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Estimation and Spatial Delineation of Demand for Broiler Meat

Chung L. Huang and Robert Raunikar*

Since the early 1970's, American consumers have changed their food consumption patterns in response to sudden increases in food prices. Also, shifts in demographic distributions and increased awareness of dietary concerns have significantly affected consumer's consumption of food items. Changes in meat consumption patterns are most evident among individual meat product categories. During the past decade, per capita beef consumption decreased from 113.5 pounds in 1970 to 104.4 pounds in 1982; pork consumption decreased from 72.6 pounds per capita to 62.7 pounds; and lamb and mutton, and veal also follow the general decreasing consumption trend (USDA). In contrast, per capita consumption of poultry meat increased by 15.3 pounds during the 1970-82 period, offsetting most of the decline in red meat consumption. Per capita consumption of broiler meat, in particular, increased rapidly from 40.4 pounds in 1970 to 52.9 pounds in 1982, accounting for over 80 percent of the increased consumption of poultry meat.

Results of two recent surveys -- the Bureau of Labor Statistics (BLS) 1972-73 Consumer Expenditure Diary Survey (CEDS) and the U.S. Department of Agriculture (USDA) 1977-78 Nationwide Food Consumption Survey (NFCS) -- also reveal changes in U.S. household food consumption patterns. The surveys suggest that, on a weekly basis,

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consumer's red meat expenditure decreased from 23.63 percent of total at-home food expenditure in 1972-73 to 22.37 percent in 1977-78. Conversely, food budgets for poultry meat increased from 4.28 percent of total at-home food expenditure in 1972-73 to 4.38 percent in 1977-78 (Huang and Raunikar, 1981).

Continued growth prospects in poultry production and consumption are expected in the 1980's. Processors have emphasized marketing broilers as cut-up chickens, parts, and numerous further processed items through grocery stores and fast-food outlets to attain growth. These marketing strategies offering greater choice, flexibility and convenience have appealed to consumers and help expand consumption.

Current data on broiler meat consumption are available only on an aggregate basis, i.e., for the entire U.S. and for total broiler meat. Disaggregated data on product forms by geographic market areas provide useful and important information for decision-making in the processing and distribution segments of a highly integrated broiler industry. Such data assist in assessing potential markets for specific products by location, evaluation of the relative position of one market versus another, and the selection of potential locations for production, processing and distribution of products.

Previous research by Raunikar et al., and by Huang and Raunikar (1982) show that the parameter estimates of an empirical demand relationship can be used to derive market demand for spatially delineated submarket areas. These approaches neglect the distributional effects of the population characteristics within a specific market area. For instance, average household income may be

similar among several markets but the income distribution patterns may be quite different and, hence, have a significant different effect on the estimated aggregate market demand.

The objectives of this study are twofold. First, the study identifies and measures effects of socioeconomic characteristics and changing income on consumer demand for broiler meat by product form. Second, the study develops a procedure which incorporates the distribution patterns of socioeconomic characteristics within a specified market area into the estimation of the market requirements for broiler meat.

The Framework

To gain an overall perspective, the steps involved in the estimation of market demand for broiler meat among spatially delineated market areas are depicted in Figure 1. Step 1 involves regression analysis of the household consumption of broiler meat using data collected from the 1977-78 USDA NFCS. Step 2 encompasses the process of data generation wherein input requirements are differentiated between parameter values and simulated exogenous variable values. The parameter values are obtained by implementing the first step. Other inputs to be used in the simulation process are generated via a random number generation function based on population characteristics distribution obtained from the 1980 Census of Population. Finally, market demand estimates among spatially delineated market areas are derived from results of the previous steps.

