

# THE DEMAND FOR INPUTS INTO U.S. HOUSEHOLD PRODUCTION, 1948-85

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## I. INTRODUCTION

This paper examines the structure of household demand for a set of inputs used in household production.<sup>1</sup> The set of inputs considered here is "derived" from maximization of a hybrid household-utility function. The hybrid utility function results from substituting a household production into a standard ordinal household utility function(Pollak and Wachter, 1975).

The set of inputs consists of domestic services, services of household durable goods, commercial laundry and cleaning services, food away from home, wife's home time, and residual category. There has been a marked change of expenditure shares of these inputs since 1945 in the United States. Among them, the decreasing trends of shares for domestic services and wife's home time are remarkable. The share of domestic services (wife's home time) in household consumption expenditures has decreased from 1.2%(19.7%) in 1947 to 0.34%(10.1%) in 1985. The share for services of household durable goods has also decreased after the late 1950s.

For the empirical analysis, an almost ideal demand system(AIDS) is developed and estimated. In the specified demand system for inputs, each of the expenditure share equations is a function of the prices of the above inputs, household income(expenditure), and a variable for technical change. The demand system is fitted to U.S. aggregate data for 1948-1985.

Expenditures on the services of household durable goods, rather than on new durable goods, are the correct measure of durables to consider in a household input demand system. In this study, the data on expenditures on the services were obtained and used. The change in concept is shown to be important empirically. The elasticities are much different for expenditures on services than for expenditures on new durable goods.

The paper is organized as follows. The second section presents the econometric

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<sup>1</sup>A critical survey and theoretical discussions on the household production model were given in Kim(1986, 1987), respectively.

model of household expenditure. The third section details the stochastic specification of the model and estimation procedure. The fourth section contains a discussion of the empirical findings and implications. The final section presents the conclusion.

## II. SPECIFICATION OF AN ECONOMETRIC MODEL

Ever since Richard Stone(1954) first estimated a system of demand equations derived explicitly from consumer demand theory, there has been a continuing search for alternative specifications and functional forms. Many models have been used, but perhaps the most important in current use, apart from the original linear expenditure system, are the Rotterdam model(Theil, 1965, 1976; Barten, 1969) and the translog model(Christensen, Jorgenson, and Lau, 1975; Jorgenson and Lau, 1975). For more details about surveys and comprehensive treatments of demand systems, see Brown and Deaton(1972), Barten(1977), and Deaton and Muellbauer(1980b). Recently another demand system, so-called Almost Ideal Demand System(AIDS) was proposed by Deaton and Muellbauer(1980a) as a solution to some of shortcomings of the other demand systems. Because of theoretical and empirical advantages, the AIDS has been perceived as a very useful tool in demand analysis(Ray, 1980; Barewal and Goddard, 1985; Blanciforti, Green, and King, 1986). In this study, the specification of the household input demand system is assumed to be the almost ideal demand system.

### 1. *Almost ideal demand system (AIDS)*<sup>2</sup>

Along with the theorems of Muellbauer(1975, 1976) which allow the exact aggregation over individual households, AIDS is derived from the necessary and sufficient conditions for the existence of a representative budget level. Thus market input demand functions can be represented as if they were the outcome of rational decisions by a representative household. These preferences, known as the PIGLOG(price independent generalized logarithm) class, are represented via the cost or expenditure function which defines the minimum expenditure necessary to attain a specific utility level at given prices. We denote this function  $c(u,p)$  for utility  $u$  and price vector  $p$ , and define the PIGLOG class as

$$(1) \log c(u,p) = (1-u) \log \{a(p)\} + u \log \{b(p)\}$$

<sup>2</sup>The name of the system stems from the properties associated with it. Deaton and Muellbauer(1980a, p.312) list the following advantages of the system: 1) it gives an arbitrary first-order approximation to any demand system; 2) it satisfies the axioms of choice exactly; 3) it aggregates perfectly over consumers without invoking parallel linear Engel curves; 4) it has a functional form which is consistent with known household-budget data; 5) it is simple to estimate, largely avoiding the need for non-linear estimation; and 6) it can be used to test the restrictions of homogeneity and symmetry through linear restrictions on fixed parameters.

where  $u$  lies between 0(subsistence) and 1(bliss) so that the positive linearly homogenous functions  $a(p)$  and  $b(p)$  can be regarded as the costs of subsistence and bliss, respectively. (About this point, see the Appendix of Deaton and Muellbauer(1980a).) Deaton and Muellbauer proposed the following specific functional forms for  $\log a(p)$  and  $\log b(p)$ ,

$$(2) \log a(p) = \alpha_0 + \sum_k \alpha_k \log p_k + 1/2 \sum_k \sum_j r_{kj}^* \log p_k \log p_j$$

$$(3) \log b(p) = \log a(p) + \beta_0 \prod_k p_k^{\beta_k}$$

so that the AIDS cost function is written

$$(4) \log c(u, p) = \alpha_0 + \sum_k \alpha_k \log p_k + 1/2 \sum_k \sum_j r_{kj}^* \log p_k \log p_j \\ + u \beta_0 \prod_k p_k^{\beta_k}$$

