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# Urban Food Consumption Patterns and Their Associated Solid Waste*

by

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## I. Introduction

Currently there is considerable public concern with the increasing level and varying composition of residential solid waste. Roughly, one third of residential solid waste emanate from food and food containers. The food industry is often accused of having aggravated the problem of managing the ever increasing waste loads through over-packaging. Reliable information which describes the level and composition of consumption residuals and their relationship to household consumption patterns is scarce if not lacking. Yet such information is fundamental to a better understanding of the solid waste problem and to the formulation of policies aimed at coping with it.

This paper addresses itself to linking solid waste from food consumption activities to consumer behavior. A theoretical framework for conceptualizing the solid waste generation process in connection with consumption behavior is given in Section II. The economic model and hypotheses are presented in Section III. Data and estimation are discussed in Section IV. Empirical results are analyzed in Section V, and some concluding remarks are given in Section VI.

## II. The Theoretical Framework

The traditional theory of consumer behavior avoids any explicit discussion of consumption residuals. It implicitly assumes that the

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act of consumption exhausts all goods that enter directly into the consumer's utility function. Fortunately, the last decade witnessed a new approach to consumer demand. Becker [1] suggested that the act of consumption is indeed a production process which utilizes physical and nonmarket goods as inputs in order to produce commodities which maximize the consumer's utility. Becker was interested in analyzing the role of time allocation in relation to household consumption behavior. Lancaster [3] [4] generalized Becker's idea of viewing consumption as a process and provided a fully integrated theory of consumer choice and demand in which the characteristics of goods are taken explicitly into account. His approach is based on the assumption that commodities, per se, do not yield utility to consumer; rather, commodities possess characteristics, and these give rise to utility.

The idea of focusing on characteristics of commodities along with commodities themselves is attributed to Hicks [2] though Menger [5] had a similar notion implicit in his view that people demand goods in order to satisfy certain "wants". Lancaster translated the psychological concept of wants into objective characteristics that have universal applications in demand analysis. The traditional demand analysis can be viewed as a special case of Lancaster's approach, where each good has one and only one characteristic.

Solid waste can be traced to materials used as inputs in the consumption process. These materials are an integral part of the commodities and also possess characteristics which yield utility to consumers. Some people, for example, prefer soft drinks in disposable cans to soft drinks in disposable bottles. Solid waste from food origin is not confined to the waste of packaging material. The goods themselves also generate waste through the consumption process. The level of their waste output depends to a great degree upon the level of processing.

The cost of solid waste collection and disposal services is fixed in many cases, in the sense that households pay a certain amount per year regardless of the waste output they generate. These fixed costs do not affect the consumer's budget allocation. Per unit costs of managing solid waste output may force the consumers' to alter their budget allocation to achieve maximum utility at a minimum cost of waste disposal.

Using Lancaster's approach, consumer behavior with respect to consumption activities and their associated residuals can be described as a maximization problem. The objective criterion is utility expressed as a function of foods' characteristics. The constraints on the other hand include: two sets of technological relations linking goods and their characteristics through a collection of consumption activities; and a set of budget constraint which incorporates any cost of waste disposal associated with the activities.

Consider an individual consumer with a utility function U defined over the characteristics space:

(1) $U = U(Z_j)$, $j = 1,\ldots,r$.

further, the consumer is faced with a budget constraint:

(2) $P'X \leq k$, where

Z is a vector of r-characteristics,

X is a vector of n-goods,

P is a vector of corresponding price of the same dimension,

k stands for the consumer's budget.

Assuming U is a quadratic[1] function, and the constraints described earlier are linear, the consumer's problem can be expressed by the following quadratic program, in matrix form:

$$\text{Max} \quad U(Z) = a'Z + 1/2 \; Z'QZ$$

Subject to

(3) (i) $Z = BY, \; Y \geq 0$

(ii) $X = AY$

(iii) $P'X + D'RY \leq k$

where,

$a'$ is a row vector of coefficients.

