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DISCRIMINATING AMONG ALTERNATIVE HABIT
FORMATION SCHEMES IN SINGLE-EQUATION
DEMAND MODELS

by

Richard D. Green, Rulon D. Pope
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Working Paper No. 80-3

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DISCRIMINATING AMONG ALTERNATIVE HABIT
FORMATION SCHEMES IN SINGLE-EQUATION
DEMAND MODELS

Economists are becoming increasingly aware of the significance that taste changes play in an analysis of household consumption behavior. Pollak (1978) states four reasons why taste change may be considered endogenous to a socio-economic system and one of the more important factors involves consumers developing habits.^{1/} Consumers' current preferences depend upon their past consumption decisions. This phenomenon has been explicitly included in demand analyses by formulating various habit formation schemes. Stone (1954), Pollak and Wales (1969), Houthakker and Taylor (1970), Philips (1974), and others have proposed and tested several different habit specifications in demand systems. Although the performance of the varied habit schemes have been evaluated by examining the plausibility of the signs and magnitudes of parameter estimates, goodness of fit measures, etc., the primary testing procedure used is the likelihood ratio procedure. However, this popular method is limited to an evaluation of models where one model is a restricted or special case of a more generalized specification. Thus, often times very interesting questions related to which habit scheme best depicts consumers' behavior are left unanswered.

The primary purpose of this paper is to present some test results that are rarely obtained from some commonly used single-equation demand models that explicitly include habit effects. The test results are based on non-nested testing procedures developed by Cox (1962) and Pesaran (1974).

These non-nested testing procedures allow demand analysts to determine if, for example, a time trend model performs better than, say, a partial adjustment model that includes a lagged consumption term. Thus, many very interesting and commonly used changing-taste demand models can be evaluated directly rather than indirectly through ad hoc procedures such as comparing R^2 's, magnitudes of coefficient estimates, etc.

The first section of the paper presents three popular changing-taste demand models that serve as a basis for the empirical results. Section two of the paper briefly explains the non-nested testing procedures used to answer the questions related to how habits affect consumer behavior. The next section discusses the empirical results and provides a brief description of the data sources. The paper concludes with a discussion of the significance of our findings and how the procedures used here can be applied to other demand analyses to answer some questions that are rarely ever treated rigorously.

All of the applications in this paper are based on U.S. time series data from 1950 to 1975 using four commodity groups: beef, pork, poultry, and fish. However, the implications of the empirical findings are applicable to a broad range of economic problems.

The Models

Taste changes can be incorporated into the analysis of consumer behavior by time trends or via habit formation schemes. Treating the

effects of changing tastes in demand relations by the inclusion of a time trend appears to have originated with Schultz (1938). Although a time trend may pick up the effects of changes in the population structure, inflation, and other effects, demand analysts have frequently employed this specification due to its simplicity. In this paper, the time trend model serves as a benchmark of comparison for the more economically plausible state adjustment model. Mathematically, the time trend model is

$$(1) \quad q_{it} = \beta_0 + \beta_1 P_{1t} + \dots + \beta_n P_{nt} + \beta_{n+1} Y_t + \beta_{n+2} t + \epsilon_{it}$$

where q_{it} is the per capita quantity demanded of the i th commodity in time period t , $P_{1t}, \dots, P_{nt}$ are the corresponding prices of the various commodities in period t , Y_t is the per capita disposable income in period t , t is a time trend which takes on the values 1, 2, $\dots$, and ϵ_{it} is a random error.

Houthakker and Taylor (1970) introduced the effects of habits into a demand function by assuming that the quantity demanded of a commodity also depends upon a psychological stock of habits variable, S_t . By assuming that the time rate of change in the stock of habits is equal to current purchases minus losses due to depreciation, i.e., $\dot{S}_t = q_t - \delta S_t$ where $\dot{S}_t = dS_t/dt$ and δ is the depreciation factor, and substituting for the unobservable psychological stock variable, S_t , in the demand function the model can be written (see, e.g., Philips, p. 168)

$$(2) \quad q_{it} = \beta_0 + \beta_1 q_{it-1} + \beta_2 P_{1t} + \dots + \beta_{n+1} P_{nt} + \\ \beta_{n+2} P_{1t-1} + \dots + \beta_{2(n+1)} P_{nt-1} + \beta_{2n+3} Y_t \\ + \beta_{2n+4} Y_{t-1} + \epsilon_{it}$$

where q_{it-1} , P_{jt-1} , and Y_{it-1} are lagged values of the quantities, prices, and income, respectively.^{2/}