Here  $\alpha_i$ ,  $\beta_i$ , and  $r_{kj}^*$  are parameters. It can easily be checked that  $c(u, p)$  is linearly homogenous in  $p$ , provided  $\sum \alpha_i = 1$ ,

$$\sum_j r_{kj}^* = \sum_k r_{kj}^* = \sum_j \beta_j = 0$$

The demand functions can be derived from equation(4). A fundamental property of the cost function (Shephard, 1953; Diewert, 1974) is that its price derivatives are the demand functions:  $\partial c(u, p) / \partial p_i = q_i$ . Multiplying both sides by  $p_i / c(u, p)$  we obtain

$$(5) \partial \log c(u, p) / \partial \log p_i = p_i q_i / c(u, p) = w_i$$

where  $w_i$  is the budget share of input  $i$ . Hence, logarithmic differentiation of (4) gives the budget shares as a function of prices and utility:

$$(6) w_i = \alpha_i + \sum_j r_{ij} \log p_j + \beta_i u \beta_0 \prod_k p_k^{\beta_k}$$

where

$$(7) r_{ij} = 1/2 (r_{ij}^* + r_{ji}^*).$$

For a utility-maximizing household, total expenditure  $E$  is equal to  $c(u, p)$ , and when  $c(u, p)$  is a single valued function, this equality can be solved for  $u$  as a function of  $p$  and  $E$ , the indirect utility function. If we do this for(4) and substitute

the result into (6) we have the budget shares as a function of  $p$  and  $E$ ; these are the AIDS demand functions in the budget share form:

$$(8) \quad w_i = \alpha_i + \sum_j r_{ij} \log p_j + \beta_i \log (E/P)$$

where  $P$  is a price index defined by

$$(9) \quad \log P = \alpha_0 + \sum_k \alpha_k \log p_k + 1/2 \sum_j \sum_k r_{kj}^* \log p_k \log p_j$$

The restrictions on the parameters of (4) plus equation (7) imply restrictions on the parameters of the AIDS equation (8). The three sets of conditions are:

$$(10) \quad \sum_i \alpha_i = 1, \sum_i r_{ij} = 0, \sum_i \beta_i = 0,$$

$$(11) \quad \sum_j r_{ij} = 0,$$

$$(12) \quad r_{ij} = r_{ji}$$

Provided (10), (11), and (12) hold, equation (8) represents a system of demand functions which add up to total expenditure ( $\sum_i w_i = 1$ ), are homogenous of degree zero in prices and total expenditure taken together, and which satisfies the Slutsky symmetry conditions.

### III. ESTIMATION

#### 1. Specification of an econometric model

In general, a functional form that can be fitted to data can be obtained by substituting (9) into (8) to give

$$(13) \quad w_i = (\alpha_i - \beta_i \alpha_0) + \sum_j r_{ij} \log p_j + \beta_i \left\{ \log E - \sum_k \alpha_k \log p_k - 1/2 \sum_k \sum_j r_{kj} \log p_k \log p_j \right\}.$$

Estimates of the parameters, i.e.,  $\alpha$ s,  $r$ s,  $\beta$ s, in this nonlinear system of equations can be obtained by applying the maximum likelihood methods. (Note that since the data add up by construction, (10) is not testable.) As Deaton and Muellbauer (1980a) suggest, it is possible to exploit the collinearity of the prices to obtain a much simpler empirical equation. Note from (8) that if  $P$  were known, the model would be linear in the parameters  $\alpha$ ,  $\beta$ , and  $r$ s, and estimation (at least without cross equation restrictions such as symmetry) can be done equation-by-

equation by applying OLS. Given normally distributed errors, OLS is equivalent to maximum likelihood estimation for the system as a whole. The adding-up constraints (10) will be automatically satisfied by these estimates. In situations where prices are closely collinear, it may well be adequate to approximate  $P$  as proportional to some known, price index, say  $P^*$ . The obvious candidate in view of (8) and (9) is Stone's (1953) index,  $\log P^* = \sum_k W_k \log P_k$ . If  $P \cong \phi P^*$ , then (8) can be written as

$$(14) \quad w_i = (\alpha_i - \beta_i \log \phi) + \sum_j r_{ij} \log p_j + \beta_i \log (E/P^*).$$

In equation (14) this framework, the  $\alpha_i$  parameters are identified only up to a scalar multiple of  $\beta_i$ . If we write  $\alpha_i = (\alpha - \beta \log \phi)$ , it is easily seen that  $\sum_k \beta_k = 0$  implies  $\sum_k \alpha_k^* = 1$ .<sup>3</sup> The empirical work below is based on a linear approximation to (14).

Household production seems likely to be affected by "embodied" and "disembodied" technical change. Prime sources of embodied technical change are new household durable goods. The impact of embodied technical change on household production may be incorporated in the effects on consumer demand through the prices or services of durable goods.

