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A PROBABILISTIC APPROACH TO ESTIMATING AGGREGATE REGIONAL DEMAND FOR BROILER MEAT

Chung Liang Huang and Robert Raunikar

Classical theory of consumer demand postulates that each consumer possesses a continuous utility function. The theory describes the behavior of a rational consumer such that the consumer's preferences for various sets of goods are given and the consumer purchases a set of goods which maximizes utility function subject to the budget constraint that total expenditure is equal to income.

The theory of consumer demand relates consumers' purchases of various goods to prices, income, and *ceteris paribus* conditions. It provides the basis for many applications such as analysis of family-budget data (Prais and Houthakker) and analyses of the demand for food (Tomek). Blakley suggests that a general theoretical demand function for product *j* may be expressed as:

$$(1) \quad Q_j = f(Y, P_1, \dots, P_r, N, T, Z)$$

where Q_j = quantity demanded for product *j*,
 P_1, \dots, P_r = unit product price of *r* products,
 N = population,
 T = tastes and preferences,
 Z = other factors.

Specific model formulation depends on whether the analysis is based on time series or cross-sectional data (Blakley, p. 70). For example, in cross-sectional analysis, price variables are usually omitted because of the assumption that all consumers face the same prices at a given point in time. This assumption is invalidated to some extent by the existence of regional price differences. However, the impacts of price changes are exceedingly difficult to measure because they may be confounded with differences in average prices per unit due to quality variations, to quantity discounts, and to regional variations in preferences.

In cross-sectional analysis, other non-economic factors are often included to reflect racial or ethnic backgrounds, urban or rural backgrounds, and variations in preferences due to household composition or to different stages of life cycle. Previous research (Blakley; Prais and

Houthakker; Raunikar, et al.) postulates the model of consumer demand for a specific food product as:

$$(2) \quad Q_{ij} = f(Y_i, SE_i) + U_i \quad \begin{matrix} i=1, \dots, n, \\ j=1, \dots, r, \end{matrix}$$

where Q_{ij} is quantity of product *j* purchased by *i*th household; Y_i is *i*th household income, SE_i represents a set of socioeconomic characteristics associated with the *i*th household, such as household size, race, location, urbanization, marital status, and stages of the household in the family life cycle; and U_i is a normally distributed random disturbance.

Raunikar et al. developed a procedure to obtain estimates of aggregate market food demand over a wide geographic area based on demand functions similar to equation (2). Market estimates were obtained by projecting demand based on population characteristics of the study area.¹ Publications of results based on data collected from the Atlanta Consumer Panel are comprehensive in coverage of various food products and consumer characteristics. Although the procedure provides estimates for spatially delineated market areas from highly disaggregated substate markets to aggregated regional markets, the procedure is computationally cumbersome and several adjustment factors must be determined before final estimates are derived.

Perhaps the major limitation of the Raunikar et al. study was its dependence on quantity data from a localized panel of households. There is a concern about the validity of the assumption that the results for a particular market segment can be applied directly to similarly described market segments over a wide geographic area (Blakley). Additionally, the procedure is lacking in terms of provisions for incorporating forecasts of demand, supply, and price changes in the determination of market shares and market demand allocations.

There is a need to develop an alternative procedure in which estimates of regional market food demand can be derived when the

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¹ The general procedure as described in Raunikar et al., required regression analysis on factors that influence the demand for poultry, and detailed spatial data on the social and economic characteristics of the population. To develop estimates of the demand for poultry by spatially delineated markets in the U.S., these two basic types of information were combined to yield initial unadjusted estimates. The aggregate U.S. poultry consumption at the base period was then used to obtain an adjustment ratio for adjusting the initial estimates.

availability of quantity data may become a limiting factor. The alternative is to adopt a qualitative choice model in which choice behavior is described in probabilistic terms. A typical qualitative choice model describes each individual making a choice from a limited number of alternatives. The conditional probability of a particular choice being made is related to various explanatory factors that include the characteristics of the decision makers as well as attributes of the alternatives (Amemiya; Judge et al., pp. 583-64).

The objective of this study is to develop and assess the usefulness of an alternative estimation procedure which incorporates a probabilistic approach for the derivation of regional demand for food in the absence of household purchase quantity data. Specifically, the objective is accomplished by using the probit procedure to estimate probable changes in market participation resulting from changes in selected characteristics of the U.S. population. The application of probit procedure and its usefulness in the process of estimating regional demand for food is demonstrated and assessed in this study by using broiler meat as an example.