A restricted version of model (2) is the partial adjustment model (see, e.g., Philips [1974], pp. 154-157). It can be obtained from the model in equation (2) by imposing the restrictions that all the coefficients on lagged variables are zero except for lagged quantity. The partial adjustment model assumes that adjustment to some desired or equilibrium value takes place gradually. It has been frequently applied in the analysis of the demand for durable commodities and in agricultural supply response models. For an analysis of commodities exhibiting habit effects, it can be interpreted in the spirit of Pollak and Wales' (1969) habit formation scheme. More specifically, the intercept term can be assumed to depend upon previous consumption levels.

In the models considered above, the static and partial adjustment models are restricted or nested versions of the more general state adjustment model.^{3/} The static model is also a special case of the time trend model. However, the time trend model and partial adjustment models are non-nested versions of one another. Likewise, the time trend model is not a restricted or nested version of the state adjustment model. Thus, in order to evaluate these non-nested models with respect to one another, non-nested testing procedures must be used.

Non-Nested Testing Procedures

The testing procedures used to evaluate the performance of the different changing taste demand formulations were developed by Cox (1962) and extended to the linear model by Pesaran (1974).

The classical likelihood ratio test is not applicable to situations where one model is not a special or restricted version of a more generalized model. For example, consider the following linear models

$$(3) \quad H_0: y = Xb_0 + u_0; u_0 \sim N(0, \sigma_0^2 I)$$

$$(4) \quad H_1: y = Zb_1 + u_1; u_1 \sim N(0, \sigma_1^2 I)$$

where y is a $T \times 1$ vector of observations of the dependent variable, the matrices X ($T \times k_0$) and Z ($T \times k_1$) are observations of the explanatory variables, b_0 and b_1 are $k_0 \times 1$ and $k_1 \times 1$ vectors of parameters to be estimated, respectively, and u_0 and u_1 are normally distributed random errors with scalar variance-covariance matrices. It is further assumed that all the columns of X cannot be obtained from those of Z and vice versa and that other statistical assumptions are satisfied.^{5/}

From equations (3) and (4) it is apparent that neither model is a nested version of the other one. In these cases, there is no maintained hypothesis and each model can arbitrarily serve as the "null hypothesis". In fact, the non-nested procedures allow for both models to be rejected, one accepted over the other one, or both models to be accepted (fail to reject either one). In the actual testing method, one model is chosen as the maintained hypothesis and tested relative to the other one, and then the roles are reversed. Thus, more outcomes are possible with these methods relative to using the likelihood ratio procedure.

The actual statistic used to test (3) against (4) and vice versa is

$$(5) \quad N_0 = T_0 / [\hat{V}_0(T_0)]^{1/2}$$

where, after a sufficient number of algebraic manipulations, it can be shown that

$$T_0 = T/2 \ln \left(\frac{\hat{\sigma}_1^2}{\hat{\sigma}_0^2 + 1/T \hat{b}_0' X' M_Z X \hat{b}_0} \right)$$

$$\text{and } \hat{V}_0(T_0) = \frac{\hat{\sigma}_0^2}{\hat{\sigma}_{10}^4} \hat{b}_0' X' M_Z M_X M_Z X \hat{b}_0.$$

Although the computations from employing the statistic in (5) look foreboding, they are actually fairly easy to calculate. $\hat{\sigma}_0^2$ and $\hat{\sigma}_1^2$ are just the ordinary least squares (OLS) estimates of σ_0^2 and σ_1^2 obtained from regressing y on X and y on Z , respectively. The only remaining unknown term in T_0 is $\hat{b}_0' X' M_Z X \hat{b}_0$ which can be shown (see, Pesaran [1974, p. 159] to be equal to the residual sum of squares found by regressing $\hat{y}_0 (X\hat{b}_0)$ on Z . The matrix $\hat{b}_0' X' M_Z M_X M_Z X \hat{b}_0$ can also be shown to be equal to the residual sum of squares obtained by regressing the residuals (from regressing $\hat{y}$ on Z) on X . Thus OLS packages can be used to compute all of the necessary computations. The statistic in (5), under H_0 , is asymptotically normally distributed as a standardized normal deviate. A significant negative value for N_0 implies rejection of H_0 in favor of H_1 .