The efficiency of household production may be enhanced by "disembodied" technical change. It causes an increase in real household income although relative prices and real cash income are held constant. A proxy for this technical change could be patents of consumer durables.

The technology variable may also solve some statistical problems encountered in empirical demand studies. Deaton and Muellbauer (1980a) found that imposing homogeneity restrictions introduced serial correlations in the disturbances of the demand equations, and lead to a rejection of homogeneity. They argued that such a phenomenon occurred due to the misspecification of the model caused by omitting some relevant variables, such as lagged dependent variables, or time trends. The hypothesis presented here is that the left-out variable is proxied by inventive activity directed at new inputs for household production.

Finally, the econometric model to be estimated is specified as follows:

$$(16) \quad w_i = \alpha_i^* + \sum_j r_{ij} \log p_j + \beta_i \log (E/P^*) \\ + \delta_i \log T + e_i, \quad i = 1, 2, \dots, 6$$

where  $i$  represent a particular household input group, and  $T$  stands for technology in household production.

<sup>3</sup>Many studies, notably Ray (1980), Blanciforti, Green, and King (1986), Goddard (1983), as well as Deaton and Muellbauer (1980a) have reported success in using this linear approximation, especially in case of time series data analysis.

## 2. Data

Annual data for the years 1948 to 1985 are used for the empirical work. Earlier data are excluded from the analysis because the Great Depression and World War II years present unusual circumstances.

Consumer expenditure series for domestic services, dry cleaning and laundry services, food away from home, and a residual input were taken from the National Income and Products Accounts published by the U.S. Department of Commerce. Expenditures for wife's home time and for services of household durables were derived.

The implicit expenditure for women's home time ( $EXP_{hp}$ ) is derived as follows:

$$(15) \quad EXP_{hp} = (1 - FLFR) W_f$$

where FLFR is the (married) female labor participation rate, and  $W_f$  is the female earnings. Data for female labor force participation rate and for earnings were taken from the Current Population Survey.

Services are the relevant input provided by the stock of household durable goods.<sup>4</sup> There are two general approaches to measuring the value of services of household durable goods: (i) the opportunity cost measure, and (ii) the user-cost measure. In both measures, the value of services is estimated by summing the costs incurred by the owner of the durable goods.

In the opportunity cost measure, the rate of return, which reflects the productivity of capital, is applied to the average value of the net stock to derive a net return, and depreciation and operating costs (e.g., expenditures on repair and maintenance) are added. In terms of a single durable, this measure can be expressed in the following form:

$$(17) \quad C_{s,t} = r_t(P_{s,t} + P_{s+1,t+1})/2 + D_{s,t} + O_{s,t}$$

where  $C_{s,t}$  is the service value of an  $s$  year old durable in year  $t$ ,  $r_t$  is the average rate of return in year  $t$ ,  $P_{s,t}$  is the purchase price of an  $s$  year old durable at the beginning of year  $t$ ,  $D_{s,t}$  is depreciation on an  $s$  year old durable in year  $t$ , and  $O_{s,t}$  are operating costs associated with an  $s$  year old durable in year  $t$ .

The user-cost measure provides an estimate of the market rental price based on costs of owners. It is directly derived from the principle that the purchase price of a durable equals the discounted present value of its expected future benefits. This measure can be expressed in the following form:

$$(18) \quad C_{s,t}^e = r_t^e P_{s,t} + (P_{s,t} - P_{s+1,t+1}^e)$$

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<sup>4</sup>The discussion in this part heavily depends upon Katz(1982, 1983) and Katz and Peskin(1980). I am thankful to Arnold Katz for providing the basic materials and giving valuable suggestions.

where  $C_{s,t}^e$  is the expected serve value of an  $s$  year old durable in year  $t$ ,  $r_t^e$  is the expected rate of return in year  $t$ , and  $P_{s+1,t+1}^e$  is the expected purchase price of this durable at the beginning of year  $t+1$  when it is  $s+1$  years old. Equation (18) states that in equilibrium the annual service value that a household expects to receive from owning a durable equals the costs that the household expects to bear from not selling it at the beginning of the year, i.e., foregone interest, plus the expected decline in the market value of the durable during the year. The expected decline in purchase price is usually partitioned into expected depreciation and expected capital losses, where the capital loss(gain) component represents the change in the price of asset due to changes in the price levels.

In this study, the user-cost measure is employed to estimate the service value of durable goods. User cost measure has advantages such as: i) the basic data are relatively easier to obtain with small measurement errors, and ii) it is possible to consider the price expectations into the household decisions for purchasing durable goods. The procedures are explained in detail in Katz(1982, 1983). As Katz reported, the series of service values are affected by using different assumptions about some procedures of estimatins, such as the relative efficiency(the ratio of service value of an old durable to that of a new durable) and expected inflation. The series actually employed for the empirical analysis is obtained assuming that the relative efficiency of capital is decreasing geometrically, and the household's expectation of inflation is "adaptive".

