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Responsiveness and Stability of Consumer Behavior: A System-Wide Approach to the Japanese Consumption Pattern

by

Kozo Sasaki

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Introduction

This study attempts to analyze the Japanese consumer behavior in the last thirty years by the Rotterdam system, a complete set of demand equations of flexible functional form and of compatibility with existing aggregated family budget data. It accounts for the characteristics of the estimated behavioral relations as well as the theoretical features of the results. It also discusses the policy implications of the empirical findings with reference to a current policy issue of opening Japanese market.

Complete systems of demand equations have been employed in applied demand analysis in various parts of the world during the last three decades, which have seen a remarkable advance. Such a demand system approach has been taken with the intention of narrowing the gap between theory and empirical research, testing the empirical validity of demand theory, and of constructing an appropriate submodel within the framework of general equilibrium analysis.

In Japan also, there are a number of empirical studies in demand systems estimation for various consumer goods or for food commodities in the main, which mostly make use of time series of family budget data. The methods employed so far are Wald's utility indicator approach[1] (Maruyama and Sasaki (1963)), the demand model derived from an additive quadratic utility function with habit formation (Tsujimura (1964, 1968), Tsujimura and Sato (1964), Egaitsu (1969)), the linear expenditure system (Yoshihara (1969), Sasaki and Saegusa (1974), Tsujimura and Kuroda (1974 ch.5), Maki (1983), Horie (1985 ch.2), Sasaki and Fukagawa (1987)) and its variant extended toward a model of non-additive preferences (Sawada, M. (1984)), the double-log demand functions associated with a CES utility function (Sato (1970, 1972)), developed as a variant of the Rotterdam system; the linear logarithmic expenditure system[2] (Kuroda and

Yotopoulos (1980)), the Rotterdam system (Sawada, Y. (1980), Sasaki (1993)), the almost ideal demand system (or the Deaton-Muellbauer system; Mori and Lin (1990), Sasaki (1993)), etc. Fifteen of these studies deal with various consumer goods, not only food commodities but also nonfood commodity groups, and the other five concentrate on the food consumption (see the references.). Many of them use the demand systems built on the assumption of additive preferences, which place severe restrictions on the cross-price effects.

As already stated, this study is intended to inquire into the Japanese consumption pattern in a comprehensive scheme, employing a more general demand system, and to interpret the empirical results from the viewpoints of economic policy and forecasting. In the case that a proper aggregation over consumers is available, analysis of the consumer demand is taken to be equivalent to that of the aggregate (or maket) demand. It is important to measure the responsiveness of demand for many commodities to changes in income, prices, and time, and to analyze the relationships of substitution and complementarity among those demands.

As for the method of this study, the absolute price version of the Rotterdam system (Barten (1967, 1969), Theil (1965, 1975, 1976)) is chosen for the following reasons: firstly, the Rotterdam system is a flexible demand system, possessed of enough behavioral parameters to provide a local second-order approximation to an arbitrary utility function. Such a demand system is interpreted to be derived from a general utility function, without imposing specialized restrictions on the parameters; secondly, it comprises a set of linear equations in parameters, so that it is rather simple to estimate. The corresponding relative price version is nonlinear in parameters; thirdly, since there are linear restrictions on parameters, the efficiency of parameter estimates is improved by incorporating the theoretical restrictions into the model. Meanwhile, homogeneity and symmetry restrictions can be empirically tested using parameter estimates; fourthly, micro (or individual) demand equations can be approximately aggregated over consumers to a macro (or aggregate per capita) demand equation for each commodity (see Barnett (1979); Theil and Clements (1987) pp.26-27). Thus the demand system is compatible with time series of yearly average of family budget data; fifthly, it is easier to examine the extent of fulfillment of the second-order condition in this system because the Slutsky substitution matrix can be given uniquely through the estimation period.

The first four charactristics are common to the linear approximate version of the almost ideal demand system (Deaton and Muellbauer (1980a, 1980b ch.3)) that is viewed as a popular alternative to the Rotterdam system.[3] The final one is an important characteristic of the model adopted when paying attention to the fulfilment of the negativity of own-price substitution terms and the second-order condition of equilibrium.

It is a subject of primary concern to investigate the changes in demand in the course of economic growth and their trend as well as the simultaneous relations between prices and quantities purchased, in which either prices or quantities can be controlled as policy instruments. Therefore a time series analysis is undertaken by applying the (aggregate) per capita model of the Rotterdam system to annual data of expenditures and prices in the 1963-1986 period. The estimated model is put to the simulation test to see its goodness-of-fit in the sample period, and to evaluate the model performance in forecasting in the 1987-1991 period.