Empirical Results

Annual U.S. time series data from 1950 to 1975 on beef, pork, poultry and fish are used to perform the non-nested tests on the different changing

taste demand models. Variables used in the time trend, partial and state adjustment models are per capita meat consumption in retail weight equivalents (1970 base), per capita income, and price indexes for the commodity groups. All variables are expressed in real terms by deflating them by the consumer price index (CPI).

Based on previous research, using the same data source, and employing the likelihood ratio procedure the state adjustment model was preferred over the static and partial adjustment models (Pope, et. al [1979]). Thus, the focus in this paper is on determining which non-nested habit formation model performs the best. That is, pairwise comparisons of the time trend and each of the other models are examined. Following the discussion given in Chang, it is argued here that the possible bias from employing a single equation model and estimating by simple maximum likelihood is zero (or small). Thus, it is assumed that price is uncorrelated with the error in each demand equation. However, before the test results are presented a brief examination of the structural estimates is given.

The structural estimates for the various models are presented in Tables 1-3. As can be observed from the Tables, the R^2 's values are all in the 80 to 90 percent range. The values of the Durbin-Watson and Durbin h statistics do not indicate the presence of positive autocorrelation. With respect to own-price coefficients and elasticities, all of them are negative for all commodities and models with the exception of fish. The t-ratios for the coefficients indicate a high level of significance except, again, for the commodity, fish. The vast majority of the cross-price effects are positive as expected for substitutes. The

absolute values of t-ratios are not as high as in the cases for own-price effects. In general, all elasticities are inelastic as would be anticipated for a meat classification. With respect to income effects, all are positive indicating superior goods.

Generally, the coefficients of time in Table 1 have lower levels of significance than own price and income coefficients. Only pork and poultry time coefficients are significant at the 90 percent level. For the partial adjustment model (Table 2) none of the coefficients of lagged consumption are significant at the 90 percent level. Table 3 indicates "insignificance" among lagged variables presumably due to collinearity among the variables and their lagged values--a problem common with this specification.

Even with the often low levels of statistical significance, non-nested tests are one of the few ways to evaluate which model of tastes is best described by the data.^{6/} The results from the Pesaran test are given in Tables 4 and 5.

From Table 4 (column 1), when the state adjustment model is treated as the maintained hypothesis versus the time trend alternative the state adjustment is accepted for every commodity in the linear and logarithmic cases for the Pesaran statistic. When H_0 and H_1 are reversed and the time trend model is taken as H_0 , then from column 2 of Table 4, the time trend model is rejected in favor of the state adjustment for all commodities and across the linear and double log forms. Thus, the non-nested test results strongly support the state adjustment model over the time trend model. Comparison of the R^2 values also indicate support for the state adjustment model, although these comparisons do not provide a rigorously evaluative procedure in these cases.

With respect to comparing the partial adjustment model with the time trend demand equation, the results are somewhat mixed (see, Table 5). When the partial adjustment model is selected as the null hypothesis it is rejected in favor of the time trend model using the Pesaran statistic in every case except for poultry in the linear case (see column 1 of Table 5). When H_0 and H_1 are reversed, the Pesaran statistic values indicate acceptance of the time trend model with the exception of pork and beef in the double log case. In these cases, the time trend model is rejected in favor of the partial adjustment model. In general, however, the time trend model is accepted over the partial adjustment model.