Q is a symmetric negative definite matrix[2] consisting of fixed elements, of n x n dimension.

Y is a vector of m-activities.

D is a vector of g-elements corresponding to cost of disposal of g-types of solid waste.

A is a matrix of n x m dimension, its element $a_{kj}$ represents the quantity of the kth good required to operate the jth activity at a unit level.

B is a matrix of r x m dimension, its element $b_{ij}$ represents the amount of ith characteristic derived from unit level of the jth activity.

R is a matrix of g x m dimension, its element $r_{wj}$ represents the amount of the ith type of solid waste generated by a unit level of the jth activity.

Each activity is assumed to be linear, and the matrices, A, B, and R are assumed to consist of fixed coefficients. The matrices A and B are known as the consumption technology matrices, as defined by the constraints (i) and (ii). (iii) is a budget constraint, and includes the costs of disposal related to various types of solid waste. In the absence of a variable cost associated with the level of solid waste output the term D'RY vanishes and (iii) collapses to (2). However, the solid waste linkage to consumption activities remains effective through (i) and (ii).

The solution will give efficient and optimal activity vectors which must be translated into goods by:

$$(4) \quad X^* = AY^*$$

Given the optimal activity level, Y*, the solid waste associated with it, SW* is:

$$(5) \quad SW^* = R\,Y^*$$

From a technical point of view, the elements of R are the same for all consumers choosing the same consumption activity. Household characteristics may affect the level of consumption activities and thus generate different waste loads.

## Aggregate Consumption Behavior

Consumer behavior represented in the above quadratic program was specified for an individual consumer. In the real world observations generally pertain to some aggregate of consumers such as households, cities, states, etc. A one-individual household is the exception rather than the rule. In Lancaster's approach, aggregation over a number of consumers is facilitated by the assumption of linearity. With linear consumption activities consumers facing the same prices but with varying incomes, still can share the same efficiency frontier.[3] This is done by a process of normalization, where each consumer or member of a household is assigned a market weight which reflects the level of his income before normalization. Viewing the household (family) as the consuming unit and summing over all members defines the household's consumption level.

Becker [1] assumed a household utility function which is maximized over a set of commodities that are produced by adding a time input to market goods. Michael [6] and Prochaska and Shrimper [9] used the same framework to investivate the opportunity cost of time in consumption. Nerlove [7] referred to Becker's household utility function as the "Chicago Utility Function." However, none of these economists discussed the properties of such function nor the conditions under which it might exist.

With fixed prices, household behavior with respect to food expenditures can be represented by Engel curve type functions. Total food expenditure (E) can be viewed as the sum of: expenditure on food prepared at home, ($E_1$), and expenditure on away-from-home meals (M)

$$(6) \quad E = E_1 + M$$

For any given time period, the value of food prepared at home (C) need not equal ($E_1$). The difference between the two reflects food inventory (I).

$$(7) \quad I = (E_1 + M) - (C + M) = E - C - M$$

Thus replacing ($E_1$) by (C), a three equation system describing (E), (C) and (M) automatically incorporates the effect of inventory.

## III. Economic Model and Hypotheses

Adding an equation to represent the solid waste (SW) associated with (C) yields the following model which links household food expenditure ($Y_1$), consumption ($Y_2$), expenditure on away-from-home meals ($Y_3$), and total food solid waste ($Y_4$) to household characteristics:

$$
\begin{aligned}
Y_1 &= f(X_1, X_2, X_3, X_4, X_5, X_6) \\
Y_2 &= f(X_2, X_3, X_4, X_5, X_6, X_8) \\
Y_3 &= f(X_1, X_2, X_3, X_5, X_6) \\
Y_4 &= f(X_2, X_3, X_4, X_5, X_6, X_7)
\end{aligned}
\tag{8}
$$

where

$Y_1$ = total food expenditure, in dollars per week (E).