Model

The (aggregate) per capita model of the Rotterdam system is specified as equation (1)[1], denoting average budget share, price and quantity purchased per capita of the ith commodity, and income (or total expenditure) per capita by w_i, p_i, q_i and m, respectively. The subscripts i and j stand for commodity numbers, and t indicates time.

$$w'_{it}\Delta\log q_{it} = a_i + b_i\Delta\log q_t + \Sigma_j k_{ij}\cdot\Delta\log p_{jt} + \varepsilon_{it} \qquad (1)$$

(i, j=1, 2, ..., N),

(t=1, 2, ..., T),

where

$$w'_{it} = (w_{it} + w_{i,t-1})/2,$$

$$\Delta\log x_t = \log x_t - \log x_{t-1} \qquad (x= \text{any positive variable}),$$

and

$$\Delta\log q_t = \Sigma_i w'_{it}\Delta\log q_{it}.$$

The logarithmic change in real income can be approximately designated by the equation:

$$\Delta\log q_t = \Delta\log m_t - \Sigma_i w'_{it}\Delta\log p_{it}.$$

a_i, b_i and k_{ij} are parameters to be estimated, implying time trend parameter, marginal budget share and Slutsky substitution parameter respectively, and ε_{it} is the disturbance term. From the demand equation in differential form, it follows that $a_i = ((\partial q_{it}/\partial_t)/q_{it})w_i$,

$b_i = p_i(\partial q_{it}/\partial m_t)$, and $k_{ij} = (p_i p_j/m)(\partial q_{it}/\partial p_{jt})_{u=const.}$.

The theoretical properties of equation (1) are represented by the restrictions on behavioral parameters. All demand equations in the system are possessed of the property that the expenditures for all commodities add up to income, homogeneous of degree zero in income and prices, symmetric in Slutsky substitution terms, and have negative own-price substitution terms when the following restrictions are imposed:

$$\Sigma_i a_i = 0,\ \Sigma_i b_i = 1,\ \Sigma_i k_{ij} = 0, \tag{2}$$

$$\Sigma_j k_{ij} = 0, \tag{3}$$

$$k_{ij} = k_{ji}, \tag{4}$$

and

$$k_{ii} < 0. \tag{5}$$

The first three restrictions, which are linear equations in parameters, can be incorporated into the estimation procedure. The fourth restriction is examined as to if the inequality holds for all commodities after all the parameters are estimated. The parameters are all treated as constants. In addition, the matrix $[k_{ij}]$ is required to be negative semidefinite to guarantee the complete fulfillment of the second-order condition of the equilibrium. This condition is also tested ex post facto, using estimated parameters.

The disturbance terms are random variables with zero mean, and with constant variances and contemporaneous covariances. Meanwhile, all lagged covariances are assumed to be zero. The adding-up property brings forth an additional statistical restriction that the sum of disturbance terms over all commodities is equal to zero in each period of time $(\Sigma_i \varepsilon_{it} = 0)$. These conditions are expressed in the form:

$$E(\varepsilon_{it})=0, \quad E(\varepsilon_{it}\varepsilon_{jt'})=\omega_{ij}(t=t') \text{ or } 0(t\neq t'), \tag{6}$$

and

$$\Sigma_i \omega_{ij} = 0. \tag{7}$$

Such features of disturbance terms result in the fact that the N disturbance terms are linearly dependent, and that their variance-covariance matrix is of rank (N-1).

The model is straightforwardly applied to family budget data without assuming the separability of utility function. The estimation of the set of demand equations (1) necessitates the adoption of the SUR (Seemingly Unrelated Regression) or Zellner's efficient iterative estimation. The system estimation is iterated, until the convergence of parameter estimates is obtained, with the three theoretical restrictions incorporated into the system, omitting one of the demand equations. Finally, the parameter estimates and related coefficients of the omitted equation are derived from the results of the estimated equations.

Besides, a similar model with intercept and family size is also estimated in comparison with the per capita model with intercept, adding family size as an explanatory variable on the right-hand side of equation (1).

Estimation

The model is estimated with the annual data on per capita consumption and consumer price indexes for all (non-agricultural) households in the whole country, which are published by the Management and Coordination Agency. Time series of the mean level income and quantities per capita are in compliance with the (aggregate) per capita model with intercept. All commodities are classified into 16 subgroups, with 5 food commodity groups and 11 nonfood groups, as shown in the following Tables. Other food includes vegetables, fruit, and processed foodstuffs. Kerosene, etc. contains coal and charcoal. Household non-durables includes interior furnishings, bedding, and domestic utensils as well, and miscellaneous consists of personal care services, toiletries, personal effects, social expenses, etc. Expenditures are given in terms of yearly average of monthly disbursements per capita (in 1,000 yen), and prices indicate subgroup indexes (1980=1.000). Quantities are expenditures at 1980 constant prices.

Table 1 represents parameter estimates $\hat{a}_i$, $\hat{b}_i$ and $\hat{k}_{ij}$ of the model, multiple correlation coefficient R, Durbin-Watson statistic D.W. The multiple correlation coefficient is relatively high, suggesting that there are many significant estimates at 5% or better. There are (N-1)=15 independent demand equations with T=23 observations on each equation in the estimation period, giving (N-1)T=345 observations in total, where the number of commodities is N=16. There are (N-1)(N+4)/2=150 unknown parameters in the set of demand equations with theoretical restrictions, and the degree of freedom is 195. The implementation of the simulation test sets forth an accuracy of 82% or better except for two of NT=391 ratios of estimated to actual quantities, which reveal 76% or better. The Durbin-Watson statistic centers around 2.