The definitions and the items covered in the six household expenditure groups are summarized in Table 1. Total expenditure on inputs for household production ( $E$ ) is the summation of expenditures on (i) domestic services, (ii) household durable good services, (iii) cleaning and laundry services, (iv) food away from home, (v) wife's home time, and (vi) residual inputs. The dependent variables in the demand system are the input expenditure shares. An implicit nominal price series for each input( $P_k$ ) is obtained by dividing current dollar expenditures on the input by the constant dollar expenditure. The implicit price index for all inputs into household production is defined as  $\log p^* = \sum w_k \log P_k$ , where  $P_k$  is the implicit price index for the  $k$ -th input and  $w_k$  is the expenditure share. The budget or expenditure constraint is  $E/P^*$ . A proxy for technology in the household sector is the cumulative number of U.S. household related patents. These data were supplied by the U.S. Patent and Trade Mark Office.<sup>5</sup>

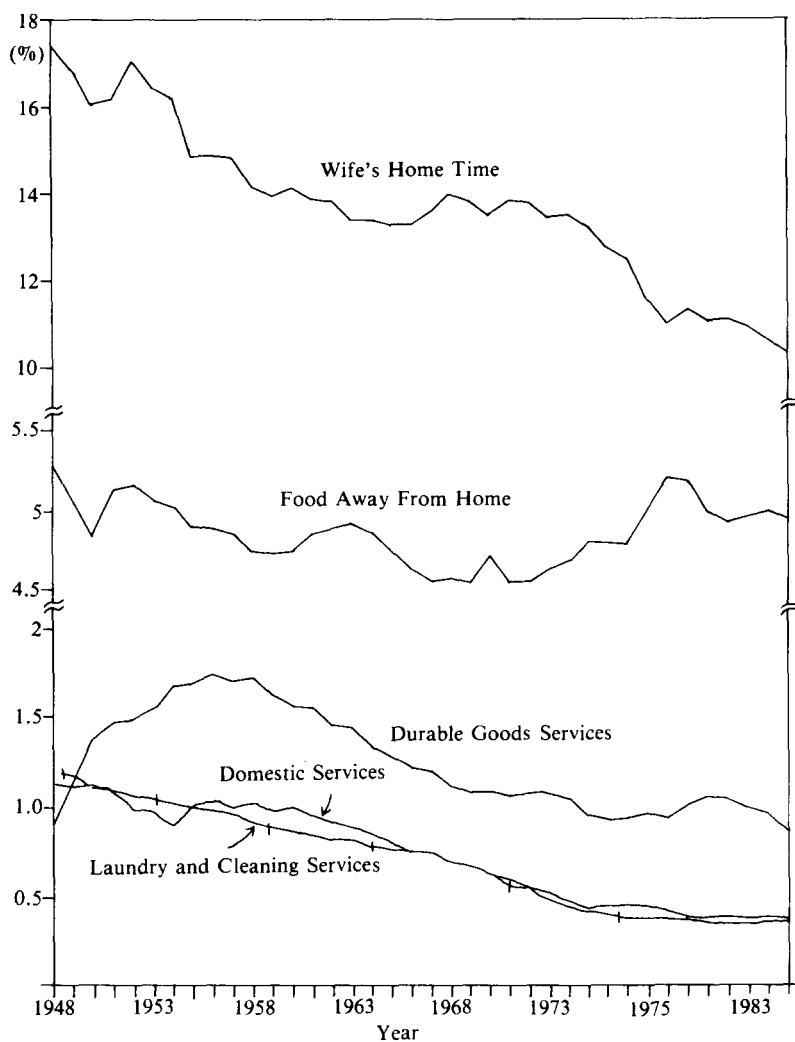
Figure 1 presents the basic trends of the weights over the period 1948-1985. In the Figure, the expenditure shares for wife's home time, domestic services, and commercial cleaning and laundry services are decreasing over time. The share for services of durable goods is also decreasing after the late 1950s. No apparent trend exists for the expenditure share on food away from home.

<sup>5</sup>The number of patents used in this study are the ones granted by the U.S. Patent Office. Some of them are foreign patents. The share of foreign patents is not significant, but it is increasing steadily.

**[Table 1]** Expenditure Groups and Definitions

Expenditure Group i	Classification in NIPA	Definitions
(1) Domestic Services	Domestic Service	Expenditures on purchasing household operation service by domestic (private) household workers, excluding child care workers.
(2) Durables Services	i) Kitchen and other household appliances ii) China, glassware tableware, and utensils iii) Other durable house furnishing	Services provided by the Stock of household durables, estimated by eq. (18). i) Includes refrigerators, freezers, cooking ranges, dish washers, laundry equipments, heater, air conditioners, sewing machines, vacuum cleaners, other electric appliances. iii) Includes principal house furnishings such as floor covering, hand, power and garden tools.
(3) Cleaning and Laundry Services	i) Cleaning, storage, and repair of clothing and shoes ii) Other clothing	Expenditures for cleaning, laundering, storage, repair, and miscellaneous personal services related to clothing
(4) Food away from Home	Purchased meals and beverages	Expenditures for purchases of meals and beverages from retail, services, and hotel, school, institutions, and industrial lunchrooms, and also tips.
(5) Expenditure on Wife's Home Time		Implicitly obtained by the formula (15).
(6) Residual Consumption Expenditure		Total consumption expend. plus (2) minus expend. on durables, (1), (3), (4), and (5).
Total Consumption Expenditures		(1) + (2) + (3) + (4) + (5) + (6)