Based on the regression results, a simulation procedure is used to predict the average household consumption of broiler meat by product

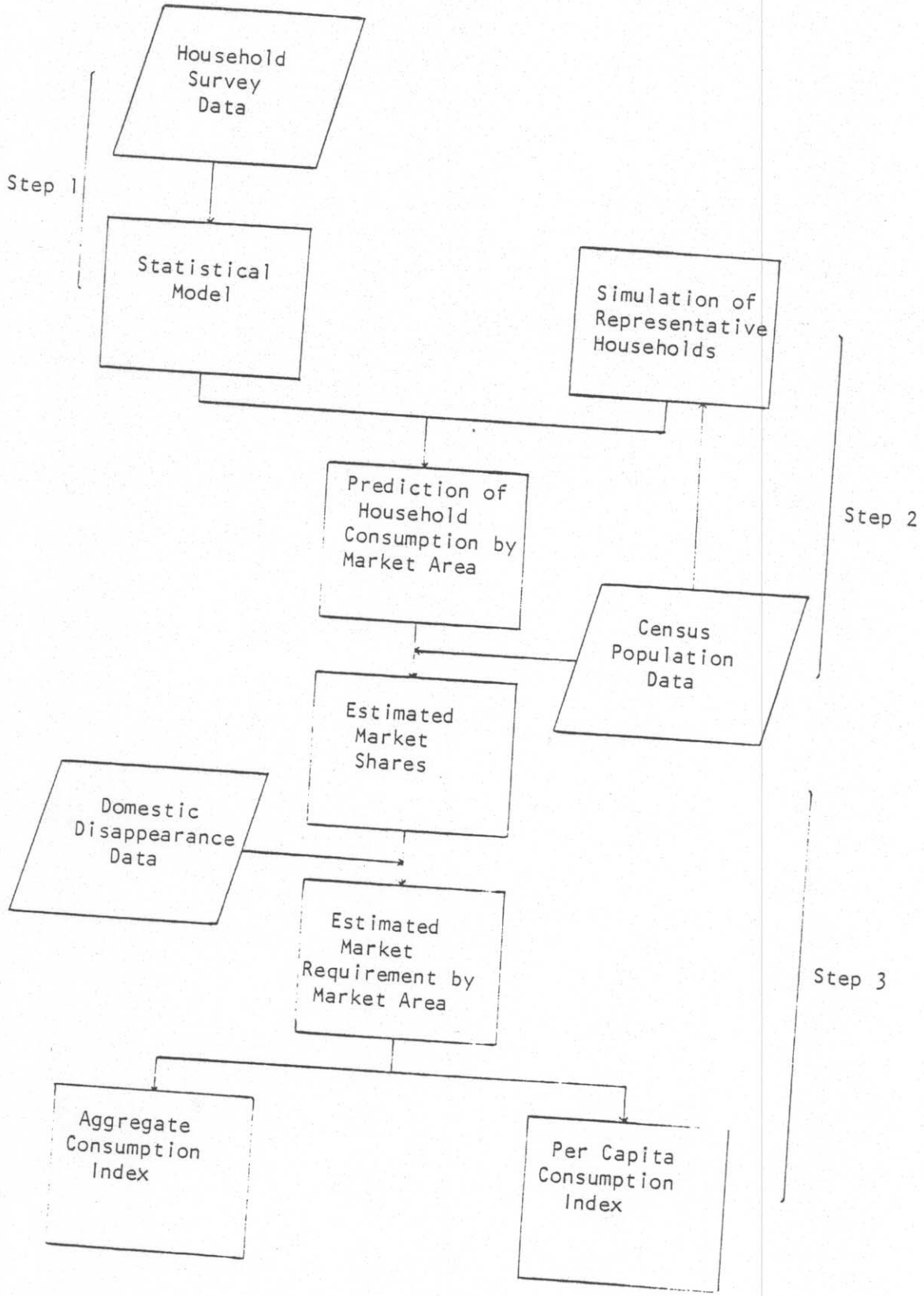

Figure 1. Framework for Market Demand Estimation

form among specified submarkets in the U.S. The market share of a given product form within a given market is computed as

$$(1) \quad MS_{ij} = (Q_{ij} \times NH_i) \; / \; \sum_{i=1}^{n} (Q_i \times NH_i),$$

where MS_{ij} represents the market share of broiler product j of market i, Q_{ij} is the average household consumption of broiler product j in market i and Q_i represents the average household consumption of total broiler product in market i, and NH_i represents the number of households in market i. Given the domestic disappearance and the estimated market shares among the geographic market areas, market demand for any specified area can be easily obtained. Furthermore, a consumption index is also computed to reflect the relative consumption position of a particular market as compared with the national average. The national average is computed as a weighted average of all submarket averages in the U.S.