Income parameter $\hat{b}_i$ is negative for cereals, insignificant for a couple of

Table 1. Estimated Demand Parameters $\hat{a}_i$, $\hat{b}_i$, $\hat{k}_{ij}$ [a] and Related Statistics

Commodity i =	$\hat{a}_i$	$\hat{b}_i$	$\hat{k}_{ij}$ j=1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	R	D.W.
1. Cereals	0.004	-2.797*	-1.243*	1.365*	-0.254*	-0.673*	0.305	-0.818°	1.097*	0.073	0.297*	-0.762*	-0.883*	2.423*	0.936*	-0.521	-0.674	-0.669	0.819	2.11
2. Livestock products & fish	-0.127*	8.246*		-8.138*	0.933*	1.169*	0.340	2.514*	-1.378*	0.292	0.116	0.364	5.680*	-2.430*	-1.666*	1.657*	2.259*	-3.076*	0.872	2.75
3. Other food	-0.101	8.856*			-8.477*	0.324°	0.874*	0.611*	0.264	0.090	0.016	0.233	0.353*	1.055*	0.345*	0.368	1.845*	1.420*	0.989	2.10
4. Beverages & tobacco	-0.064°	3.923*				-2.983*	0.286	2.151*	0.792*	0.065	0.098	0.706*	-0.507°	-0.742°	0.449*	0.780°	1.290*	-3.205*	0.871	2.45
5. Eating-out	0.065*	10.457*					-8.209*	-1.936*	-0.171	-0.103	-0.439*	1.876*	-1.710*	1.839*	0.671*	-0.504	-0.153	7.034*	0.889	2.76
6. Housing	0.024	8.424*						-5.866*	0.744°	-0.203	-0.555*	1.214*	1.962*	-1.245°	0.358	0.009	2.396*	-1.335	0.841	2.43
7. Electricity & gas	0.150*	0.318							-2.595*	0.477*	-0.115	-0.696*	0.614*	0.120	0.049	0.492	0.982	-0.674	0.617	2.76
8. Kerosene, etc.	0.004	0.059								-0.463*	0.089*	-0.286*	0.314*	-0.147	-0.109	-0.651*	-0.152	0.715°	0.638	2.17
9. Water charges	0.035*	0.011									-0.082*	-0.516*	0.573*	0.533*	0.169*	0.173	0.146	-0.502°	0.447	2.33
10. Household durables	-0.023	1.934*										-0.839*	-0.629*	0.333	-0.478*	0.291	-2.239*	1.428°	0.838	1.86
11. Household non-durables	-0.063°	3.069*											-2.069*	-0.999*	0.001	-2.581*	0.686	-0.807	0.828	2.04
12. Clothing [b]	-0.244*	12.561*												-1.858*	0.837*	1.076°	-2.324*	1.531	0.908	2.23
13. Medical care	-0.086*	4.748*													-3.190*	-0.596*	-0.384	2.606*	0.979	2.56
14. Transportation [c]	0.279*	6.350*														-2.104*	-2.415*	4.527*	0.733	2.12
15. Rec. & educ.	0.039	11.553*															-6.806*	5.542*	0.885	1.81
16. Miscellaneous	0.109	22.287*																-14.536*	0.971	1.83

a. All parameters are multiplied by 10^2 to save space.
b. Clothing includes footwear.
c. Transportation also includes communication.
* significant at 5%. ° significant at 10%.

energy-related commodities and water charges, and positive for all other commodities. Intercept $\hat{a}_i$, which serves to represent the effect of taste changes, shows an upward tendency for eating-out, electricity and gas, water charges and transportation, and a downward tendency for livestock products and fish, beverages and tobacco, household non-durables, clothing, and medical care. As for price parameters $\hat{k}_{ij}$'s, which are also termed the Slutsky substitution parameters, 93 out of 136 parameter estimates (or 68.4%) are found to be significant at 5 or 10%. It is striking that all of the own-price substitution parameters turn out to be negative and significant at 5% or better. It leads to the outcome that own-price elasticities of demand are all negative. Since cross-price substitution parameters are symmetric, the upper triangle suffices to designate the whole substitution matrix in Table 1.

The relationship of net substitutes or net complements can be defined depending on whether the sign of cross-price parameters is positive or negative. The substitution matrix being of rank (N-1)=15 due to the homogeneity of degree zero, the matrix for the first 15 commodities is used to compute eigenvalues, yielding 14 negative values and a positive one. Hence the second-order condition of the equilibrium is almost fulfilled over the estimation period.