[Figure 1] Trends of Household Expenditure Shares

#### IV. EMPIRICAL RESULTS AND IMPLICATIONS\*

In this section, we examine estimates of the AIDS for household inputs that is fitted to U.S. aggregate data, 1948-85. Table 2 reports the results from fitting equation (16) when constraints on the parameters are not imposed. In the column headed  $\sum_j r_{ij}$ , the row sums of the unconstrained  $r_{ij}$  matrix shows  $10^2$  times the

\*In this study, we also estimated the specified demand system (16) using the expenditure on the household durable goods. The results are reported and interpreted briefly in Appendix 5.2 of Kim(1987). Both results are largely consistent with each other except the equation of value of services provided by the household durable goods stock. For more details, see Appendix 5.2.

absolute effect on each expenditure share of a 1% increase in all prices and total expenditure. Under homogeneity, this number should be zero. For the durable goods services and food consumption away from home, homogeneity is rejected at 5% significance level among the six equations. For the other input groups, the coefficients are each not significantly different from zero at 5% level. The results imply that a proportional increase in prices and income or expenditure increases the demand for household durable goods services and food consumption away from home. This results support the notion that adding conditioning variables (T which represents technology in this study) contributes to the acceptance of the homogeneity hypothesis. Table 3 reports the parameter estimates when the homogeneity restrictions are imposed in the estimation process.

When symmetry of  $r_{ij}$  is imposed on the equation system, the expenditure equations must be estimated jointly and not equation-by-equation.<sup>7</sup> Because the dependent variables sum to unity across the equations, the variance-covariance matrix is singular for the  $m$  equations system. This means that one equation can be deleted from the system of equations, and estimates of the coefficients can be recovered from the coefficients of the other  $m-1$  equations. When the coefficients of the  $m-1$  equations are estimated by full-information maximum likelihood or iterative seemingly unrelated methods, the estimates are unaffected by the choice of the equation to delete (Barten, 1969; Kmenta and Gilbert, 1968).

[Table 2] Unconstrained Maximum Likelihood Estimates of the Household Expenditure System. U.S., 1948-1985

Input/ Equation i	Coefficients										R <sup>2</sup> D-W
	$\alpha_i$	$r_{11}$	$r_{12}$	$r_{13}$	$r_{14}$	$r_{15}$	$r_{16}$	$\beta_i$	$\delta_i$	$\sum_j r_{ij}$	
(1) Domestic Service	0.02277 (0.39)*	-0.00137 (-0.52)	0.00194 (1.21)	0.00555 (1.58)	-0.00428 (-0.65)	-0.01071 (-1.27)	0.00513 (1.27)	-0.00342 (-0.70)	0.00265 (0.37)	-0.00006 (-1.38)	0.98 2.00
(2) Durables Service	-0.03069 (-0.76)	-0.00303 (-1.69)	0.01102 (9.98)	-0.00932 (-3.86)	0.00273 (0.60)	0.01927 (3.30)	-0.01653 (-5.93)	-0.01053 (-3.12)	0.00006 (1.98)	0.99 1.05	
(3) Cleaning, Laundry	0.08856 (3.72)	-0.00436 (-3.30)	-0.00015 (-0.23)	0.00595 (4.22)	-0.00963 (-3.63)	0.00593 (1.74)	0.00065 (0.40)	0.00438 (2.22)	-0.01027 (-3.53)	-0.00001 (-0.67)	0.99 2.12
(4) Food away from Home	0.59567 (3.99)	-0.00648 (-0.99)	-0.00580 (-1.43)	0.00552 (0.63)	0.00797 (0.48)	0.03859 (1.81)	-0.01919 (-1.88)	0.01529 (1.24)	-0.06481 (-3.57)	-0.00031 (2.72)	0.99 1.67
(5) Wife's Home Time	1.38564 (2.01)	0.00744 (0.25)	-0.03433 (-1.84)	-0.04723 (1.16)	-0.02517 (-0.33)	0.02049 (0.21)	0.05714 (1.21)	0.0030 (0.06)	-0.09577 (-1.14)	-0.00032 (-0.70)	0.99 1.92
(6) Residual Consum.	-1.06177 (-1.60)	0.00689 (0.24)	0.02733 (1.52)	0.03952 (1.00)	0.02839 (0.38)	-0.07357 (-0.78)	-0.02720 (-0.60)	-0.00903 (-0.16)	0.15834 (1.95)	0.00002 (0.05)	0.99 2.01

\*The t-ratios are in parentheses.