THE MODEL

In this study, the household unit endowed with a set of economic and socioeconomic factors is assumed to be the basic decision-making consumer unit. The individual household is assumed to choose between events E and not E, i.e., purchase or no purchase of a particular food product. The household purchase decision is related to a criterion function or an index, I_i such that:

$$(3) \quad I_i = \alpha + x_i' \beta + e_i \quad i = 1, \dots, n$$

where I_i is a binary variable valued either one or zero, if the household made a purchase or otherwise; x_i represents a vector of arguments in f ; e_i is a random disturbance, and α and β are unknown parameters.

Assuming that the larger the value of the index I_i , a decision to choose the event E more likely will be made and, hence, the greater the probability of E's occurring. Thus, the model can be transformed into a monotonic relationship between the value of I_i and the probability of observing the event E. Theoretically, by comparing I_i to some critical or threshold value of the random index, denoted as I^* , which reflects the underlying attributes of the household characteristics and preferences, the individual household makes a choice of the event E only if $I_i \geq I^*$. Therefore, the conditional probability of event E's occurring, given I_i , is:

$$(4) \quad \text{Prob}(E | I_i) = \text{prob}(I_i^* \leq I_i) = F(x_i' \beta)$$

where $F(\cdot)$ is a cumulative distribution function

(CDF) evaluated at the value of the argument (Judge et al., p. 591).

The conceptual approach used in this study is to transform the estimation of a traditional demand function into a qualitative choice model. As a result, it is not necessary to predict the quantity demanded by individual households within a given market area when deriving market food demand estimates. Instead of estimating quantity demanded directly, a decision choice model is used to assess the probability that a household will purchase a particular food product and, hence, to predict the proportion of purchasing households within a given market area.

ESTIMATION PROCEDURE

The emphasis of the present analysis is to illustrate that a qualitative choice model, an alternative to previously used procedures, can be developed to derive estimates of regional market demand for broiler meat. Two statistical procedures are commonly used to estimate the conditional probability of equation (4). The selection probabilities may be related to the index I_i by way of the standard normal CDF or the logistic CDF. The probit procedure assumes that $F(\cdot)$ in equation (4) is a normal CDF, whereas the logit procedure assumes $F(\cdot)$ is a logistic CDF. The conditional probit and logit models have been extensively considered by Amemiya. The logit procedure has an advantage of numerical simplicity. The advantage of the probit procedure is that it does not rely on a very strong behavioral assumption of independence of irrelevant alternatives but is computationally burdensome. The probit procedure is used in this analysis.

The framework of the computational procedure consisting of three steps is depicted in a flow chart represented by Figure 1. The first step is to obtain estimates of the number of purchasing households by market area. The second step is to compute market shares among market areas; and the final step is to allocate total domestic disappearance among market areas.

The estimation procedure for step 1 involves probit estimation of the purchasing decision equation (4) using data collected from a national household survey taken in the base year (USDL 1977). Probability estimates for market participation by market area for the projection year are then developed using parameter estimates of the purchasing decision equation and census data on population characteristics. Estimation of the number of purchasing households by market area is obtained from the estimated probability of market participation and census projected number of households by market area.

Step 2 is designed to obtain market shares among spatially delineated markets for allocation of total domestic disappearance for a given year.