Conclusions

With the use of non-nested testing procedures different models can be compared even when the classical likelihood ratio procedure is inapplicable. Based on these non-nested procedures the state adjustment model was selected as the best model to account for taste changes in demand equations for meat. When the partial adjustment model was tested relative to the time trend model the results were somewhat mixed, but using the Pesaran statistic the time trend specification was, in general, chosen over the partial adjustment model. Generally, based upon the results reported here, taste changes represented by lagged values appear to be superior to the exogenous time trend formulation. Application of the non-nested statistic to demand

systems to determine the best habit formation scheme among the many proposed would be a most fruitful extension of the research conducted in this paper.

FOOTNOTES

1/ The other three reasons why taste change may be considered to be endogenous are (1) interdependent preferences which are related to the consumption patterns of others, (2) advertising which influences the tastes of individuals, and (3) the "snob appeal" whereby people prefer higher priced goods because their purchases enhance their snob appeal (Pollak [1978]).

2/ The characterization of Houthakker and Taylor's model used in this paper makes no attempt to impose the structure of the state adjustment model. Thus, we are considering the model in its unrestricted reduced form. The advantage of this approach is that it allows us to perform certain hypothesis tests that would be very cumbersome to perform if these nonlinear structural restrictions were imposed. However, even though these restrictions are not imposed we will refer to the model as the state adjustment model in this paper.

3/ The static demand model assumes that quantity demanded is a function of current prices and income.

4/ Pesaran (1974) also treats the case where the disturbance terms assume a first-order autoregressive process. The computations become much more difficult in these situations.

5/ The matrices X and Z are assumed to be fixed in repeated samples and the following limits are assumed to exist and be finite

$$\lim (1/TX'X) = \Sigma_{x'x}$$

$$T \rightarrow \infty$$

$$\lim_{T \rightarrow \infty} (1/TZ'Z) = \Sigma_{z,z}$$

$$T \rightarrow \infty$$

$$\lim_{T \rightarrow \infty} (1/TX'Z) = \Sigma_{x,z}$$

$$T \rightarrow \infty$$

where $\Sigma_{x,x}$ and $\Sigma_{z,z}$ are nonsingular and $\Sigma_{x,z} \neq 0$ (Pesaran [1974, p. 156]).

Further, it is assumed that the errors in each demand equation are uncorrelated with the errors of the other equations.

6/ Ad hoc procedures may involve, for example, comparison of adjusted R's or mean absolute deviations from beyond sample forecasts. However, when structural features of the two non-nested models are to be compared, the Pesaran test seems to be the best statistical approach to the evaluation of the two models.

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TABLE 1

Maximum Likelihood Estimates of the Parameters for the Time Trend Demand Equation, 1950-1975

Commodity	Explanatory Variables							R ²	Durbin-Watson
	Constant	Beef Price	Pork Price	Poultry Price	Fish Price	Income	Time		
1. Beef									
a. linear ^{a/}	106.629 (11.16) ^{b/}	-76.920 (15.67)	0.891 (0.186)	10.71 (1.37)	4.22 (0.463)	45.3 (2.72)	0.903 (1.27)	.9902	2.47
b. double log	4.466 (54.01)	-0.830 (12.28)	0.041 (0.54)	0.128 (1.16)	0.0015 (0.011)	0.339 (1.44)	0.0135 (1.51)	.9831	1.71
2. Pork									
a. linear	78.817 (5.79)	20.924 (2.99)	-75.646 (-11.11)	17.44 (1.57)	16.63 (1.28)	55.32 (2.33)	-1.19 (-1.18)	.9114	1.68
b. double log	4.83 (45.46)	0.234 (2.7)	-0.835 (-8.54)	0.121 (0.85)	0.333 (1.84)	0.856 (2.83)	-0.021 (-1.83)	.8813	1.42
3. Poultry									
a. linear	22.09 (1.1)	34.385 (3.33)	6.728 (0.7)	-48.96 (-2.99)	-16.88 (-0.88)	118.078 (3.37)	-1.21 (-0.814)	.9864	1.47
b. double log	4.74 (72.18)	0.328 (6.11)	0.282 (4.66)	-0.71 (-8.02)	-0.103 (-0.92)	0.97 (5.2)	-0.12 (-1.77)	.9961	1.84
4. Fish									
a. linear	18.165 (1.07)	16.712 (1.92)	6.67 (0.787)	-10.58 (0.765)	31.636 (1.96)	54.63 (1.85)	-1.53 (-1.21)	.8505	1.81
b. double log	4.78 (45.67)	0.143 (1.67)	0.097 (1.01)	-0.133 (-0.95)	0.432 (2.43)	0.556 (1.87)	-0.015 (-1.37)	.844	1.79

^{a/} The linear and double log models refer to situations where the observations are expressed in linear and logarithmic forms, respectively.

