1} + \beta_{k0}.LI_{t-1})\}$$

$$+ \Sigma_j b_{ij}.(LX_{jt} - LX_{jt-1}) + b_{i0}.(LI_t - LI_{t-1}) + v_t \qquad i,j,k=1..n \qquad (3)$$

Figure 3: ALTERNATIVE PARAMETRIC SPECIFICATIONS



The parameter restrictions to allow homogeneity and symmetry in the steady state are the same as in model (2) above. However, symmetry may not hold in the short run, although homogeneity (implying the absence of "money illusion") would be expected to[5]. Homogeneity, in the short run, is implied by $\Sigma_j b_{ij}=0$. Taste change can be incorporated in the equilibrium specification in a similar manner as in the static model.

It should be noted that the adjustment parameters (δ_{ik}) are of full dimension, implying that the adjustment in a budget share will depend on the extent of disequilibrium in all budget shares. A restricted form of the model (termed "diagonal adjustment") can be investigated by setting $\delta_{ik} = 0$ for $i \neq k$. However, in this form of the model adding-up implies that $\delta_{ii} = \delta_{kk}$; hence there is the same adjustment coefficient (δ_{oo}) for each share.

The empirical exercise is then quite extensive. It covers 9 versions of the AIDS model (Figure 3). In turn, each version is estimated, for the period 1961(2) to 1987(4), in its unrestricted form and with homogeneity and symmetry imposed. The Log Likelihood values for each model are reported in Appendix 2, Table A2.

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[5] If homogeneity did not hold in the short run, an equal increase in all prices and expenditure would cause the system at equilibrium to diverge and then return to the same equilibrium.

Model Selection

The static and dynamic AIDS models are not nested and hence we cannot formally test whether there are significant differences between them. Within the static group of equations, however, the Likelihood Ratio tests indicate that the dominant model is that with symmetry imposed, and with a quadratic trend representing tastes; of the set of dynamic systems, the preferred one is the diagonal adjustment model, again with symmetry and a quadratic trend representing taste changes.

In a final round of LR tests, we check whether the functions may be further constrained to be homothetic[6], implying that all expenditure elasticities are unity. Homotheticity is rejected in the static model but may be imposed validly in the dynamic version. Furthermore, for the dynamic model, symmetry and homotheticity do not hold in the short run (but homogeneity is accepted).

Long run equilibrium elasticities derived from the dynamic model are presented in Tables 1a and 1b; elasticities from the static model are given in Tables 2a and 2b. Apart from the expenditure elasticities which are constrained in the dynamic model, the elasticities are broadly similar in two models[7]. All own-price elasticities have the correct sign and there is a sub-system comprising beef, lamb, and pork, in which the cross-price elasticities are positive as expected. However, some cross-price elasticities involving chicken and fish are perverse in sign. Nevertheless, when the compensated elasticities[8] are examined (Tables 1b and 2b), we find that cross-price elasticities are positive, or, if negative, very small. So it may be concluded that all of the "meats" are "net substitutes", in the Hicksian sense.

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[6] A homothetic function f(x) can be written as g(h(x)), where g is monotonic and h is homogeneous of degree 1. Homothetic preferences imply that at given prices a constant proportion of expenditure is allocated to each good, all Engel curves are linear and pass through the origin, with elasticity of unity.

[7] These results are also very similar to those obtained by Bewley and Young (1987), who estimate an alternative demand system using NFS data for 1969-83.

[8] Compensated cross-price elasticities are the substitution effects of price changes (holding real income or utility constant), expressed in elasticity form:
$e^*_{ij} = s_{ij}.P_j/Q_i$ where s_{ij} is the substitution effect. Although the $[s_{ij}]$ are required to be symmetric, the compensated elasticities will not be. However, to preserve symmetry when using the elasticity form, we compute $W_i.e^*_{ij}$ and these are the values which appear in Tables 1b and 2b.