<sup>7</sup>Deaton and Muellbauer(1980a) noted that it is a matter of choice to impose symmetry when homogeneity is rejected. Mizon(1977) criticized this procedure and suggested that optimal inference requires that further testing be abandoned as soon as a rejection is encountered. But this criticism would be correct if we were certain of the maintained hypothesis. Many economists would choose not to test homogeneity, treating absence of money illusion as a maintained hypothesis.

**[Table 3]** Maximum Likelihood Estimates of the Household Expenditure System, Homogeneity Restrictions Imposed, U.S., 1948-1985

Input/ Equation i	Coefficients									R <sup>2</sup>	D-W
	$\alpha_i$	$r_{i1}$	$r_{i2}$	$r_{i3}$	$r_{i4}$	$r_{i5}$	$r_{i6}$	$\beta_i$	$\delta_i$		
(1) Domestic Service	0.07893 (1.79)*	-0.00193 (-0.74)	0.00276 (1.83)	0.00666 (1.93)	-0.00084 (-0.14)	-0.00657 (-0.82)	-0.00009 (-0.06)	0.00022 (0.05)	-0.00646 (-2.03)	0.99	2.02
(2) Durables Service	-0.09317 (-2.92)	-0.00240 (-1.27)	0.01010 (9.22)	-0.01055 (-4.21)	-0.00108 (-0.24)	0.01467 (2.52)	-0.01074 (-9.20)	-0.01457 (-4.78)	0.01997 (8.68)	0.99	1.30
(3) Cleaning, Laundry	0.09920 (5.72)	-0.00357 (-3.48)	0.00001 (0.01)	0.00616 (4.53)	-0.00898 (-3.68)	0.00672 (2.12)	-0.00034 (-0.53)	0.00507 (-9.59)	-0.01200 (-1.62)	0.99	2.26
(4) Food away from Home	0.28520 (2.30)	-0.00333 (-0.45)	-0.01037 (-2.44)	-0.00061 (-0.06)	-0.01102 (-0.63)	0.01566 (0.69)	0.00966 (2.13)	-0.00484 (-0.41)	-0.01444 (-1.62)	0.99	1.41
(5) Wife's Home Time	1.71201 (3.41)	0.00413 (0.14)	-0.02953 (-1.72)	-0.04079 (-1.04)	-0.00521 (-0.07)	0.02681 (0.49)	0.02447 (1.46)	-0.14871 (0.51)	0.99 (-4.11)	1.92	
(6) Residual Consum.	-1.0827 (-2.25)	0.00710 (0.25)	0.02703 (1.64)	0.03912 (1.04)	0.02714 (0.40)	-0.07508 (-0.86)	-0.02530 (-1.44)	-0.01035 (-0.23)	0.16164 (4.67)	0.99	2.01

\*The t-ratios are in parentheses.

The null hypothesis that all symmetry conditions hold jointly can not be rejected at the 5% significance level.<sup>8</sup> The sample value of chi-square( $X^2$ ) is 10.0 and the critical value with 10 degrees of freedom at the 5% significance level is 18.3. Table 4 reports the results homogeneity and symmetry restrictions are imposed.

The interpretation of the parameters of the AIDS model are as follows; the estimated  $r_{ij}$ s represent  $10^2$  times the effect on the  $i$ -th expenditure(budget) share of a 1% change in the price of the  $j$ -th input, holding "real" expenditure ( $E/P$ ) constant. The estimates of the  $r_{ij}$ s are in general positive for substitutes and negative for complements, and the  $r_{ii}$ s are positive for price-inelastic inputs and negative for price-elastic inputs. Luxury inputs are identified by a positive  $\beta_i$ ; necessities have negative  $\beta_i$ s.

The price, expenditure, and technology elasticities for the AIDS model are defined in equations(20)-(23).

$$(20) \quad e_{ii} = -1 + r_{ii}/w_i - \beta_i(20)$$

$$(21) \quad e_{ij} = (r_{ij} - \beta_i w_j)/w_i$$

$$(22) \quad e_{iE} = 1 + \beta_i/w_i$$

$$(23) \quad e_{iT} = \delta_i/w_i$$

<sup>8</sup>The symmetry hypothesis can be tested using the chi-square ( $x^2$ ) statistic

$$N (\ln/\Sigma_R - \ln/\Sigma_U) - x^2 (df),$$

where  $\Sigma_R$  and  $\Sigma_U$  are the determinants of the covariance matrices of restricted and unrestricted models, respectively, and  $N$  is the number of observations and  $df$  is the number of degrees of freedom which equals the number of restrictions imposed.