$Y_2$ = value of food consumed at home, in dollars per week (C).

$Y_3$ = value of away-from-home meals, in dollars per week (M).

$Y_4$ = quantity of solid waste of food origin, in pounds per week (SW).

$X_1$ = number of person meals eaten away from home per week.

$X_2$ = annual household income before taxes in dollars.

$X_3$ = a zero-one variable for sex of the head (M = 1, F = 0).

$X_4$ = household size in number of persons.

$X_5$ = education of the housewife (years of schooling)

$X_6$ = age of the head in years.

$X_7$ = a zero-one variable for a garbage disposal unit (1=with,0=without)

$X_8$ = a zero-one variable for a home freezer (1=with,0=without)

Number of away-from-home meals, household income, and household size are assumed to have positive coefficients. On the average, eating outside costs more than eating at home. Engel's law indicates that as people's incomes rise, their expenditure on food rises but at a less than proportionate rate. Households with a larger number of persons spend more on food than smaller sized households with similar characteristics. The above hypotheses apply to all four equations of the model.

Household income as used here represents gross income taken from the household's federal income tax records. As far as this study is concerned, this was the most accurate form of household income available. Gross income might not be the exact income figure to which households react but it should be highly correlated with other measures of income to which households might be reacting. Others [6], [8] have used total consumption expenditure as a proxy for permanent but this leads to biased estimates.

There is no real good basis for specifying hypotheses about the effects of the housewife's education level and age and sex of the head of the household on food expenditures, consumption, expenditures on away-from-home meals and total food solid waste. The use of housewife's education in the model may be viewed as a measure of economic status thus having the same role as income. Alternatively, it could be viewed as source of economic efficiency in consumption and in this case it might have an opposite effect to that of income. Michael [6] hypothesized[4] that the education elasticity coefficient in the household consumption function could be $\gtreqless 0$ depending on whether $\eta_i \gtreqless 1$ ($\eta_i$ = elasticity of consumption of commodity or group i with respect to income). Theoretically $\eta_i$ is unknown a priori. Indeed, the theory provides very little if any information about the size of this variable in our model.

The availability of a home freezer implies a saving in the cost of food consumed provided the household is able to benefit from large purchase discounts and sales. This variable is expected to be negatively related with the value of food consumed at home.

Garbage disposal units should have no effect on the total quantity of residuals produced through consumption activities, yet they channel a considerable proportion of food wastes into the sewage system. This in turn reduces the quantity of solid waste being considered here and thus this variable is expected to be negatively related to the quantity of solid waste of food origin.

## IV. Data and Estimation

The data required for estimation were secured through survey questionnaires and a panel study conducted in the Lafayette-West Lafayette SMSA of Indiana during May-June of 1973. Data related to consumption and its associated solid waste were collected through residential solid waste composition analysis. Participants were provided with plastic bags to collect their trash and garbage, and were instructed to keep containers in a good enough shape to identify the origin product and its price. Consumption data thus reflect the total food consumed as gathered from prices on various discarded food containers. Detailed description of data and data methodology can be found in Saleh [10, pp. 159-183].

Grocery expenditures and expenditures on away-from-home meals were provided by the panel members. Households were provided with special forms and cassette tape recorders and were given the option of filling the forms or recording their expenditures on tape. About 16 percent of the participants chose the latter option.

A total of 93 households cooperated in providing data for the study and an observation consists of a four-week average for each cooperating household. Data averaging was necessitated by the fact that consumers' shopping habits differ. Some households shop weekly, others monthly and many in between.