Table 1a Equilibrium Price and Expenditure Elasticities for the Dynamic Model

	w.r.t					
	Beef	Lamb	Pork	Chicken	Fish	Exp.
Beef	-1.76	0.29	0.14	0.30	0.01	1.00
Lamb	0.62	-1.62	0.30	-0.17	-0.13	1.00
Pork	0.14	0.14	-1.07	-0.16	-0.09	1.00
Chicken	0.81	-0.21	-0.34	-1.14	-0.13	1.00
Fish	0.02	-0.11	-0.16	-0.09	-0.66	1.00

Table 1b Equilibrium Compensated Price Elasticities for the Dynamic Model

	w.r.t				
	Beef	Lamb	Pork	Chicken	Fish
Beef	-0.42	0.13	0.13	0.12	0.05
Lamb		-0.21	0.08	-0.01	0.00
Pork			-0.23	-0.00	0.02
Chicken				-0.11	0.00
Fish					-0.08

Table 2a Price and Expenditure Elasticities for the Static Model

	w.r.t.					
	Beef	Lamb	Pork	Chicken	Fish	Exp.
Beef	-1.66	0.24	-0.00	0.09	0.02	1.32
Lamb	0.58	-1.42	0.21	-0.13	-0.32	1.07
Pork	0.15	0.14	-1.03	-0.03	-0.01	0.79
Chicken	0.34	-0.15	-0.15	-0.90	-0.11	0.98
Fish	0.19	-0.22	-0.01	-0.05	-0.67	0.76

Table 2b Compensated Price Elasticities for the Static Model

	w.r.t				
	Beef	Lamb	Pork	Chicken	Fish
Beef	-0.37	0.12	0.11	0.07	0.07
Lamb		-0.18	0.07	-0.00	-0.02
Pork			-0.24	0.02	0.03
Chicken				-0.09	0.01
Fish					-0.09

Tables 3a and 3b indicate how, in the dynamic model, the own-price and expenditure elasticities evolve over time (the adjustment coefficient, $\delta_{oo,}$ is equal to 0.729). Consumer responsiveness to price changes is less elastic in the short run than in the long run. Notably, with respect to chicken consumption, the impact (period 1) elasticity is half that of the long run response. On the other hand, the expenditure elasticities for beef, lamb and chicken approach the long run value from above; for pork and fish, the impact elasticity is inelastic.

Table 3a Evolution of Dynamic Own Price Elasticities

	Period			
	Impact	2	3	LR
Beef	-1.54	-1.69	-1.73	-1.76
Lamb	-1.40	-1.55	-1.60	-1.62
Pork	-1.04	-1.06	-1.07	-1.07
Chicken	-0.57	-0.96	-1.08	-1.14
Fish	-0.59	-0.64	-0.65	-0.66

Table 3b Evolution of Dynamic Expenditure Elasticities

	Period			
	Impact	2	3	LR
Beef	1.26	1.08	1.02	1.00
Lamb	1.11	1.04	1.01	1.00
Pork	0.85	0.95	0.99	1.00
Chicken	1.10	1.03	1.01	1.00
Fish	0.66	0.89	0.97	1.00

Although there is little to choose between the two models in regard to the estimated elasticities, when judged on overall statistical fit the dynamic model is preferred. When dealing with a consistent system of equations, it is by no means clear what an appropriate test for autocorrelation would be. Conventional single equation test statistics can, however, be used as a guide. For the static model, the hypothesis of no serial correlation is rejected for all products other than chicken, on the usual Durbin-Watson criteria; for chicken, the DW test statistic falls in the inconclusive range (Table 4). Durbin h statistics are computed for the dynamic model. In each case the null hypothesis (of no serial correlation) cannot be rejected. The overall fit may also be gauged by how well each model simulates past behaviour. On the basis of the Theil U2 test (Table 5), the dynamic model tracks better for each of the 5 products. This is particularly encouraging since a full dynamic simulation is undertaken here, i.e. the model is allowed to generate its own values for lagged dependent variables. Finally, system R^2 values are computed: 0.282 for the dynamic model and 0.213 for the static. Given that the dependent variables are fourth-differenced, these are considered to be quite satisfactory[9].