**[Table 4]** Maximum Likelihood Estimates of the Household Expenditure System, Homogeneity and Symmetry Restrictions Imposed, U.S., 1948-1985

Input/ Equation i	Coefficients								R <sup>2</sup>	D-W
	$\alpha_i$	$r_{i1}$	$r_{i2}$	$r_{i3}$	$r_{i4}$	$r_{i5}$	$\beta_i$	$d_i$		
(1) Domestic Service	0.08530 (2.27)*	-0.004048 (-1.75)	0.000845 (0.73)	-0.003432 (-3.92)	-0.001384 (-0.31)	0.009759 (1.75)	0.001306 (0.33)	-0.007749 (-3.07)	0.94	1.71
(2) Durables Service	-0.05207 (-1.45)	0.000845 (0.73)	0.009671 (7.98)	0.000350 (0.66)	-0.006579 (-2.08)	0.005457 (1.27)	-0.014810 (-5.00)	0.016820 (7.05)	0.95	1.17
(3) Cleaning, Laundry	0.09165 (5.59)	-0.003432 (-3.92)	0.000350 (0.66)	0.005105 (4.31)	-0.008442 (-3.91)	0.006631 (2.33)	0.004833 (3.12)	-0.011190 (-9.99)	0.99	2.13
(4) Food away from Home	0.19998 (1.91)	-0.001384 (-0.31)	-0.006579 (-2.08)	-0.007956 (-3.91)	0.012990 (-0.49)	-0.006161 (0.70)	-0.006161 (-0.55)	-0.006528 (-0.95)	0.96	1.50
(5) Wife's Home Time	1.01190 (5.26)	0.009759 (1.75)	0.005457 (1.27)	0.0906631 (2.33)	0.012999 (0.70)	-0.080190 (-2.71)	0.031920 (1.03)	-0.099620 (-5.41)	0.96	1.70

\*The t-ratios are in parentheses.

**[Table 5]** Estimates Price, Expenditure, and Technology Elasticities of Demand for Inputs in the Household Expenditure System, U.S., 1948-1985

Input/ Equation i	Prices					Expen- diture	Tech- nology
	$p_1$	$p_2$	$p_3$	$p_4$	$p_5$		
(1) Domestic Service	-1.561	0.115	-0.476	-0.200	1.324	1.181	1.089
(2) Durables Service	0.078	-0.190	0.037	-0.482	0.616	0.878	1.374
(3) Cleaning, Laundry	-0.496	0.042	-0.274	-1.242	0.854	1.692	-1.632
(4) Food away from Home	-0.028	-0.134	-0.173	-1.162	0.284	0.873	-0.135
(5) Wife's Home Time	0.070	0.037	0.047	0.083	-1.616	1.233	-0.735

where  $e_{ij}$ ,  $e_{ij}$ ,  $e_{iE}$ , and  $e_{iT}$  are the own-price, cross-price, expenditure, and technology elasticities, respectively. The NIPA implicit deflator, a Paasche Index, is used for  $p^*$ . (For derivations, see Appendix 5.1. of Kim(1987).)

The estimates of the price, expenditure, and technology elasticities for this data set are presented in Table 5. The coefficients were taken from Table 4, and sample mean values of the  $w_i$ 's were employed. The estimates in the Tables 4 and 5 are reasonable. All own-price elasticities(regression coefficients) have the right signs and 17 (20) out of the 35 regression coefficients are statistically significant at 5% (10%) level. The technology variable — the cumulative number of patents for household-related goods — has regression coefficients that are generally significantly different from zero.

The estimates of  $\beta_i$  classify domestic services, cleaning and laundry services, and wife's home time as luxuries, but services of household durable goods, and food consumption away from home as necessities.<sup>9</sup> Within this six input expen-

<sup>9</sup>This classification scheme applies only to the six commodity system, i.e., the weight summation of the expenditure elasticities for these six commodities sum to one. The luxury-necessity classification might be different if more commodities were included.

diture system, the luxury-necessity classification is reasonable. As general economic growth occurs, productive activities are shifted from the household to the market sector and other outside activities, e.g., social activities, travelling. Also, the females' labor force participation rate is generally increased. Such economic growth has resulted in changes in the traditional food consumption patterns, i.e., from home prepared meals to restaurant prepared meals. The results in this study is consistent with a Canadian study (Goddard, 1983).

The expenditure share for wife's home time is increased as total household expenditures increase. The share decreases as the wage rates for female increases. However, the increased real household income(expenditure) increased the total quantity demanded of wife's home time, other things equal, i.e., the demand curve shifted to the right. The second result shows that household production-consumption becomes relatively less femaletime intensive when the opportunity cost of their time increases. It also implies that the demand curve for wife's home time has a negative slope. In fact the wage elasticity of demand for women's time is quite large, -1.62, showing that households are very responsive to the opportunity cost of women's time.

Both the own-price and expenditure elasticities of demand for domestic services are large. The own-price elasticity is -1.56, and the expenditure elasticity is 1.18. The cross price coefficients and elasticities show that household durable goods services( $e_{12}=0.12$ ) and wife's home time( $e_{15}=1.32$ ) are substitutes for domestic services, and cleaning and laundry services( $e_{13}=-0.48$ ) and food consumption away from home ( $e_{14}=-0.20$ ) are complements to domestic services. The complementary relationships may seem surprising, but the determination is an empirical rather than a theoretical issue.