The data provided information about the rate of solid waste flow per dollar of consumption and per dollar of expenditure on various food categories, and the ratio of consumption to expenditure on various foods classified by type of container. The rates are given in Table 1. The computed rates indicate that glass and metal are major components with high rates of solid waste per dollar of consumption or expenditure on food in these containers. Households, on the average, generate .538 pound of solid waste for each dollar they spend on food, and .614 pound for each dollar of food consumed at home. The ratio of consumption to expenditure amounted to .876. The difference from unity would be due to inventory. Products with the lowest rate of solid waste per dollar of consumption or expenditure are those packaged in plastic, styrofoam, or cellophane. Highest rates are related to beverages in glass and metal containers. Soft drinks in glass generated 2.230 pounds of solid waste per dollar of expenditure and 3.576 pounds per dollar of consumption. The rate of solid waste flow per dollar of consumption and per dollar of expenditure on foods in paper are .225 and .195, respectively. Most solid waste classified as food paper is generated through the consumption of milk and breakfast cereals.

A linear stochastic form of the economic model was estimated using Zellner's [11] method of Seemingly Unrelated Regressions (SUR). In this method, two rounds of estimation are carried out. In the first round, OLS is applied to each equation separately. The error terms are estimated and so are their variances and covariances. In the second round, all

Table 1. Average Weekly Values of Expenditure (E) $, Consumption (C) $, and Solid Waste (SW) Lbs., Solid Waste as Percent of Total (PCT TSW), Consumption per Dollar of Expenditure (C/E), Solid Waste per Dollar of Expenditure (SW/E), and Solid Waste per Dollar of Consumption (SW/C), By Type of Container, for Households in the Lafayette-West Lafayette Area of Indiana.

| Item No. | Description and Type of Container | E ($) | C ($) | SW (LBS) | PCT TSW | C/E | SW/E | SW/C |
|---|---|---|---|---|---|---|---|---|
| | Glass | | | | | | | |
| 1. | All Food Glass | 2.041 | 2.259 | 3.067 | 8.567 | 1.107 | 1.503 | 1.358 |
| 2. | Soft Drink | .500 | .312 | 1.114 | 3.111 | .623 | 2.230 | 3.576 |
| 3. | Beer, Alcohol | .239 | .847 | .470 | 1.314 | 3.547 | 1.971 | .556 |
| 4. | Other Food Glass | 1.303 | 1.101 | 1.483 | 4.142 | .845 | 1.138 | 1.346 |
| | Metal | | | | | | | |
| 5. | All Food Metal | 3.091 | 3.211 | 1.959 | 5.473 | 1.039 | .634 | .610 |
| 6. | Vegetables | .320 | .354 | .306 | .854 | 1.108 | .957 | .863 |
| 7. | Fruits | .268 | .250 | .174 | .485 | .931 | .647 | .695 |
| 8. | Juice, Drink | .270 | .238 | .221 | .617 | .881 | .818 | .929 |
| 9. | Soft Drink | .295 | .442 | .371 | 1.037 | 1.497 | 1.259 | .841 |
| 10. | Beer | .206 | .522 | .229 | .640 | 2.531 | 1.110 | .439 |
| 11. | Soup | .263 | .200 | .135 | .378 | .760 | .514 | .676 |
| 12. | Meat, Seafood | .384 | .446 | .076 | .212 | 1.163 | .198 | .170 |
| 13. | Other Food Metal | 1.084 | .758 | .355 | .993 | .700 | .328 | .469 |
| | Plastic | | | | | | | |
| 14. | All Food Plastic | 9.015 | 7.089 | .418 | 1.166 | .786 | .046 | .059 |
| 15. | Luncheon Meat | .524 | .355 | .011 | .031 | .677 | .021 | .031 |
| 16. | Frozen Vegetable | .081 | .063 | .003 | .008 | .777 | .033 | .043 |
| 17. | Dehyd. Vegetable | .007 | .003 | .000 | .001 | .406 | .029 | .071 |
| 18. | Oth. Food Plastic | 8.403 | 6.668 | .403 | 1.127 | .794 | .048 | .061 |
| | Paper | | | | | | | |
| 19. | All Food Paper | 6.921 | 5.995 | .347 | 3.763 | .866 | .195 | .225 |
| 20. | TV Dinners, etc. | .464 | .381 | .053 | .147 | .821 | .113 | .138 |
| 21. | Frozen Cakes, Pies | .063 | .043 | .012 | .034 | .687 | .196 | .285 |
| 22. | Frozen Vegetable | .101 | .073 | .023 | .063 | .726 | .224 | .308 |
| 23. | Milk | 1.321 | 1.366 | .393 | 1.099 | 1.034 | .298 | .288 |
| 24. | Breakfast Cereal | .423 | .411 | .171 | .477 | .972 | .404 | .416 |
| 25. | Snacks, Pot. Chips | .160 | .321 | .054 | .151 | 1.998 | .336 | .168 |
| 26. | Other Food Paper | 4.388 | 3.400 | .642 | 1.793 | .775 | .146 | .189 |
| 27. | Other Food Containers | .180 | .057 | .003 | .008 | .318 | .015 | .047 |
| 28. | Garbage | -- | -- | 4.626 | 12.921 | -- | -- | -- |
| 29. | Total Food Prepared at Home | 21.247 | 18.611 | 11.420 | 31.899 | .876 | .538 | .614 |