In this study, the delineation of geographic market areas are by state boundaries. Thus, the total U.S. market is represented by the 50 states plus the District of Columbia. The demand for broiler meat is defined in terms of two product forms, representing whole broilers and broiler parts.

The Statistical Model

To implement the first objective of the study, a model of consumer demand for broiler meat is postulated. The model follows the conventional demand specification based on cross-sectional analysis (Haidacher et al.; Prais and Houthakker; Raunikar et al.; Salathe). However, analysis of cross-sectional data often encounters the problem

that the dependent variable is censored normal. To account for the underlying structure of a stochastic model in which the dependent variable has some limited values, the model is specified as

$$(2) \quad \begin{aligned} Y_j &= X_{ij}\,\beta + e_j, && \text{if RHS} > 0 \\ &= 0 && \text{otherwise,} \end{aligned}$$

where Y_j is quantity of broiler meat consumed by the j^{th} household, X_{ij} represents a set of socioeconomic characteristics associated with the j^{th} household, such as income, race, urbanization, age-sex composition of the household members, β is an unknown parameter vector; and e_j is a normally distributed random disturbance.

The maximum likelihood procedure suggested by Tobin for estimating the limited dependent variable model, known as Tobit regression, is used to estimate equation (2). An important property of Tobit regression is that it accounts for the fact that the dependent variable is affected by both the size of nonlimit responses and the probability of the occurance of such responses.

Results of Statistical Model

Estimation of the statistical model of equation (2) is based on data obtained from the 1977-78 USDA NFCS. Household at-home consumption of whole broilers and broiler parts are selected for this analysis. The U.S. sample consists of 10,964 households selected from approximately 15,000 households that participated in the nationwide survey. Nearly 25 percent of the households surveyed were excluded from the sample due to incomplete information reported for household income.

Differences in broiler meat consumption among regions are evident among sampled households. Average broiler meat consumption per household per week appears to be greater in the South and Northeast regions than in the North Central and West regions. Consumption of whole broilers accounts for about 55 percent of total broiler meat in the Northeast region. In contrast, consumption of whole broiler meat accounts for a greater proportion of total broiler meat consumption among other regions, ranging from about 71 percent in the West to 78 percent in the South. The Northeast region appears to be a major market for broiler parts as compared with other regions of the U.S.

Results of Tobit regression for whole broilers and broiler parts are presented in Table 1. In general, the results indicate that most household characteristics exhibit significant impacts on broiler meat consumption. The magnitudes of the coefficients associated with the age-sex composition variables indicate that greater impacts are exerted by adults than children and by male than female members of the household unit. The coefficients of the dummy variables also suggest significant differences existed in household consumption of broiler meat among regions of the U.S., between black and nonblack households, and between rural and nonrural residences.

Results suggest distinctive patterns between consumption of whole broilers and broiler parts. Specifically, household income was found to have a negative effect on consumption of whole broilers, but a positive effect on consumption of broiler parts. Similar findings were reported by Huang and Raunikar, and by Salathe using the 1972-73 BLS CEDS, and by Haidacher et al. using the 1977-78 USDA NFCS data.

Table 1. Regression Results of Household Consumption of Whole Broilers and Broiler Parts, U.S. 1977–78.