Table 4 Durbin Watson and h Statistics

	Static Model (DW)	Dynamic Model (Dh)
Beef	1.43	0.31
Lamb	1.56	-0.49
Pork	1.54	-0.17
Chicken	1.62	0.68
Fish	1.37	1.47

Table 5 Simulation Evaluation: Theil U2 Results

	Static Model	Dynamic Model
Beef	0.681	0.640
Lamb	0.694	0.666
Pork	0.739	0.723
Chicken	0.779	0.762
Fish	0.786	0.776

[9] As we are dealing with a consistent system of equations, single equation R^2 statistics have no obvious interpretation. The system R^2 compares the current model with a benchmark, which in this case is a model with intercepts only. It is calculated as

$$1 - \frac{1}{1 + 2.(LR_u - LR_b).\frac{(T-k)}{T.T.(n-1)}}$$

where LR_u is the Log Likelihood of the model, LR_b that of the 'base' model, T the number of observations, n the number of commodities and k the average number of parameters in each equation.

The Effects of Tastes

Having established that taste changes have been a significant determinant of the demand for meat, the next step is to examine the direction and extent of their impact. Given its consistently better performance, this was undertake with the dynamic model only, by simulating the time path of each meat budget share (i) holding tastes constant (i.e. only prices and expenditure, "the economic factors", affect demand), and (ii) allowing tastes, prices and meat expenditure changes. By comparing the two time paths we can decompose the observed changes in budget shares into those due to economic factors and those due to changes in tastes.

Figure 4 depicts the cumulative impacts (in percentage points) of taste changes on meat budget shares. It is clear that the influence of tastes has been markedly different in each case. Throughout the period, the effect of taste changes has been to reduce the budget shares of pork (at an increasing rate) and of lamb (at a decreasing rate), while raising (at an increasing rate) the share of chicken. The effects on beef and fish appear to be more complex. At the beginning of the data period, taste changes favoured beef; by the mid 1970s the budget share of beef was almost 7 percentage points higher than it would have been if tastes had remained constant. But, thereafter tastes moved against beef consumption and by the end of the period the positive effect on market share was almost dissipated. The effect of taste changes on fish consumption is almost the mirror image of that on beef. Up until 1973, changes in tastes reduced the portion of the consumer budget going to fish but thereafter taste changes moved in favour of fish, with the result that, at the end of the data period, the budget share is higher than it would have been if tastes had remained unchanged throughout the data period. By the end of the estimation period the marginal impact of tastes implied a reduction in beef consumption of 0.20 oz/head/week (equivalent to 2.8%) over a 12 month period, for lamb and pork, reductions of 0.06 oz (2.2%) and 0.10 oz (1.2%) respectively, while chicken and fish were increasing by 0.37 oz (4.4%) and 0.22 oz (4.5%).

Our methodology does not allow us to determine the underlying causes of these changes in consumer preferences. It is apparent, however, that a simple explanation, such as increasing concerns about health and diet, could not adequately account for the differential effects which our analysis has found[10] .

[10]Jones (1984?) suggests a number of possible causes including a "vintage effect" allowing for changes in tastes and habit across generations, increased freezer ownership and changes in the structure of outlets for meat.