A single informational measure is calculated to examine the goodness(or badness)-of-fit of the estimated model. Theil's information inaccuracy (in Nit: Natural logarithmic digit) is defined as below, which is in inverse proportion to the goodness-of-fit, and reduces to 0 if the prediction is perfect for all commodities in each year. The average information inaccuracy over the estimation period $\bar{I}$ and the value adjusted for the degrees of freedom $\bar{I}_c$ are computed where w_{it} and $\hat{w}_{it}$ are observed and estimated budget shares, respectively, and the number of unknown parameters is K=(N-1)(N+4)/2:

$$\bar{I}=\Sigma_t\Sigma_i w_{it}\log(w_{it}/\hat{w}_{it})/T$$

$$=665 \quad (10^{-6}\text{Nits}), \quad (1963\text{-}1986)$$

and

$$\bar{I}_c=(\Sigma_t\Sigma_i(\hat{w}_{it}-w_{it})^2/2T\ w_{it})((N-1)T/((N-1)T-K))$$

$$=1207 \quad (10^{-6}\text{Nits}).$$

These values are viewed to be relatively low for the 16-commodity model, taking account of the goodness-of-fit in the ratios of actual to estimated quantities. The extrapolation is also conducted to evaluate the model performance in prediction for the future. The average information inaccuracy for the 1987-1991 period is more than double the figure of the interpolation test.

$$\bar{I}=\Sigma_t\Sigma_i w_{it}\log(w_{it}/\hat{w}_{it})/5$$

$$=1586 \quad (10^{-6}\text{Nits}), \quad (1987\text{-}1991).$$

The accuracy of prediction is still high for most commodities except for kerosene, etc. Demand for kerosene, etc. is overestimated appreciably, which might be a temporary phenomenon. In the meantime, electricity and gas is somewhat overstimated while household non-durables is underestimated, both with the accuracy of 82% or better.

Another per capita model with intercept and family size is estimated introducing the number of persons per household as an additional explanatory variable. The original model proves to fit the data better than the modified one in both of the interpolation and the extrapolation tests.[5] The former is also preferable to the latter in respect of the fulfillment of the second-order condition because the latter model obtains 13 negative eigenvalues and 2 positive ones from the Slutsky substitution matrix.

Empirical Results

Demand relations are conveniently represented in terms of elasticity and rate of shift in demand per annum, which are derived from estimated parameters and actual data. In the statistical test of estimated elasticities, nearly 60% of all price elasticities are significant at 5 or 10%. It is noticeable that all of the 16 own-price elasticities and 13 income elasticities are significant at 5% or better while 9 commodities show a significant rate of shift in demand at 5 or 10%.

Table 2 gives income and own-price elasticities, annual rate of shift in demand, and average budget share of each commodity, calculated at the sample means. Own-price elasticities are all negative, and the 3 commodities of eating-out, housing, and medical care are price-elastic. There are also some income-elastic commodities such as eating-out, beverages, medical care, housing, clothing, and miscellaneous. For household durables and non-durables, transportation, and recreation, income elasticity is almost unity. Unexpectedly, electricity and gas, kerosene, and water charges are hardly responsive to income although electricity and gas, and water charges increase substantially in demand with time, _ceteris paribus_. The average annual rate of shift due to time trend is large and positive for transportation and eating-out as well. Those positive rates of shift reflect the widespread and augmented use of electrical and gas appliances, automobiles, telephones, etc., increases in service consumption and leisure, and so on.

All cross-price elasticities turned out to be of reasonable magnitudes, though the sign of some estimates is contrary to expectation. There are only 3 estimates that lie between 1 and 2 in absolute value, and all other estimates are less than unity in absolute terms. Hence demands for almost all commodities

Table 2. Income and Own-Price Elasticities [$\overline{E}_i$, $\overline{e}_{ii}$], and Annual Rate of Shift in Demand [$\overline{R}_i$] Estimated at the Sample Means in 1963-1986, and Sample Mean Average Budget Share [$\overline{w}_i$].

Commodity i=	Income Elasticity $\overline{E}_i$	Own-Price Elasticity $\overline{e}_{ii}$	Annual Rate of Shift $\overline{R}_i$ [a] (%)	Average Budget Share $\overline{w}_i$
1. Cereals	-0.521*	-0.204*	0.078	0.05368
	(0.137)	(0.061)	(0.468)	
2. Livestock products & fish	0.833*	-0.904*	-1.279*	0.09902
	(0.168)	(0.116)	(0.594)	
3. Other food	0.808*	-0.862*	-0.916	0.10958
	(0.141)	(0.027)	(0.580)	
4. Beverages & tobacco	1.130*	-0.898*	-1.835°	0.03473
	(0.286)	(0.110)	(1.003)	
5. Eating-out	1.917*	-1.610*	1.202*	0.05454
	(0.250)	(0.231)	(0.573)	
6. Housing	1.788*	-1.329*	0.512	0.04712
	(0.296)	(0.284)	(0.789)	
7. Electricity & gas	0.087	-0.709*	4.153*	0.03678
	(0.323)	(0.123)	(1.163)	
8. Kerosene, etc.	0.072	-0.568*	0.483	0.00817
	(0.604)	(0.109)	(2.053)	
9. Water charges	0.019	-0.132*	5.801*	0.00619
	(0.379)	(0.058)	(0.994)	
10. Household durables	1.047*	-0.473*	-1.244	0.01848
	(0.484)	(0.177)	(1.677)	
11. Household non-durables	0.964*	-0.680*	-1.968°	0.03184
	(0.296)	(0.107)	(1.031)	
12. Clothing [b]	1.363*	-0.327*	-2.614*	0.09216
	(0.154)	(0.096)	(0.546)	
13. Medical care	1.861*	-1.298*	-3.316*	0.02551
	(0.187)	(0.076)	(0.540)	
14. Transportation [c]	0.997*	-0.394*	4.486*	0.06370
	(0.283)	(0.147)	(1.061)	
15. Rec. & educ.	0.973*	-0.689*	0.327	0.11869
	(0.140)	(0.132)	(0.461)	
16. Miscellaneous	1.115*	-0.950*	0.548	0.19981
	(0.133)	(0.184)	(0.377)	