Variable	Whole broilers	Broiler parts
Constant	0.756	-7.762
Northeast	-1.194 (-8.959)[a]	1.683 (11.799)
North Central	-0.866 (-6.655)	-0.635 (-4.024)
West	-0.830 (-5.547)	-0.233 (-1.350)
Black	2.485 (16.680)	0.680 (3.856)
Rural	0.029 (0.258)	-1.241 (-9.064)
Log (income)	-0.574 (-7.774)	0.418 (4.987)
Household size squared	-0.072 (-6.593)	-0.013 (-1.026)
Male $\geq$ 35 years	1.628 (11.541)	-0.189 (-1.195)
Female $\geq$ 35 years	1.947 (13.043)	0.443 (2.687)
19 $\leq$ Male $\leq$ 34 years	1.410 (10.266)	0.115 (0.749)
19 $\leq$ Female $\leq$ 34 years	1.313 (8.931)	0.397 (2.447)
13 $\leq$ Male $\leq$ 18 years	1.338 (9.734)	0.093 (0.581)
13 $\leq$ Female $\leq$ 18 years	1.260 (9.138)	0.517 (3.234)
6 $\leq$ Child $\leq$ 12 years	1.371 (12.291)	0.364 (2.909)
Child $\leq$ 5 years	1.376 (11.360)	0.166 (1.211)

[a]Numbers in parentheses are t-ratios.

Furthermore, the results imply that there are economies of scale associated with consumption of whole broilers as household size increases. In contrast, no significant economies of scale were found on the consumption of broiler parts. It is interesting to note that average household consumption of broiler parts tends to increase significantly with the addition of female members rather than male members in the household.

Microanalytic Simulation

To satisfy the second step of the objective, a microanalytic simulation process was used to predict average household broiler meat consumption within a specified geographic market area.[1] Amstutz (pp. 112-13) defines a microanalytic simulation model as one that "provides an integrated statement of that which is known and assumed about actions, reactions, and responses within the environment being simulated." He also distinguished several types of simulation models. The model used in this study is simplistic, econometric and static.

Given the statistical model of equation (2), the underlying assumption is that the estimated parameters convey the empirical generalization of households consumption behavior with regard to the

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[1]Since the unconditional expected value of Y in equation (2) is no longer equal to $X\beta$ in the case of Tobit estimator, the computation of household broiler meat consumption is based on $E(Y) = X\beta F(z) + \sigma f(z)$, which is the unconditional expected value of Y using Tobit regression. Where $z = X\beta/\sigma$, σ is the standard error of estimates from regression, and $f(z)$ and $F(z)$ are the unit normal density function and cumulative normal distribution, respectively.

impacts of various socioeconomic characteristics of the sample households. Hence, the resulting regression model states that household consumption of a particular broiler meat is identical for households with the same characteristics.

Assuming that the population characteristics within a market area are known, the procedure is then to simulate a household unit with certain characteristics according to the distributions of the population characteristics within that market area.[2] Table 2 provides an example of a single run results on simulating the household characteristics for the U.S. sample. The simulated results are fairly close to the actual sample. As the number of household being simulated increases, further improvement in the accuracy of the results in approximating the actual sample would be expected. In the study, a sample of 500 households is simulated for any given state market according to the distribution of population characteristics within that particular state.

The simulation process generates a large number of households of differing types which are representative of a sample population.

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[2]The procedure makes use of a random number generator which draws a number randomly from a uniform distribution of range from 0 to 1. This random number is then compared with the probability that a particular event will occur to determine the values of the simulated variable. For example, to determine the race of a household, a decision function of the form A = B - UNIFORM(X) is used to obtain a binary -- black household, white household -- decision. Where B is the proportion of black households within the defined market, and X is the argument of a uniform distribution function which generates a random number between 0 and 1. Thus, if B is less than UNIFORM(X), then A is negative and the household is assumed white and hence, the races variable is assigned a value of 0. Otherwise, if A is nonnegative, the household is assumed black and the race variable is assigned a value of 1.

Table 2. Sample Statistics and Simulated Results of Household Socio-economic Characteristics, U.S.