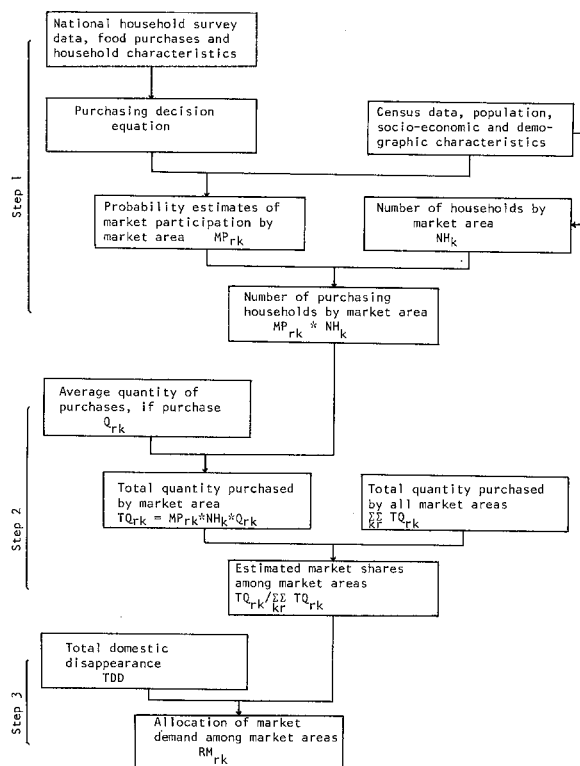


FIGURE 1. Diagram of the Three-Step Procedure for Estimation of Market Demand

This is accomplished by obtaining estimates of average quantity purchased by purchasing households. Estimation procedure at this stage may involve a simultaneous equations system which approximates the structural behavior of demand and supply of the food products. Parameter estimates for this step may be based on time series analysis. The results provide information for the projection year with regard to effects of changes in economic conditions on household food consumption. Alternatively, when statistical estimation for this variable is not available, the average quantities purchased by purchasing households may be derived by incorporating available information such as income elasticities and own-price and cross-price elasticities.

Step 3 allocates market demand estimates for the projection year based on information compiled from previous steps.

In this study, the largest market aggregations designated as regional markets are used. The U.S. market is represented by four census regions; i.e., Northeast, North Central, South, and West. The demand for broiler meat is defined as

two product forms, representing broiler meat purchased as a whole bird and purchased as separated parts.

Regional market shares are initially estimated for the base year 1973-74. To develop estimates of regional market demand for broiler meat products in 1979, a number of modifications are made to simplify the procedure, partially due to lack of some detailed information. Specifically, basic data on household socioeconomic characteristics of the U.S. population among the regions in 1979 (USDC 1980a, 1980b) are used to evaluate the probable changes in market participation by region. Average quantities purchased for broiler meat products by purchasing households are not available for 1979. Thus, household income and household size elasticities estimated by Salathe are used to derive the estimated changes in quantities purchased by purchasing households in 1979, with respect to whole broilers and broiler parts.

In summary, the procedure used to develop regional market demand for broiler meat in a given year is formulated as:

$$(5) \quad RM_{rk} = (WQ_{rk} / \sum_k \sum_r WQ_{rk}) * TDD$$

$$r = 1, 2$$

$$k = 1, 2, 3, 4$$

and

$$WQ_{rk} = (MP_{rk} * Q_{rk}) * (NH_k / NH_{us})$$

where RM_{rk} represents the market demand for the r th product form in the k th region; WQ_{rk} is the weighted quantities of purchase for the r th product form in the k th region;² TDD represents total domestic disappearance of broiler meat; MP_{rk} is the probability of market participation for the r th product form in the k th region; Q_{rk} is the average quantities purchased for the r th product form by purchasing households in the k th region; NH_k represents the number of households in the k th region; and NH_{us} is the total number of households in the U.S.

RESULTS AND DISCUSSION

The Bureau of Labor Statistics' 1972-73 *Consumer Expenditure Diary Survey* (CEDS) consists of two information files of public use tapes for expenditure and quantity data, separately (USDL 1977, 1979). Of the two-year survey period, only the second-year survey, consisting of 12,121 households, was used. Separate editing

² The formulation of WQ_{rk} in equation (5) is slightly different from TQ_{rk} as defined in Figure 1. The formulations, however, lead to identical results. Specifically,

$$\begin{aligned} WQ_{rk} / \sum_k \sum_r WQ_{rk} &= [(MP_{rk} * Q_{rk}) * (NH_k / NH_{us})] / \\ &= [\sum_k \sum_r (MP_{rk} * Q_{rk}) * (NH_k / NH_{us})] / \\ &= [(MP_{rk} * Q_{rk} * NH_k) / NH_{us}] / \\ &= [\sum_k \sum_r (MP_{rk} * Q_{rk} * NH_k)] / NH_{us} \\ &= (MP_{rk} * Q_{rk} * NH_k) / \sum_k \sum_r (MP_{rk} * Q_{rk} * NH_k) \\ &= TQ_{rk} / \sum_k \sum_r TQ_{rk} \end{aligned}$$

By using (NH_k / NH_{us}) as a weighting factor, the computations to be performed in equation (5) are simplified in the sense that the magnitude of the numbers is reduced from aggregated total to weighted averages.

procedures were performed on expenditure and quantity tapes. Households that reported inconsistent information or lack of it were deleted. A sample of 9,283 households selected from the expenditure tape was used to estimate equation (4). Average quantities purchased by product form and by region were obtained from the quantity tape.