equations are treated as one set and re-estimated jointly by applying Aitken's Generalized Least Squares procedure (GLS). The latter makes use of the estimated variance-covariance matrix of the structural disburgances as weights in deriving the parameter estimates by the least squares method. The SUR procedure yields estimators that are asymptotically BLUE. In addition to yielding efficient estimators, the SUR technique enforces the linkage between consumption patterns and their associated solid waste, empirically.

## V. Empirical Results

The OLS estimates of the model are given in Table 2. The overall regression of each equation is significant as indicated by F-tests conducted at the .05 level.

The level of total food expenditure is significantly associated with the number of away from home meals, household income, and household size. The coefficients of these variables are statistically significant at the .05 level and have positive signs as hypothesized. The elasticities for these variables, estimated at the means, are as follows: meals away from home, .21, income, .17, and .44 for household size. The coefficient of number of meals away from home is 1.27 which reflects the dollar cost of an average meal away from home. Adding a member to the household results in a 4.04 dollar increase in total food expenditure, per week. A 1,000 dollar increase in household annual income yields a .37 dollar increase in food expenditure per week.

The $R^2$ for the consumption equation is .61. Income, household size, and the level of housewife's education are key variables in this equation. Their coefficients have the hypothesized signs and are

Table 2. Ordinary Least Squares Estimates (OLS): Regression Coefficients, Standard Errors,[a] Coefficients of Determination, ($R^2$), Adjusted Coefficients of Determination ($\bar{R}^2$) and Calculated F-Ratios.

| Independent Variables | Dependent Variables: Total Food Expenditure $Y_1$ | Value of Food Consumed at Home $Y_2$ | Value of Meals Away From Home $Y_3$ | Total Food Solid Waste $Y_4$ |
|---|---|---|---|---|
| Constant | 2.315324 | 2.924208 | -1.441491 | 4.878537 |
| $X_1$ Meals Away | 1.266342<br>( .215125)** | N.I.[b] | 1.245954<br>(.083860)** | N.I. |
| $X_2$ Income | .000365<br>(.000171)** | .000276<br>(.000112)** | .000245<br>(.000066)** | -.000033<br>(.000081) |
| $X_3$ Sex of the Head | -6.062378<br>(3.767962) | -3.514584<br>(2.321979) | -.835463<br>(1.473404) | -2.672038<br>(1.795874) |
| $X_4$ Household Size | 4.041203<br>( .651439)** | 3.553482<br>(.410007)** | N.I. | 1.671632<br>(.307905)** |
| $X_5$ Housewife's Education | .500229<br>(.273368) | .403681<br>(.168339)** | .036636<br>(.105445) | .495955<br>(.129743)** |
| $X_6$ Age of the Head | .071097<br>(.069626) | .022788<br>(.042845) | .000201<br>(.027101) | -.000736<br>(.032635) |
| $X_7$ Garbage Disposal | N.I. | N.I. | N.I. | -3.33619<br>(1.178496)** |
| $X_8$ Home Freezer | N.I. | -1.846253<br>(1.525876) | N.I. | N.I. |
| $R^2$ | .60 | .61 | .77 | .47 |
| $\bar{R}^2$ | .57 | .59 | .76 | .43 |
| F | 21.71** | 23.01** | 59.60** | 12.46** |

[a] Standard errors appear in parentheses.