^{b/} Values in parentheses are t-statistics.

TABLE 2

Maximum Likelihood Estimates of the Parameters for the Partial Adjustment Demand Equation, 1950-1975

Commodity	Constant	qit-1	Explanatory Variables					R ²	Durbin-h
			Beef Price	Pork Price	Poultry Price	Fish Price	Income		
1. Beef									
a. linear	103.36 (12.46)	-0.078 (-1.08)	-80.91 (-14.19)	3.04 (0.63)	0.983 (0.302)	10.47 (1.43)	70.31 (10.53)	.99	-.0563
b. double log	4.98 (12.53)	-0.086 (-0.99)	-0.892 (-11.05)	0.096 (1.29)	-0.029 (-0.59)	0.143 (1.34)	0.727 (7.19)	.9819	1.359
2. Pork									
a. linear	98.27 (9.9)	-0.089 (-0.98)	22.75 (3.23)	-79.355 (-11.29)	31.18 (6.36)	7.81 (0.75)	30.257 (4.12)	.9094	0.785
b. double log	4.82 (9.45)	-0.04 (-0.36)	0.269 (2.9)	-0.911 (-8.891)	0.357 (4.61)	0.114 (0.79)	0.345 (2.98)	.8603	1.171
3. Poultry									
a. linear	34.558 (3.1)	0.201 (1.04)	29.82 (2.59)	5.6 (0.576)	-31.54 (-3.82)	-25.06 (-1.67)	70.49 (3.19)	.9867	0.572
b. double log	4.77 (9.66)	-0.031 (-0.29)	0.357 (5.48)	0.245 (3.98)	-0.584 (-9.13)	-0.24 (-2.73)	0.688 (5.86)	.9954	1.157
4. Fish									
a. linear	45.09 (3.48)	-0.296 (-1.12)	18.52 (2.14)	0.902 (0.101)	9.04 (1.33)	33.51 (1.88)	25.786 (2.55)	.8489	N/A ^{a/}
b. double log	5.58 (4.56)	-0.203 (-0.77)	0.171 (1.97)	0.02 (0.2)	0.07 (0.84)	0.367 (1.95)	0.217 (1.79)	.8386	N/A

^{a/} N/A indicates cases in which the Durbin-h statistic could not be calculated, due to the presence of complex roots.

TABLE 3

Maximum Likelihood Estimates of the Parameter for the State Adjustment Demand Equation, 1950-1975

Commodity	Constant	Beef Price	Pork Price	Poultry Price	Fish Price	Income	Quantity t-1	Beef Price t-1	Pork Price t-1
1. Beef									
a. linear	121.46 (4.57)	-86.21 (-12.39)	0.309 (0.063)	6.58 (0.917)	23.87 (1.63)	37.238 (1.93)	-0.232 (-0.89)	-6.54 (-0.33)	-2.113 (-0.44)
b. double log	5.586 (4.31)	-1.03 (-9.79)	0.01 (0.13)	0.107 (1.1)	0.572 (2.57)	0.317 (1.06)	-0.213 (-0.76)	0.038 (0.16)	-0.006 (-0.08)
2. Pork									
a. linear	58.393 (2.34)	27.654 (3.47)	-73.799 (-10.94)	15.805 (1.68)	21.073 (1.32)	30.933 (1.37)	0.218 (0.945)	4.71 (0.55)	24.23 (1.37)
b. double log	2.82 (2.49)	0.353 (3.28)	-0.832 (-8.14)	0.16 (1.24)	0.216 (1.0)	0.474 (1.41)	0.389 (1.6)	0.028 (0.24)	0.376 (1.76)
3. Poultry									
a. linear	13.3 (1.17)	32.747 (3.56)	13.21 (1.7)	-56.568 (-5.12)	-8.05 (-0.38)	51.688 (1.75)	0.57 (2.92)	0.382 (0.036)	-9.84 (-1.31)
b. double log	3.95 (4.56)	0.331 (5.54)	0.213 (4.05)	-0.576 (-9.0)	0.073 (0.56)	0.571 (2.98)	0.146 (0.78)	0.049 (0.56)	-0.056 (-0.81)
4. Fish									
a. linear	32.755 (1.93)	17.025 (1.55)	8.14 (0.83)	-11.66 (-0.74)	60.354 (2.2)	73.56 (2.15)	-0.069 (-0.23)	10.485 (0.94)	-11.457 -1.38
b. double log	4.74 (3.02)	0.167 (1.3)	0.099 (0.77)	-0.084 (-0.48)	0.615 (2.05)	.734 (1.75)	-0.026 (-0.07)	0.098 (0.73)	-0.147 (-1.5)