Figure 4: IMPACT OF TASTES ON SHARES

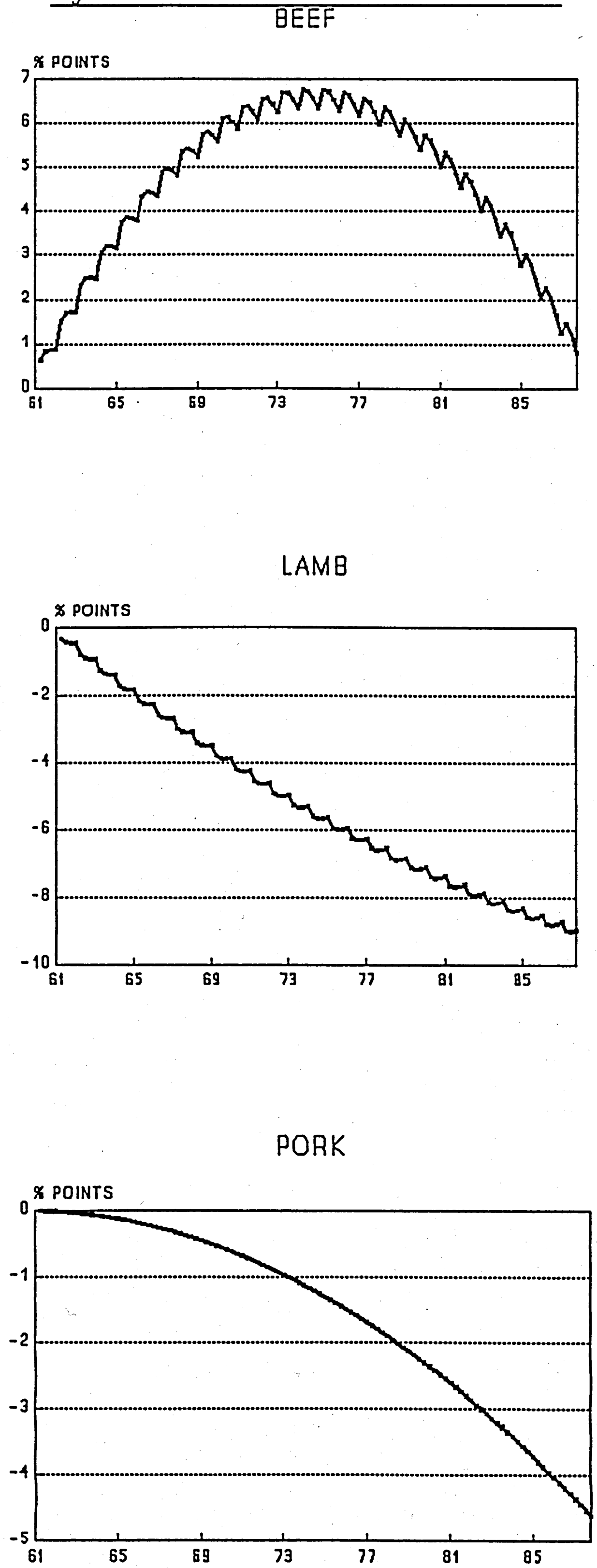
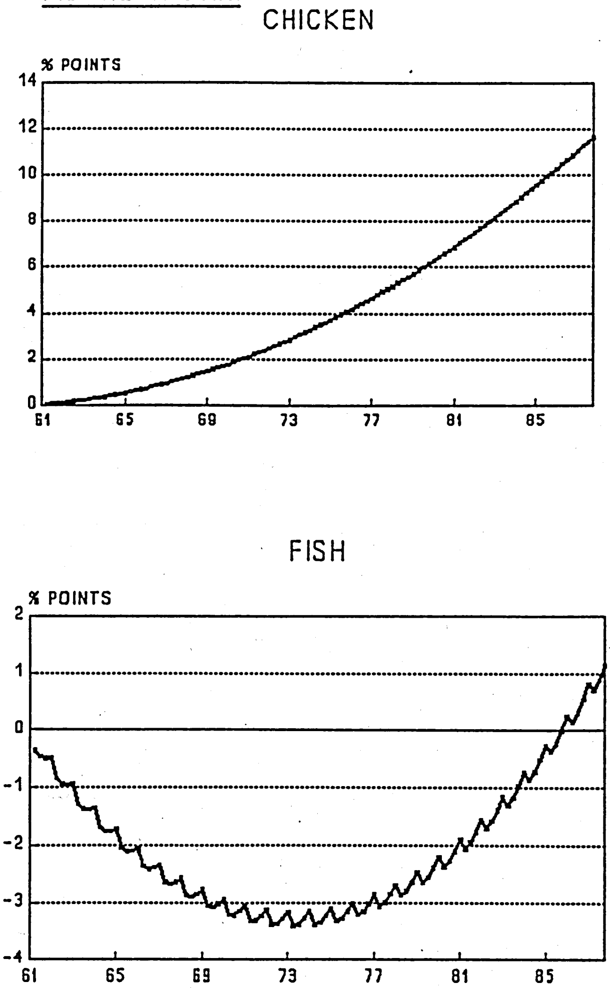


FIGURE 4: Cont.