Characteristics	Sample[a]			Simulated[b]		
	Mean	Min	Max	Mean	Min	Max
Northeast region	0.25	0	1	0.25	0	1
North Central region	0.24	0	1	0.20	0	1
West region	0.17	0	1	0.16	0	1
Black	0.12	0	1	0.07	0	1
Rural	0.28	0	1	0.24	0	1
Log (income)	9.27	5.70	12	9.32	6.96	10.78
Household size	2.94	1	15	2.87	1	14
Male $\geq$ 35 years	0.54	0	4	0.50	0	2
Female $\geq$ 35 years	0.64	0	4	0.60	0	3
19 $\leq$ Male $\leq$ 34 years	0.34	0	4	0.33	0	3
19 $\leq$ Female $\leq$ 34 years	0.39	0	4	0.47	0	3
13 $\leq$ Male $\leq$ 18 years	0.19	0	4	0.15	0	2
13 $\leq$ Female $\leq$ 18 years	0.18	0	5	0.23	0	5
6 $\leq$ Child $\leq$ 12 years	0.38	0	6	0.32	0	5
Child $\leq$ 5 years	0.28	0	5	0.27	0	3

[a]Compiled from the 1977-78 USDA Nationwide Food Consumption Survey.

[b]Based on a single run with 100 simulated households.

Specifically, the simulated results become a weighted average of the consumption levels of the household types in the market area, the weighting being proportional to the numbers of such households in the studied market area.

The reliability of the model's performance is assessed by examining whether successive replications of a given system will produce results within acceptable limits. Therefore, a sequential estimation procedure as described in Fishman is employed. Fishman (p. 69) defines the stopping rule for determining the number of replications run in a sequential estimation as

$$(3) \qquad k^* = \min [k: S_k^2 (Y) \leq kd^2/t_{k-1,\alpha}^2]$$

and

$$S_k^2(Y) = \left(\sum_{i=1}^{k} (Y_i - \overline{Y}_k)^2 \right)/k-1, \quad \overline{Y}_k = \left(\sum_{i=1}^{k} Y_i \right)/k,$$

where k is the number of replications, d is a user-specified quantity for a tolerance level, and $t_{k-1,\alpha}$ corresponds to the $1-\alpha/2$ quantile of the Student t distribution with k-1 degree of freedom. Essentially, the procedure is to collect one observation Y_i at each run with the objective of obtaining a result with a given accuracy. Specifically, if k^* is determined by equation (3), then it is suggested that

$$\text{Prob} \left(\overline{Y}_{k^*} - d \leq \mu \leq \overline{Y}_{k^*} + d \right) \geq 1 - \alpha,$$

where μ is the true population mean. The sequential estimation not only provides evidence of reliability but also provides a means for obtaining the estimate at a prescribed level of accuracy.

Evaluation of the Simulation Results

Given that the estimation procedure is based on the total U.S. sample, one would then be interested in examining how the model performs when used to predict broiler meat consumption on subdivided geographic market areas. The performance of the model is evaluated by simulating household consumption of whole broilers and broiler parts for regional markets, i.e., Northeast, North Central, South and West. Results of predicting the regional broiler meat consumption are summarized in Table 3. Regional consumption was simulated by applying the regional socioeconomic and demographic characteristics distributions as inputs into the model. Applying the stopping rule of equation (3), the results indicate that in most cases only two replications are required. In addition, the resulting estimates are very similar regardless of the use of different random seedings in the simulation process.

Estimates of regional average broiler meat consumption based on conventional approach are also presented in Table 3 for purpose of comparison. These results are computed by substituting the average household characteristics of a regional market into the regression equation. As shown in Table 3, this approach consistently underestimates the magnitudes of broiler meat consumption within each regional market. Furthermore, the results tend to predict incorrectly the relative magnitude of whole broilers to broiler parts consumption in the Northeast regional market.