a. $\overline{R}_i=((\partial q_i/\partial t)/\overline{q}_i)\times 100$, which can be approximated by $(\hat{\alpha}_i/\overline{w}_i)\times 100$.

b. Clothing also includes footwear.

c. Transportation also includes communication.

Figures in ( ) are estimated standard errors.

* significant at 5% or better.

° significant at 10%.

are inelastic with respect to cross-prices.

Table 3 presents the cross-price elasticities, calculated at the sample means. A look at the cross-price elasticities reveals that practically all pairs of symmetric estimates have either the positive or the negative sign except for cereals, other food, and electricity and gas. Especially, most pairs of significant and symmetric estimates signify the relationships of gross substitutes or gross complements, depending on whether they are positive or negative values. They coincide with the significant relationships of net substitutes or net complements, which are shown in Table 1.

It is certainly important to estimate all cross-price elasticities in the analysis of demand system. However, inasmuch as the interrelations of demand in elasticity form appear to be somewhat complicated, it would be convenient to express all effects of nominal price changes on each commodity in an annual rate of change in quantity demanded. In preparation for deriving the overall effect of a change in relative price, the average annual rate of change in the estimated quantity is computed, and income elasticity is then converted to the average annual rate of shift in demand, multiplying income elasticity by the growth rate of real income per annum (3.440%) through the estimation period. The uncompensated effect of a change in relative price is obtained in terms of the average annual rate of change in quantity demanded, simply deducting both of the effects with respect to real income and time trend from the average annual growth rate of demand.

Table 4 shows the average annual growth rate of the estimated quantity, and the contributions of changes in relative price, real income, and time trend to the annual growth rate for each commodity. The average growth rate of demand is particularly high for transportation (8.3%), electricity and gas (7.4%),

Table 3. Cross Elasticities of Demand Estimated at the Sample Means of All Variables in 1963-1986 [$\bar{e}_{ij}$] [a]

Commodity i =	j=1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1. Cereals		0.306*	0.010	-0.107*	0.085	-0.128	0.223*	0.018	0.059*	-0.132*	-0.148*	0.499*	0.188*	-0.064	-0.064	-0.020
2. Livestock products & fish	0.093*		0.003	0.089°	-0.011	0.215*	-0.170*	0.023	0.007	0.021	0.547*	-0.322*	-0.190*	0.114	0.129	-0.477*
3. Other food	-0.067*	0.005		0.002	0.036°	0.018	-0.006	0.002	-0.004	0.006	0.007	0.022	0.011	-0.018	0.072*	-0.032
4. Beverages & tobacco	-0.255*	0.225*	-0.030		0.021	0.566*	0.186*	0.010	0.021	0.182*	-0.182*	-0.318*	0.101*	0.153	0.237	-1.149*
5. Eating-out	-0.047	-0.127	-0.050*	-0.014		-0.455*	-0.102	-0.035	-0.092*	0.309*	-0.375*	0.160	0.074	-0.214°	-0.256	0.907*
6. Housing	-0.270*	0.357*	-0.066*	0.394*	-0.508*		0.092	-0.058	-0.129*	0.225*	0.359*	-0.429*	0.030	-0.112	0.296	-0.640*
7. Electricity & gas	0.294*	-0.383*	0.062	0.212*	-0.051	0.198°		0.129*	-0.032	-0.191*	0.164*	0.025	0.011	0.128	0.257	-0.200
8. Kerosene, etc.	0.086	0.350	0.102	0.077	-0.130	-0.252	0.581*		0.108*	-0.352*	0.382*	-0.186	-0.135	-0.802*	-0.195	0.862°
9. Water charges	0.480*	0.185	0.024	0.157	-0.710*	-0.898*	-0.186	0.143*		-0.834*	0.926*	0.859*	0.272*	0.278	0.234	-0.816°
10. Household durables	-0.468*	0.093	0.011	0.346*	0.958*	0.608*	-0.415*	-0.164*	-0.286*		-0.374*	0.084	-0.285*	0.091	-1.336*	0.564
11. Household non-durables	-0.329*	1.688*	0.005	-0.193*	-0.589*	0.571*	0.157°	0.091*	0.174*	-0.215*		-0.402*	-0.024	-0.872*	0.101	-0.446°
12. Clothing [b]	0.190*	-0.399*	-0.035	-0.128*	0.125*	-0.199*	-0.037	-0.027	0.049*	0.011	-0.152*		0.056*	0.030	-0.414*	-0.106
13. Medical care	0.267*	-0.837*	-0.069*	0.112°	0.162	0.053	-0.049	-0.058°	0.055*	-0.222*	-0.059	0.157°		-0.352*	-0.372*	0.650*
14. Transportation [c]	-0.135*	0.161	-0.052	0.088	-0.133	-0.046	0.041	-0.110*	0.021	0.027	-0.437*	0.077	-0.119*		-0.497*	0.511*
15. Rec. & educ.	-0.109*	0.094	0.049*	0.075	-0.066	0.156°	0.047	-0.021	0.006	-0.207*	0.027	-0.286*	-0.057°	-0.265*		0.272°
16. Miscellaneous	-0.093*	-0.264*	-0.051*	-0.199*	0.291*	-0.119	-0.075°	0.027	-0.032*	0.051	-0.076*	-0.026	0.102*	0.156*	0.145	