The main reason for employing domestic (private) household workers is for housekeeping, mainly house cleaning and miscellaneous household operation, for the working married women, or for old, disabled persons. The expenditure on cleaning and laundry is tied to clothing, not with other household operations. Moreover the major portion of the expenditure is for high quality laundry services (e.g., dry cleaning) which is an unlikely substitute for domestic services. Thus, the increasing real wage rates and labor force participation of women has resulted in changes in household demand for inputs so that domestic services and cleaning-and-laundry services are complements in household production. A similar line of reasoning can be applied to explain the complementary relationships between domestic services and food away from home.

The disembodied technical change in the household production which is proxied by an increase in patenting activity for consumer goods, has caused the budget share for domestic services to decrease. The technology elasticity of demand for domestic services is -1.09. The embodied technical change could be picked up by the changes in the household demand structure caused by the change in prices of the durable inputs services. During the time period under study, the technological

progress in the food, textile, and electricity industries is remarkable. Many new consumer goods are equipment and materials that are saving on the home time of wives (and other household members). The continuous substitution and technical change may largely explain the declining budget share of domestic services over time.

The estimates of the coefficients and elasticities of the demand for household durable goods services are reasonable and are significantly different from the ones for expenditures on new household durable goods. The own-price elasticity of demand for services is -0.19, and the expenditure elasticity is 0.88. (See Appendix 5.2 of Kim (1987) for comparison of these results with results obtained using expenditures on new durable goods.) According to the data in the *Surveys of Current Business*, the real stock of consumer durables per household increased about three times during the last four decades. Expenditure on new durable goods (investment) can be own-price elastic, but expenditures on capital services can be price inelastic.

The estimated other price coefficients and their elasticities show that domestic service, cleaning and laundry services, and wife's home time are substitutes for household durable goods services. This provides additional evidence of households substituting household durables for domestics and wife's time in household production-consumption as the relative price of capital services have fallen. This is an appealing finding and consistent with arguments developed and evidence presented by Bryant (1986). The complementary relationship between services of household durable goods and food away from home ( $e_{24} = -0.48$ ) was hinted at above. The weak cross price relationshi between services of household durables and cleaning and laundry ( $e_{23} = 0.04$ ) may be attributed to high quality commercial laundry services being a very different commodity than that produced at home. The technology elasticity of demand for the services of household durable goods is larger than one ( $e_{2T} = 1.37$ ). Thus, increase in inventive activity increases the budget share spent of services of household durable goods.

The own-price elasticity of demand for cleaning and laundry services is relatively small ( $e_{33} = -0.27$ ), but the expenditure elasticity is relatively large ( $e_{3E} = 1.69$ ). An increase in inventive activity decreases the relative share of household expenditures on cleaning and laundry services ( $e_{3T} = -1.63$ ).

The own-price elasticity of demand for food away from home is -1.16, and the expenditure elasticity is 0.87. Thus, although there is evidence from other studies that the income elasticity of demand for food away from home is relatively large and is larger than one, these results do not support that conclusion. This study shows that expenditure elasticities are larger for domestic services and cleaning-and-laundry services. Increased inventive activity reduces the budget share spent on food away from home, but it also shifts to the right the demand for food away from home.

The demand for wife's time is highly price or wage elastic, and the large wage

elasticity is consistent with the large increase in labor force participation and average hours of market work of women over the period of analysis. An increase of household expenditure or income, holding the wife's wage constant, however, shifts the demand curve for wife's home time to the right. Thus, over the sample period rising real household income(expenditure) has been a mitigating force to increased labor force participation of women. All inputs in this demand system are substitutes for wife's home time. An increase of inventive activity reduces the budget share spent on wife's home time and shifts the demand curve for wife's home time to the left ( $e_{5T} = -0.74$ ). Thus, increased inventive activity, which is a source of disembodied technical change in household production, has contributed to the rise in female labor force participation.

Finally, the results in this study show that the technical change in household production is not neutral on input usage. The results support the general conception about household production: the rise in the price of human time relative to the price of capital inputs and the increased market opportunities of females caused the household production technology to become labor-saving(or capital-intensive).

## V. CONCLUDING REMARKS

In this chapter, we utilized the AIDS model to specify a household demand system for household inputs. Plausible estimates of own and cross price elasticities and income (or expenditure) elasticities were obtained. There is evidence of significant substitution among inputs by households as their relative prices change. Although the effect of inventive activity can not be distinguished statistically from the effects of a pure time trend, the effects of the patenting activity variable on households demand for inputs used in household production are consistent with our expectations about the effect of technical change in the household sector on demand for inputs. Disembodied technical change for household sector —proxied by the number of patents of consumer durable goods— has caused the demand curve for capital services to shift to the right but demand curves for other inputs have shifted to the left. The leftward shift has been especially large for domestic services and commercial laundry and cleaning services.

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