Estimation of State Markets

Approximately 11,295 million pounds of chickens were consumed in the U.S. in 1980, or about 50.1 pounds per capita (USDA). However,

Table 3. Sample Average and Simulated Regional Average Broiler Meat Consumption, Pounds Per Household, Per Week[a]

Region/ Broiler type	Sample[b]	Experiment 1[c] Simulation 1	Experiment 1[c] Simulation 2	Experiment 2 Simulation 1	Experiment 2 Simulation 2	Non-simulated
Northeast						
Whole broilers	1.172 (2.209)[d]	1.053	1.063	1.065	1.082	0.920
Broiler parts	0.951 (1.802)	0.960	0.954	0.950	0.958	0.929
North Central						
Whole broilers	1.193 (2.01)	1.175	1.163	1.167	1.172	1.045
Broiler parts	0.396 (1.19)	0.350	0.359	0.359	0.359	0.335
South						
Whole broilers	1.713 (2.401)	1.704	1.732	1.698	1.700	1.573
Broiler parts	0.473 (1.270)	0.453	0.452	0.459	0.460	0.427
West						
Whole broilers	1.086 (1.86)	1.065	1.057	1.083	1.088	0.961
Broiler parts	0.450 (1.14)	0.461	0.458	0.462	0.459	0.441

[a]Simulation results are based on sequential estimations with d=.25 and α=.05.

[b]Compiled from the 1977-78 USDA Nationwide Food Consumption Survey.

[c]Experiments 1 and 2 simulate 1000 and 500 households per single run, respectively. Simulations 1 and 2 differ only with respect to the use of random number seedings.

[d]Numbers in the parentheses are standard deviations.

there are no available data to show how the total consumption of broiler meat was distributed by product form and by submarket areas, either on a state or regional basis. Neither does the current data indicate how per capita consumption of broiler meat varies among different market areas. Based on the procedure developed and discussed in this study, estimates of aggregate and per capita demand for broiler meat for 1980 were derived for regional and state markets.

The estimated regional demand for broiler meat in the nine subdivisions of the U.S. regional markets in 1980 is presented in Table 4. The South accounted for 38.1 percent of total U.S. domestic disappearance of broiler meat followed by the Northeast, North Central, and West, accounting for 24.1 percent, 21.5 percent and 16.3 percent, respectively. The results are generally in agreement with regional market estimates reported by Huang and Raunikar (1982) for 1979 of 38.0 percent, 25.6 percent, 21.0 percent, and 15.4 percent for the South, Northeast, North Central, and West, respectively.

The South ranked first in whole broiler consumption, accounting for 42.5 percent of the U.S. market demand for whole broilers. On the other hand, the Northeast, the largest regional market for broiler parts, accounted for 37.8 percent of the U.S. market demand for broiler parts in 1980. The results suggest that, as might be expected, the greatest proportion of broiler meat consumption occurs in the South and Northeast where population concentrations are high relatively to other regions. For brevity, only estimated broiler meat consumption for state markets in the North Central region are shown in Figure 2. Averages of state market demand for broiler meat within

Table 4. Estimated Broiler Meat Consumption in the Regional Markets, U.S., 1980.

Regional Market	Whole Broilers	Broiler Parts	Total
	million pounds		
Northeast	1,374.79	1,342.66	2,717.45
Division I	319.86	325.31	645.17
Division II	1,054.93	1,017.35	2,072.28
North Central	1,814.41	616.47	2,430.88
Division III	1,294.10	445.36	1,739.46
Division IV	520.31	171.11	691.42
South	3,286.48	1,020.87	4,307.35
Division V	1,638.31	512.23	2,150.54
Division VI	656.88	181.91	838.79
Division VII	991.29	326.73	1,318.02
West	1,263.43	575.89	1,839.32
Division VIII	330.32	140.49	470.81
Division IX	933.11	435.40	1,368.51
Total	7,739.12	3,555.88	11,295.00