a. $\bar{e}_{ij}$= elasticity of the ith commodity with respect to the jth price, estimated at the sample means ($i \neq j$).
b. Clothing also includes footwear.
c. Transportation also includes communication.
* significant at 5% or better. ° significant at 10%.

Table 4. Average Annual Rates of Change in the Estimated Quantity, Relative Price Effect, Real Income Effect, and Time Trend Effect in 1963-1986(%).

Commodity i=	Quantity	Relative Price Effect	Real Income Effect	Time Trend Effect
1. Cereals	-1.611	0.103	-1.792	0.078
2. Livestock products & fish	1.727	0.140	2.866	-1.279
3. Other food	1.546	-0.318	2.780	-0.916
4. Beverages & tobacco	3.333	1.281	3.887	-1.835
5. Eating-out	3.553	-4.243	6.594	1.202
6. Housing	2.075	-4.588	6.151	0.512
7. Electricity & gas	7.391	2.939	0.299	4.153
8. Kerosene, etc.	-1.537	-2.268	0.248	0.483
9. Water charges	6.956	1.090	0.065	5.801
10. Household durables	5.021	2.663	3.602	-1.244
11. Household non-durables	4.061	2.713	3.316	-1.968
12. Clothing [a]	1.372	-0.703	4.689	-2.614
13. Medical care	5.464	2.378	6.402	-3.316
14. Transportation [b]	8.251	0.335	3.430	4.486
15. Rec. & educ.	3.433	-0.241	3.347	0.327
16. Miscellaneous	5.557	1.173	3.836	0.548

a. Clothing also includes footwear.

b. Transportation also includes communication.

water charges (7.0%), miscellaneous (5.6%), medical care (5.5%), household durables (5.0%) and non-durables (4.1%). The high growth rate of demand for transportation is attributable to time trend and real income effects while that for electricity and gas is due to time trend and relative price effects. In addition, increases in demand for the other four commodities, exclusive of water charges, originate from both of an increase in real income and a fall in relative price.

In response to a rise in relative price, on the other hand, the rate of change in quantity per annum turned out to be negative for eating-out (-4.2%), housing (-4.6%), kerosene (-2.3%), clothing (-0.7%), etc. Growth for those commodities is partly cancelled by a negative price effect. They are deemed to be in short supply. Actually, the annual rate of rise in relative price (deflated by the Divisia price index) is estimated at 1.4% for eating-out, 1.7% for housing, and nearly 1.0% for kerosene. If the commodities mentioned above are amply supplied in the market, consumers will be able to afford more consumption of those commodities at lower prices. In this context, the impacts of a relative change in quantity of a commodity on all prices will be estimated with the aid of price flexibilities, which can be obtained as the inverse of the price elasticity matrix in question. Anyway, it seems that there is room for increases in demands and imports of the four commodities so as to reduce their prices.

Meanwhile, the combined effect in growth rate terms with respect to real income and time trend is large for quite a number of commodities, especially for transportation (7.9%), eating-out (7.8%), housing (6.7%), water charges (5.9%), electricity and gas (4.5%), miscellaneous (4.4%), recreation (3.7%), and so forth. Domestic markets such as related to most of these commodities should be more opened to foreign manufactured products and services. In view of the relative importance of real income effect, it is also required that every possible measure be taken to expand the nationwide effective demand and income in the existing economic circumstances.

As regards the empirical test of theoretical restrictions, both of homogeneity and symmetry properties are supported to be acceptable. In testing the homogeneity restriction (3), demand equation (1) is estimated for each commodity, separately, by the ordinary least squares. In each equation with so many explanatory variables, the variances for the estimates of price parameters are large, and so is the variance for the sum of all estimated price parameters. Thus the horizontal sum of the estimated price parameters is not significantly different from zero, so that it is not inconsistent with the homogeneity restriction.