[b] N.I.: The variable is not included in the equation.

** Significant at the .05 level.
* Significant at the .10 level.

statistically different from zero at the .05 level. The estimated coefficients for income (.000276) and household size (3.55) are slightly lower than those of the expenditure equation. A one year increase in the housewife's level of education will increase food consumption by .40 dollar per week. Consumption elasticities are .19 with respect to income, .52 with respect to household size and .28 with respect to housewife's education. The $R^2$ for the equation describing the expenditure on away-from-home meals is .77, the highest among the four equations of the model. Income and the number of away-from-home meals were the only significant variables at the .05 level. The coefficient of income (.000245) is lower than the corresponding ones in the expenditure and consumption equations. The income elasticity (.45), however, is higher than those in the above equations. The same applies to the elasticity with respect to the number of meals outside home (.80). The average price per meal as estimated in this equation 1.25 is close to that in the total food expenditure equation (1.27).

The $R^2$ for the equation describing household food solid waste amounts to .47. The variables that appear to have a significant association with the level of total food solid waste output are: household size, housewife's education, and the availability of a garbage disposal in the house. Elasticity coefficients of total food solid waste with respect to these variables evaluated at the mean are as follows: household size .46 and .56 for housewife's education. No meaningful elasticity figure exists for the zero-one variable representing the availability of a garbage disposal unit. However, the availability of such a unit could reduce the waste load by as much as 3.337 pounds, as indicated by the slope of this intercept shifter in the equation.

Table 3. Efficient Estimates (SUR) of Regression Coefficients and Their Standard Errors.[a]

| Independent Variables | Dependent Variables | | | |
|---|---|---|---|---|
| | Total Food Expenditure $Y_1$ | Value of Food Consumed at Home $Y_2$ | Value of Meals Away-From-Home $Y_3$ | Total Food Solid Waste $Y_4$ |
| Constant | .189567 | 3.423119 | -1.430540 | 4.714545 |
| $X_1$ Meals Away | 1.426794 (.178185) | N.I. | 1.242508 (.083062) | N.I. |
| $X_2$ Income | .000302 (.000169) | .000243 (.000108) | .000246 (.000066) | - .000036 (.000081) |
| $X_3$ Sex of the Head | -6.456295 (3.764492) | -3.606270 (2.320177) | -.831486 (1.473346) | -2.684721 (1.794042) |
| $X_4$ Household Size | 4.826833 ( .607624) | 3.380236 (.404321) | N.I. | 1.750478 (.306916) |
| $X_5$ Housewife's Education | .436242 (.272707) | .413527 (.168308) | .036817 (.105443) | .490068 (.129702) |
| $X_6$ Age of the Head | .086877 (.069295) | .016379 (.042634) | .000034 (.027095) | .000084 (.032634) |
| $X_7$ Garbage Disposal | N.I. | N.I. | N.I. | -3.388072 (1.079319) |
| $X_8$ Home Freezer | N.I. | -.511951 (1.119628) | N.I. | N.I. |

[a] Standard Errors appear in parentheses.

[b] N.I. The variable is not included in the equation.

Statistical tests applied to the OLS residual correlation matrix indicated that most of the off diagonal elements were different from zero at the .05 level. The diagonal elements of the residual variance-covariance matrix were also found to be heteroscedastic. Thus, the use of the GLS technique, as expected, resulted in more efficient parameter estimates as evident from comparing OLS and SUR standard errors. The SUR estimates are given in Table 3.