The results of probit analyses in estimating equation (4) for whole broilers and broiler parts are presented in Table 1. The majority of socioeconomic variables included in the model are statistically different from zero at the 0.05 significance level. The columns denoted as "change in probability" in Table 1 are derivatives of the probability function; i.e., equation (4), with respect to the particular independent variable evaluated at independent variable means.³ Specifi-

cally, the derivative of the probability function provides a direct assessment of the change in the probability for a given change in a particular independent variable, *ceteris paribus*. Thus, their interpretations, except in terms of probabilities, are equivalent to the partial regression coefficients of a conventional regression model. This provides information to assess probable changes in market participation and is used to derive market estimates for the projection year.

The results suggest different patterns of household food purchasing decisions for whole broilers and broiler parts. While most household characteristics have significant effects on the household purchase decision for a particular form of broiler meat at a given point in time, the effect of household income on the decision to purchase whole broilers is opposite that of broiler parts. The level of household income has a negative and significant effect in determining whole broilers purchases (also reported by Salathe). Furthermore, the results indicate that households in the South, as compared with other regions, are most likely to purchase whole broilers while households in the Northeast are most likely to purchase broiler parts.

In general, the nature of demand for these two broiler product forms are quite different, suggesting that the relatively less costly and less processed whole broilers are less preferred than broiler parts as household income increases. Although household size is significant in determining purchases of both whole broilers and broiler parts, the probability of observing purchase of whole broilers versus broiler parts is greatly increased as household size increases, *ceteris paribus*. Based on the results of Table 1, the aggregate regional market demand for whole broilers and broiler parts in 1979 was estimated using equation (5). The estimated regional demand for broiler meat in the four regions of the U.S. in 1979 is presented in Table 2.

TABLE 1. Probit Analysis of Household Purchases of Whole Broilers and Broiler Parts, U.S., 1973-74

Variable ^a	Whole broilers		Broiler parts	
	Coefficient	Change in probability	Coefficient	Change in probability
Constant	-0.57		-0.256	
Household income	-1.08E-2* (2.37E-3)	-0.004	3.10E-3 (2.42E-3)	0.001
Household size	0.112* (9.39E-3)	0.041	3.77E-2* (9.60E-3)	0.013
Race	-0.438* (4.64E-2)	-0.162	-0.358* (4.66E-2)	-0.120
North Central	-0.110* (3.95E-2)	-0.041	-0.416* (3.97E-2)	-0.140
South	0.190* (3.91E-2)	0.070	-0.267* (3.94E-2)	-0.090
West	-1.66E-2 (4.24E-2)	-0.006	-0.324* (4.27E-2)	-0.109
Central city	0.101* (3.33E-2)	0.037	9.89E-2* (3.36E-2)	0.033
Urban	4.82E-2 (4.48E-2)	0.018	-5.55E-2 (4.64E-2)	-0.019
Rural	1.18E-3 (4.19E-2)	0.000	-0.214* (4.44E-2)	-0.072
Marital status	0.281* (3.61E-2)	0.104	0.108* (3.68E-2)	0.036
Life cycle stage 1	-0.141* (5.49E-2)	-0.052	-0.190* (5.68E-2)	-0.064
Life cycle stage 3	0.211* (3.27E-2)	0.078	0.101* (3.34E-2)	0.034
Life cycle stage 4	0.228* (4.44E-2)	0.084	0.159* (4.52E-2)	0.053
-2 Log likelihood ratio	608.518*		338.195*	
Percent households purchasing	35.43		28.68	

Note: Numbers in parentheses are standard errors.

* Significant at the 0.05 significance level.

^a Variable identifications are: Race = 1, if the household is white, and = 0, otherwise; four regions in the U.S. are defined as Northeast, North Central, South, and West; degrees of urbanization are defined as SMSA's central city, SMSA's other than central city, urban, and rural; marital status = 1, if the household head is married, and = 0, otherwise; life cycle stage 1, if age of household head is less than 25; life cycle stage 2, if age of household head is between 25 and 44; life cycle stage 3, if age of household head is between 45 and 64; life cycle stage 4, if age of household head is 65 or older.

TABLE 2. Results of Regional Market Estimates for Broiler Meats, U.S., 1979

Regional Market	Present estimates			Raunika's estimates ^a	Difference
	Whole broilers	Broiler parts	Total		
	million pounds				
Northeast	1,478	1,252	2,730	2,570	160
North Central	1,422	818	2,240	2,620	-380
South	2,837	1,215	4,052	3,763	289
West	967	674	1,641	1,710	-69
Total	6,704	3,959	10,663	10,663	0

^a Source: Raunika, 1980.