Concluding Remarks

On the basis of non-parametric analysis, consumer preferences with respect to meat and fish appear to have been stable over the data period and indeed we were able to find an estimated demand system which accorded with the hypothesis of stable preferences and with the general restrictions of demand theory. However, upon further investigation it was concluded that empirical demand systems which permit structural change provide a better explanation of observed consumption patterns.

It should be stressed that our methodology does not permit us to discern the underlying causes of changing tastes. Our results, however, suggest that these causes are likely to have been diverse. To take the analysis further, substantially more complex models would have to be constructed. A number of routes could be explored. For example, some attempt could be made to take account of changes in household constraints and in household production functions in particular. But at least for the present, we are shirking this rather daunting task.

APPENDIX 1.

Implementation of the Test of the Weak Axiom of Revealed Preference.

Define n commodities and T time periods.
Define the vectors of prices (dimension [n,1]) and quantities (dimension [1,n]) at time t as P_t and Q_t.
Define a matrix M such that $M[i,j] = Q_i.P_j$

Elements in column j represents the implied expenditure in period j when the quantities are valued at period i prices. Thus the leading diagonal M[i,i] represents the actual expenditure in each period.

Define a matrix Z such that the element Z[i,j]=M[i,j]/M[j,j]

If any element Z[i,j]< =1 then Q_j is revealed preferred to Q_i (i.e commodity bundle i was affordable at period j prices, but bundle j was selected).

If Z[i,j]< =1 and Z[j,i]< =1 then the weak axiom is violated.

Implementation of the Test for the Strong Axiom

Define a matrix X such that X[i,j]=1 if Z[i,j]< =1, 0 otherwise.
Perform the following algorithm (from Varian (1982)).

```
For k=1 to T
For i=1 to T
For j=1 to T
If X[i,k]=1 AND X[j,k]=1 THEN X[i,j]=1
Next j:i:k
```

If X[i,j]=1 and X[j,i]=1 then the strong axiom is violated

Clearly weak violations imply a strong violation, but not the reverse.

Test Results

Analysis is for 112 data points from 1960:1 to 1987:4, over the 5 commodities.
There are 6 violations of the weak axiom:

Observations

i	j	Z[i,j]	Z[j,i]
51	111	0.9941454	0.9956661
56	98	0.9985352	0.9997039
56	110	0.9852017	0.9970814
58	110	0.9950883	0.9904590
71	111	0.9950883	0.9986683
101	110	0.9981402	0.9956609

There are 51 pairs of matrix points involved in violations of the strong axioms but this only brings in an additional 6 data points (54, 62, 74, 105, 106, 109).

Of the 12432 off-diagonal points in the matrix, 6623 (53%) are greater than 1; 5809 (47%) are less than 1. 69% of those greater than 1 are above the diagonal, implying that there has been some decline in real expenditure on meats, but perhaps not enough to call the power of the test into doubt for that reason.

Varian's test of the significance of the violations proceeds as follows. Assume that the 'true' quantity data set (Y_{it}) is measured with error, the variance of which is known, and given by σ^2. Further assume that the observed data set (Q_{it}) violates the axioms of revealed preference but that some set of adjustments (E_{it}) to the observed data set results in no violations. The question then arises, are the adjustments required consistent with the variance of the true data set? This could be formally tested with the statistic

$$S = \Sigma_i \Sigma_t (E_{it})^2/\sigma^2$$

which is distributed as a chi-squared. If S were greater than the critical value at the desired level of significance, one could reject the null hypothesis that the violations were due to measurement error.