## VI. Concluding Remarks

In this paper, Lancaster's demand framework was modified to explicitly incorporate solid waste residuals from food consumption activities as a secondary output of utility maximization. This framework suggested a four equation model linking food solid waste to food consumption-expenditure behavior.

A linear form of the model was estimated using Zellner's method of Seemingly Unrelated Regressions. The data used were collected through a panel study and survey questionnaires in the Lafayette SMSA of Indiana. Consumption and solid waste data were obtained by a waste composition analysis. On the average households produce about .538 pound of solid waste for each dollar spent on food prepared at home and .614 for each dollar of food consumed at home. The ratio of food consumed at home to expenditure on food prepared at home is .876. On the average, about 32 percent of residential solid waste can be traced to food and food containers.

The amount of variation in total food expenditures, value of food consumed at home, value of away-from-home meals and quantity of solid waste of food origin accounted for by the respective estimated equations was significant at the .05 level. The coefficients of determination ranged from .47 to .77. The lowest being the solid waste response function and the highest for expenditure on away-from-home meals. Key variables and their corresponding elasticities estimated at the means are:

1. Total food expenditure: income .17, number of away-from-home meals .21, and family size .44.
2. Value of food consumed at home: income .19, household size .52, and housewife's education .28.
3. Expenditure on away-from-home meals: income .45 and number of meals .80.
4. Total food solid waste: Family size .46 and housewife's education .56. The variable for a garbage disposal unit entered as a significant intercept shifter. Its effect amounts to a 3.337 pound reduction in the level of waste, on the average.

Age and sex of the head, and the availability of a home freezer were not significant variables in the model. The level of solid waste output is not significantly related to changes in household income.

## Notes

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[1]The quadratic form of utility yields indifference curves strictly convex to the origin as postulated in the traditional demand theory.

[2]Q here is identical to the Hessian matrix in the traditional analysis, except the characteristics replace goods.

[3]Efficiency frontier with respect to consumption is synonymous with production surface in production theory. The reader unfamiliar with Lancaster's approach is advised to glance through Chapters 1-4 of his book [4] and in particular, Chapter 4, pp. 50-71.

[4]Michael's analysis is based on the neutrality assumption in the Hicksian sense, i.e. the effect of education on other factors in the household production function (process) is the same and thus induces no factor substitution.

## References

[1] Becker, Gary S., "A Theory of the Allocation of Time," Economic Journal 75 (September 1965): 493-517.

[2] Hicks, J.R., A Revision of Demand Theory (London: Oxford University Press, 1956).

[3] Lancaster, Kelvin, "A New Approach to Consumer Theory," J.P.E. 74 (April 1966): 132-57.

[4] Lancaster, Kelvin, Consumer Demand: A New Approach (New York, Columbia University Press, 1971)

[5] Menger, Karl, Principles of Economics (English Translation 1950).

[6] Michael, Robert T., The Effect of Education on Efficiency in Consumption, NBER Occasional Paper 111, New York, 1972 (Distributed by Columbia University Press, New York and London).

[7] Nerlove, Marc, "Household and Economy: Toward a New Theory of Population and Economic Growth," J.P.E. 82 No. 2 Part II (March-April 1974) S. 200-221.

[8] Praise, S.J. and Honthaker, H.S., The Analysis of Family Budgets, Cambridge, Cambridge University Press, 1955.

[9] Prochaska, Fred J. and Schrimper, R.A., "Opportunity Cost of Time and Other Socioeconomic Effects on Away-From-Home Food," AAJA, 55 No. 4, Part I November 1973.

[10] Saleh, Abdullah A., "An Analysis of Consumer Food Expenditures and Consumption Waste," Unpublished Ph.D. Dissertation, Purdue University, May 1974.

[11] Zellner, Arnold, "An Efficient Method of Estimating Seemingly Unrelated Regressions and Tests for Aggregation Bias," JASA, 57, 1962.