In order to examine the empirical validity of the symmetry restriction (4), the likelihood ratio test is conducted (see Theil (1971) ch.7, Johnston (1984) ch.5). The test statistic is formed as the F ratio in which the numerator is the difference between the symmetry-constrained and the unconstrained residual sums of squares, divided by the number of constraints $g=(N-1)(N-2)/2$, and the denominator is the unconstrained residual sum of squares, divided by the difference between the number of samples and the number of unknown parameters $h=((N-1)T-(N-1)(N+1))$. It follows the F distribution with $g=105$ degrees of freedom in the numerator and $h=90$ degrees of freedom in the denominator if the hypothesis is true. The value of the F ratio is:

$F(g, h)=1.09.$

Now that the F value is below the 5% critical value of 1.46, there is no reason to reject the hypothesis of the symmetry.

Concluding Remarks

A system-wide approach is made to investigate the Japanese consumer behavior in budgeting the total expenditure for the 16 subgroups of commodities for the last three decades. The (aggregate) per capita model with intercept of the Rotterdam system is estimated with the All Household data by Zellner's efficient iterative estimation, yielding maximum likelihood estimates of parameters, together with another per capita model with intercept and family size. The former model fitted the same data set a little better than the latter one, although both of them produced fairly good to satisfactory estimation results. Major results obtained by the original (aggregate) per capita model are summarized as follows.

Regarding the theoretical aspects of the results, the first finding is that the homogeneity of degree zero is not in conflict with the observed data, and that the symmetry property is confirmed to be empirically acceptable. The latter property implies that the integrability condition holds true in reality. The imposition of the three theoretical restrictions on the model gives rise to a considerable gain in the efficiency of parameter estimates, bringing about a large number of statistically significant estimates.

Secondly, the second-order condition of equilibrium is almost satisfied through the estimation period. All eigenvalues but one are found to be negative for the Slutsky substitution matrix of rank (N-1)=15. The whole substitution matrix for the 16 subgroups is composed of fixed parameters over the estimation period, and is uniquely determined to be almost negative semidefinite. So far as the stability condition of the consumer equilibrium holds, the revealed consumption pattern along the locus of the equilibrium points would still persist. It can be examined by the simulation of the model for a certain span of time beyond the estimation period. Practically, the extrapolation test for the 1987-1991 period results in an accuracy of 82% or better except for kerosene, etc. Hence it is indicative of high predictive power of the model.

The empirical features of the results are stated below. First of all, the estimated model shows high measures of goodness-of-fit in terms of multiple correlation coefficient, ratio of estimated to observed quantities, and average information inaccuracy. All of own-price substitution parameters and own-price elasticities of demand proved to be negative, producing evidence to support the law of demand. Eating-out, housing, and medical care are responsive to own-price. Income elasticity is 1.0 or more for 10 commodities while the time trend effect is greater than 1.0% per annum for 4 commodities.

Secondly, relationships of net substitutes and net complements are recognized by estimating a set of Hicksian demand equations. Own- and cross-price effects are brought out in elasticity form without putting specialized restrictions on the demand parameters. For convenience, all effects of nominal price changes are lumped together as the effect of a change in relative price, which is manifested in an annual rate of change in the quantity demanded of each commodity. Then the total change in demand is broken down into the effects of changes in relative price, real income, and time. Increases in the consumption of eating-out, housing, kerosene, and clothing are considered to have been cut down significantly whereas their relative prices rose continuously.

Conclusively, to begin with, imports of the above 4 commodities should be pushed forward to expand the domestic demand and to reduce the large trade surplus. In view of the large shift in demand with respect to real income and time trend, specific markets should be more opened to foreign goods and services which pertain to the lines of automobiles, communication, eating-out, housing, oil products, gas, miscellaneous, recreation, etc. Since many commodities are responsive to real income, much emphasis is placed on increasing disposable income for the expansion of the consumer demand. It is also important to relax or to remove the regulations against the entry of foreign firms into Japanese market. It may be of interest to compare the present results with that of other flexible demand systems.

Notes

1. See Wald (1940) for the detail of his utility indicator.
2. See Lau, Lin and Yotopoulos (1978) for the detail of that system.
3. Recently, there are interesting articles on the choice of functional form (see Barten (1993), Alston and Chalfant (1993)).
4. The left-hand side of equation (1) is one of the three components which compose of a finite change in the average budget share ($\Delta w_{it}=w_{it}-w_{i,t-1}$):

$$\Delta w_{it}=w'_{it}\Delta \log p_{it}+w'_{it}\Delta \log q_{it}-w'_{it}\Delta \log m_t$$

This equation is utilized for the simulation test of the estimated model, given the average budget shares of all commodities in the initial year.
5. A couple of average information inaccuracies are $\bar{I}$=623, and $\bar{I}_c$=1221 (10^{-6} Nits) in the estimation period, where the number of unknown parameters is (N-1)(N+6)/2. The extrapolation test results in the average information inaccuracy $\bar{I}$=2173 (10^{-6} Nits) over the 1987-1991 period.