³ The derivatives of the probability function are computed as

$$\partial F(x_i' \beta) / \partial x_{ik} = \phi(x_i' \beta) * \beta_k \quad i = 1, \dots, n$$

where F and ϕ are standard normal CDF and density function, respectively; and β_k is the estimated coefficient of the k th independent variable. The standard normal density function may be evaluated at various values of x_i as i ranges from 1 to n , or at the sample mean of x_i , if a unique estimate of the derivative is desired.

The South accounted for 38.0 percent of total U.S. domestic disappearance of broiler meat. The Northeast, accounting for 25.6 percent, was ranked second and was followed by the North Central and West, accounting for 21.0 percent and 15.4 percent, respectively. The results are generally in agreement with those regional market estimates reported by Raunika. The distribution of broiler meat among the four regions estimated by Raunika in 1979 was 24.1 percent, 24.6 percent, 35.3 percent, and 16.0 percent for the Northeast, North Central, South, and West, respectively. The greatest difference between the two studies was 3.6 percent in the allocation of broiler meat for the North Central region. Considering different procedures and independent estimates developed in the two studies, the results are encouraging and suggest that the alternative approach has potential for future application.

More significantly, the present study provides estimates of regional market demand for broiler meat in terms of whole broilers and broiler parts which are not available from previous research. The estimated distribution patterns between whole broilers and broiler parts were similar to total broiler meat. The South accounted for 42.3 percent of the whole broiler market, followed by the Northeast and North Central regions, accounting for 22.0 percent and 21.2 percent, respectively, of the U.S. market demand for whole broilers (Table 2). In contrast, the Northeast, the largest regional market for broiler parts, accounted for 31.6 percent, followed by the South which accounted for 30.7 percent of the U.S. market demand for broiler parts in 1979. The results reveal that the greatest proportion of broiler meat consumption occurs in the South and Northeast where the production of broilers is high relative to other regions.⁴

U.S. domestic disappearance of broiler meat increased from 7,864 million pounds in 1973-74 to 10,663 million pounds in 1979 or an overall increase of about 35.6 percent (USDA). Using

1973-74 as a base year, Table 3 shows the estimated change of broiler demand distributed among regions and by product form. Of the total increase in domestic consumption, the largest proportion, 42.5 percent, was allocated in the southern regional market. Distribution of the increased broiler meat consumption was 48.3 percent and 51.7 percent between whole broilers and broiler parts, respectively, representing a relative increase in consumer demand for broiler parts versus whole broilers. These results appear consistent and conform to current developments in the broiler meat market. According to the latest USDA survey, "whole broilers accounted for more than 85 percent of the food service chicken purchased in 1969, but for only 40 percent a decade later. On the other hand, chicken parts rose from 9 percent to more than 53 percent in the same period" (Schwartz).

The South accounted for 25.8 percent of the increased total broiler meat consumption in the form of whole broilers, while 16.7 percent and 14.4 percent of the increase was in the form of broiler parts in the South and the Northeast, respectively. Distribution of the increase for whole broilers and broiler parts between the North Central and West regions was about equal.

Comparison of market shares by region and product form for broiler meat between the 1973-74 and 1979 periods reveals that the Northeast and North Central regions lost about 2.5 percent of the U.S. broiler market to the South and the West (Table 3). This change in market shares reflects the trend of net population migration which occurred during this time. Results in Table 3 suggest that whole broilers lost about 5.2 percent of the total market share to broilers sold in the form of parts during the same period. Income is the primary factor influencing changes in product mix between whole broilers and broiler parts. As shown in Table 1, the probability of purchasing broiler parts is positively related to income, while the opposite occurs for whole broilers. Thus, increased demand and, hence, market share for broilers in the form of parts can be expected.

One advantage of the procedure developed in the present study lies in its relatively simple probabilistic procedure for estimating market shares. This procedure is designed to determine market shares through the estimation of market participation and average quantities purchased as two separate variables. While the procedure developed by Raunika et al. relies on availability of quantity data for initial parameter estimates of the demand function, the present procedure postulates a decision choice model to estimate the probabilities of market participation for which initial parameter estimates are not depen-

TABLE 3. Changes in Regional Market Estimates and Market Shares for Broiler Meats, U.S., from 1973-1974 to 1979