Two problems arise in implementing this approach:

a) Identifying the set of adjustments (E_{it}) that will result in no violations. Ideally this should be the minimum set of adjustments and Varian formulates a quadratic programming problem that will identify this set while minimising the variance of the adjustments (in either absolute or % terms).

b) Identifying the variance of the true data set, σ^2. This will usually be unknown, but the test can still be used to identify the maximum variance which would allow us to reject the null hypothesis. If a priori we believe the variance to be greater than this, then we can assume that the adjustments (and hence the violations) are not statistically significant.

In the current case, implementing the quadratic program is seen as infeasible, as it would involve 560 variables and approximately 7000 constraints. However, it was found that by arbitrarily increasing 3 of the beef consumption quantities (observations 98, 110, 111) it was possible to generate a data set that satisfied both the weak and strong axioms. The variance of the (percentage) perturbations was equal to 0.1427, and at the 5% confidence level the critical value of the chi-squared test is 13499 (for 560 degrees of freedom). This gives the critical value for the standard error of 0.32%. It should be noted that this is an over-estimate, as the programming approach could identify a set of adjustments with a smaller variance than 0.1427. Thus in order to claim that the violations are significant, one would have to claim that the data set is measured with a standard error of less than 0.32%. In the current case this appears unlikely.

Appendix 2 Log Likelihood Values and Test Procedures

Table A1 Log Likelihood Values: Static Model

	Unrestricted	Homogeneity	Symmetry
No Tastes	1424.3 (24)	1416.8 (20)	1415.6 (14)
With +Tastes	1433.0 (28)	1428.0 (24)	1426.3 (18)
With ++Tastes	1444.9 (32)	1438.0 (28)	1436.7 (22)
With ++Tastes Homotheticity	1435.2 (28)	1429.8 (24)	1425.4 (18)

N.B. Number of parameters in system in parentheses.
+Tastes denotes an intercept only, ++ denotes both intercept and trend term. +Tastes implies a linear trend in the levels model, while ++Tastes implies both linear and quadratic terms in the levels model.

Table A2 Log Likelihood Values: Dynamic Model

	Unrestricted	Homogeneity	Symmetry
Full Adj. No tastes	1480.3 (60)	1476.9 (56)	1473.6 (50)
Full Adj. + Tastes	1488.5 (64)	1484.8 (60)	1480.1 (54)
Full Adj. ++ Tastes	1496.3 (68)	1491.1 (64)	1485.5 (58)
Diagonal Adj. No Tastes	1466.9 (45)	1463.6 (41)	1460.6 (35)
Diagonal Adj. + Tastes	1472.8 (49)	1469.7 (45)	1465.6 (39)
Diagonal Adj. ++ Tastes	1482.4 (53)	1478.4 (49)	1473.5 (43)
Diagonal Adj. ++ Tastes Homotheticity	1480.9 (49)	1476.7 (45)	1471.0 (39)

Critical values of the X^2 distribution

	95%	97.5%	99%
4df	9.49	11.14	13.28
6df	12.59	14.45	16.81
10df	18.31	20.48	23.21
15df	25.00	27.49	30.58

In all cases, a small sample adjustment factor of (T-k)/T was employed, where T is the number of observations and k the average number of parameters per equation (see Bewley, 1983)

There is no unique order in which the restrictions of the dynamic specification can be nested within one another, and so the pathway through the tests is largely arbitrary. However, given the interest in the demand restrictions one can consider these first. In all cases, homogeneity and symmetry are accepted. Whichever path is taken for testing dynamics and tastes, one is led to the diagonal adjustment model with symmetry and homotheticity. A series of additional tests were then conducted on this final model, but given that they were rejected in this model, they were not pursued through all specifications. These included a quadratic trend in the difference model (i.e. a cubic trend representation of tastes in the levels model), short run symmetry and short run homotheticity. In the diagonal model with ++Tastes and <u>no</u> long run homotheticity, an interaction term between a linear trend and the income variable was included to allow the elasticities to vary over time, but this was also rejected.

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