References

Alston, J.M., and J.A. Chalfant. "The Silence of the Lambdas: A Test of the Almost Ideal and Rotterdam Models." American Journal of Agricultural Economics, 75 (1993):304-313.

Barnett, W.A. "Theoretical Foundations for the Rotterdam Model." Review of Economic Studies, 46 (1979):109-130.

Barten, A.P. "Evidence on the Slutsky Conditions for Demand Equations." Review of Economics and Statistics, 49 (1967):77-84.

Barten, A.P. "Maximum Likelihood Estimation of a Complete System of Demand Equations." European Economic Review, 1 (1969):7-73.

Barten, A.P. "Consumer Allocation Models: Choice of Functional Form." Empirical Economics, 18 (1993):129-158.

Deaton, A.S., and J. Muellbauer. "An Almost Ideal Demand System." American Economic Review, 70 (1980a):312-327.

Deaton, A.S., and J. Muellbauer. Economics and Consumer Behavior, Cambridge University Press, Cambridge, 1980b.

Egaitsu, N. "Econometric Analysis of Changes in Household Demand and Consumer Prices." Journal of Rural Economics, 41 (1969):1-7.

Horie, Y. Studies in Contemporary Japanese Economy, Toyokeizai, Tokyo, 1985. (in Japanese)

Johnston, J. Econometric Methods 3rd ed., McGraw-Hill, New York, 1984.

Kuroda, Y., and P.A. Yotopoulos. "A Study of Consumption Behavior of the Farm Household in Japan — An Application of the Linear Logarithmic Expenditure System —." Economic Review, 30 (1980):1-15.

Lau, L.J., W. Lin, and P.A. Yotopoulos. "The Linear Logarithmic Expenditure System: An Application to Consumption-Leisure Choice." Econometrica, 46 (1978):843-868.

Maki, A. Consumer Preferences and Demand Measurement, Yuhikaku, 1983. (in Japanese)

Maruyama, Y., and K. Sasaki. "Study in Farmer's Economic Activity—An Analysis by Utility Index Function" Journal of Rural Economics, 34 (1963): 241-264.

Mori, H., and B. Lin. "Japanese Demand for Beef by Class: Results of the Almost Ideal Demand System Estimation and Implications for Trade Liberalization." Journal of Rural Economics, 61 (1990):195-203.

Sasaki, K. "The Structure of Food Demand in Japan: An Application of the Rotterdam System." Agribusiness, 9 (1993):425-439.

Sasaki, K. "An Analysis of Consumer Demand in Japan by the Deaton-Muellbauer System." Institute of Socio-Economic Planning D.P.528, University of Tsukuba, Tsukuba, 1993.

Sasaki, K., and Y. Fukagawa. "An Analysis of the Japanese Expenditure Pattern: An Application of a Dynamic Linear Expenditure System to the 1961-1982 Data." Agribusiness, 3 (1987):51-68.

Sasaki, K., and Y. Saegusa. "Food Demand Matrix in an Approximate Linear Expenditure System." American Journal of Agricultural Economics, 56 (1974):263-270.

Sato, K. "On Japan's Household Utility Function and Consumer Demand." Economic Review, 21 (1970):10-20.

Sato, K. "Additive Utility Functions with Double-Log Consumer Demand Functions." Journal of Political Economy, 80 (1972):102-124.

Sawada, M. "A Hierarchical Model of Demand for Food in Japan." Journal of Rural Economics, 56 (1984):163-173.

Sawada, Y. "Estimating Substitutional Relationships of Meat Demand: An Approach by Rotterdam Model." Journal of Rural Economics, 52 (1980):101-109.

Theil, H. "The Information Approach to Demand Analysis." Econometrica, 33 (1965):67-87.

Theil, H. Principles of Econometrics, New York: John Wiley & Sons, Inc., 1971.

Theil, H. Theory and Measurement of Consumer Demand I, II, North-Holland, Amsterdam, 1975, 1976.

Theil, H., and K.W. Clements. Applied Demand Analysis: Results from System-Wide Approaches, Ballinger Publishing Co., Cambridge, MA, 1987.

Tsujimura, K. The Theory of Consumer Behavior, Yuhikaku, Tokyo, 1964. (in Japanese)

Tsujimura, K. Consumption Structure and Prices, Keisoshobo, Tokyo, 1968. (in Japanese)

Tsujimura, K., and M. Kuroda. General Equilibrium Analysis of Japanese Economy, Chikumashobo: Tokyo, 1974. (in Japanese)

Tsujimura, K., and T. Sato. "Irreversibility of Consumer Behavior in Terms of Numerical Preference Fields." Review of Economics and Statistics, 46 (1964):305-319.

Wald, A. "The Approximate Determination of Indifference Surfaces by Means of Engel Curves." Econometrica, 8 (1940):144-175.

Yoshihara, K. "Demand Functions: An Application to the Japanese Expenditure Pattern." Econometrica, 37 (1969):257-274.