Regional Market	Change from 1973-74 period in aggregate market estimates			Change from 1973-74 period in aggregate market shares		
	Whole broilers	Broiler parts	Total	Whole broilers	Broiler parts	Total
	percent					
Northeast	6.3	14.4	20.7	-2.7	1.0	-1.7
North Central	8.4	10.5	18.9	-1.8	1.0	-0.8
South	25.8	16.7	42.5	-0.3	1.9	1.6
West	7.8	10.1	17.9	-0.4	1.3	0.9
Total	48.3	51.7	100.0	-5.2	5.2	0.0

⁴ Broiler production is highly concentrated in Arkansas and Georgia and to a lesser extent in other southern states and states along the eastern seaboard of the U.S. In 1979, the South produced over 88 percent of total broilers produced in the U.S., while production of broilers in Arkansas and Georgia accounted for over 35 percent of broilers produced in the South (USDA). Although production is moved through trade channels to many consuming locations, one might expect, to a large extent, that consumption patterns are closely related to production because of the relative availability of the commodity and relative low price as compared with other available substitutes.

dent on quantity purchased by households. By separating quantity purchased from the decision to purchase, this approach provides more flexibility in the sense that quantity purchased may be treated as an endogenous variable and formulated into the model or it may be approximated with extraneous information depending on the availability of quantity purchase data.⁵

Another advantage of the present procedure is related to its simplification of updating market estimates. In order to update market estimates, the procedure developed by Raunika et al. requires that all estimates, including adjustment factors, be recalculated at each detailed intermediate step. However, given available information on changes in socioeconomic characteristics of the population, the present procedure provides ready access for assessment of probable changes in market participation and, hence, updating the market estimates accordingly. Thus, much of the computational burden in the updating process can be avoided in the present procedure. Furthermore, the present procedure provides flexibility in the updating process in which adjustments of probabilities of market participation and average quantity of purchase can be carried out either independently or jointly.

Although the procedure developed in this study has the advantage of relative simplicity and flexibility, a drawback is recognized in the computational procedure that assumes all purchasing households in a given market area purchase the same amount of quantity. If only aggregated market estimates are of interest, the assumption of using average quantity in the computation of market shares perhaps is not a serious limitation. Furthermore, the present procedure develops market estimates from highly aggregated markets to disaggregated market areas. Thus, its computational simplicity may decrease rapidly as the degree of market disaggregation increases.

CONCLUSIONS

An alternative estimation procedure which incorporates a probabilistic approach was developed for the derivation of aggregate regional demand for food products. Regional market demand for broiler meat was used to illustrate the estimation procedure. The study provides information not presently available from other sources which is useful for decision-making in the food processing and food distribution industries, and for farm producers seeking potential markets by location for their products.

The conceptual approach used in this study is to transform the estimation of a traditional demand function into a qualitative choice model. As a result, instead of predicting quantity demanded directly, the probit procedure can be used to assess the probability that a household will purchase a particular food product and, hence, to predict the proportion of purchasing households within a given market area. This information is then used to derive market shares and to allocate total domestic disappearance among market areas.

The alternative estimation procedure yields results which generally agree with previously reported estimates and appear to conform to the current trend in broiler meat consumption patterns. The results suggest different patterns of household food purchasing decisions for whole broilers and broiler parts. The relatively less processed and less expensive whole broilers are less preferred than broiler parts as household income increases. The probability of observing purchase of whole broilers versus broiler parts is greatly increased as household size increases, *ceteris paribus*. Furthermore, the results indicate that households in the South, as compared with those in other regions, are most likely to purchase whole broilers while households in the Northeast are most likely to purchase broiler parts.

The framework for this analysis is highly aggregated and simplified; however, detailed delineation of spatial markets and product forms can be incorporated. The estimation procedure developed in this study is designed to provide more flexibility in the sense that quantity purchased may be treated as an endogenous variable and formulated into the model, or it may be approximated with extraneous information depending on the availability of quantity purchase data. Although not addressed in this study, the framework offers the flexibility of explicitly incorporating information on predicted changes in prices into final estimates of market demand.

The recently available data base, the U.S. Department of Agriculture's 1977-78 Nationwide Food Consumption Survey (NFCS), provides the most complete and comprehensive information for updating parameter estimates. The 1977-78 NFCS also provides insights regarding changes in U.S. household food consumption patterns among various socioeconomic classifications and means for improving model specification and estimation. Hence, future study should be able to address some of the unresolved aspects of demand estimation.

⁵ When individual household quantity data are available, the Tobit model may be used to estimate parameters for market demand directly. The alternative procedure of this study, which incorporates the probit procedure, does not strictly depend on the availability of quantities purchased by individual households.

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