continued on next page....

TABLE 3..continued

Commodity	Poultry Price t-1	Fish Price t-1	Income t-1	R ²	Durbin-h
1. Beef					
a. linear	-.748 (-0.12)	-20.006 (-1.48)	49.626 (2.03)	.9936	N/A ^{a/}
b. double log	-0.06 (-0.65)	-0.514 (-2.56)	0.567 (1.59)	.9889	N/A
2. Pork					
a. linear	9.634 (1.26)	-38.555 (-2.51)	-1.467 (-0.05)	.9637	N/A
b. double log	0.131 (1.31)	-0.478 (-2.22)	-0.113 (-0.29)	.946	N/A
3. Poultry					
a. linear	44.33 (3.46)	-35.55 (-1.64)	-0.801 (-0.02)	.9955	-0.081
b. double log	0.187 (1.45)	-0.45 (-3.18)	0.116 0.48	.9983	-1.429
4. Fish					
a. linear	20.737 (1.71)	-40.018 (-1.72)	-51.86 (-1.33)	.9116	N/A
b. double log	0.191 (1.42)	-0.382 (-1.44)	-0.51 (-1.06)	.8897	N/A

^{a/} N/A indicates cases in which the Durbin-h statistic could not be calculated, due to the presence of complex roots.

TABLE 4

Non-Nested Test Results for the State Adjustment and Time Trend Models

Commodity	$N_0^{a/}$	$N_1^{c/}$	$\bar{R}^2$	
			state adj.	time trend
1. Beef				
a. linear	-8.94	-8.39	.99	.99
b. double log	-6.80	-6.97	.99	.88
2. Pork				
a. linear	-0.41	-18.19	.96	.91
b. double log	-2.17	-10.97	.95	.88
3. Poultry				
a. linear	1.23	-32.22	.99	.99
b. double log	-1.84	-12.20	.99	.99
4. Fish				
a. linear	0.60	-10.61	.91	.85
b. double log	-0.39	-6.35	.89	.84

a/ Subscript "0" refers to the case where H_0 is the state adjustment model and the time trend model is the alternative. N is the statistic developed by Pesaran.

b/ Subscript "1" refers to the case where H_0 is the time trend model and the alternative hypothesis is the state adjustment model.

TABLE 5

Non-Nested Test Results for the Partial Adjustment and Time Trend Models

Commodity	$N_0^{\text{a/}}$	$N_1^{\text{c/}}$	$\bar{R}^2$	
			partial adj.	time trend
1. Beef				
a. linear	-3.06	-1.84	.99	.99
b. double log	-13.50	-4.02	.98	.99
2. Pork				
a. linear	-63.64	-38.56	.91	.96
b. double log	-400.98	-3.97	.86	.95
3. Poultry				
a. linear	-0.74	-1.86	.99	.99
b. double log	-13.43	0.52	.99	.99
4. Fish				
a. linear	-2.13	-1.64	.85	.91
b. double log	-5.55	-0.89	.83	.90

a/ Subscript "0" refers to the case where H_0 is the partial adjustment model and the time trend model is the alternative. N is the statistic developed by Pesaran.

b/ Subscript "1" refers to the case where H_0 is the time trend model and the alternative is the partial adjustment model.