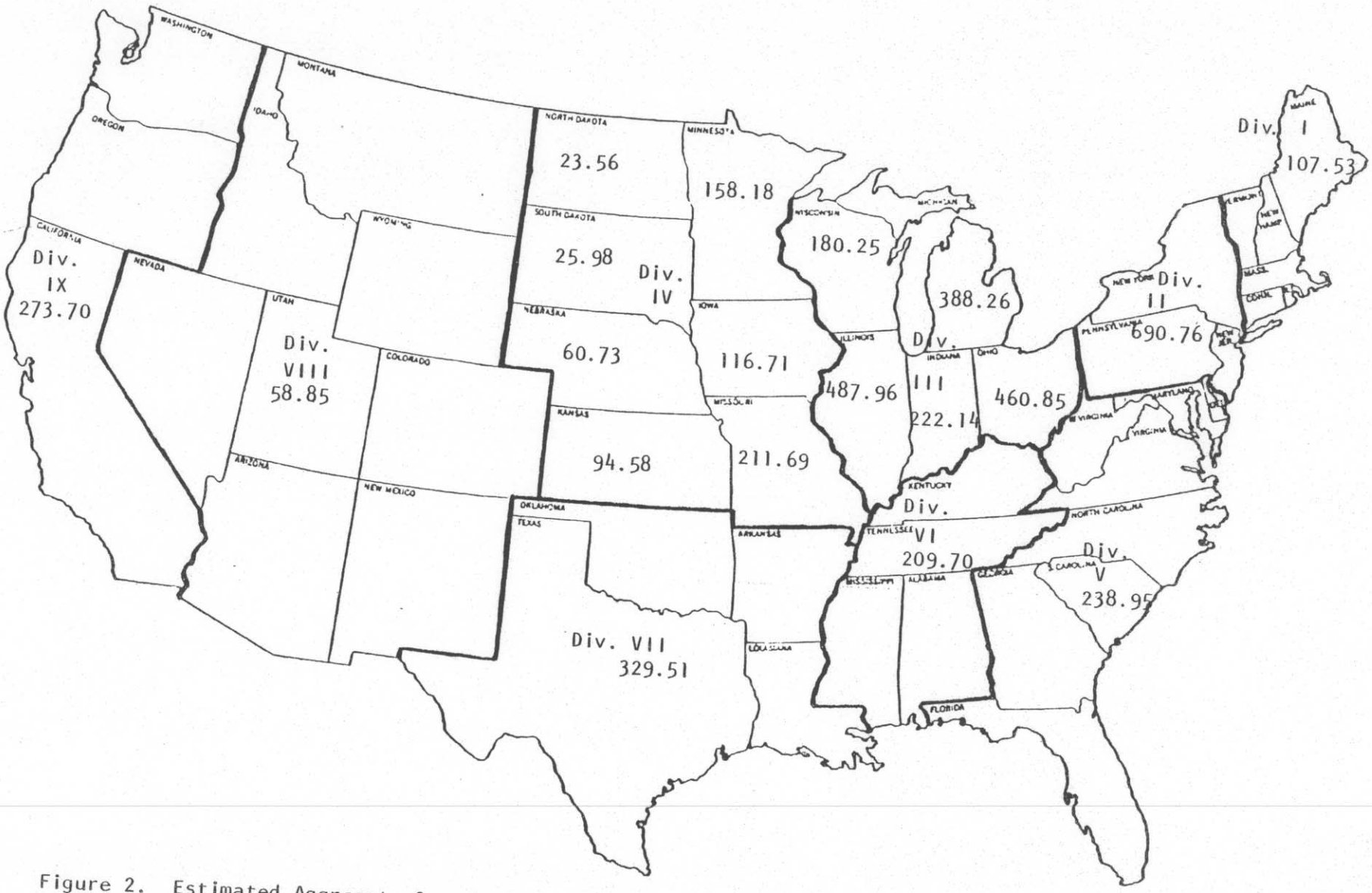

Figure 2. Estimated Aggregate Consumption of Broiler Meats (Mil. lbs.) by State Markets, North Central Region, U.S., 1980.

other regional subdivisions are also presented for purpose of comparison. Comparing the estimated broiler meat consumption with production among states in the North Central region indicate that each state in the North Central region is a deficit state in broiler meat production and, hence, the entire North Central region showed a deficit of broiler meat production over consumption in 1980. Illinois, Ohio and Michigan are the largest broiler meat markets in the North Central region. Total broiler meat consumption among these three states accounted for about 55 percent of total broiler meat consumed in the region whereas about 53 percent of the population in the region resided within these three states in 1980.

Consumption indices on aggregate and per capita bases for states in the North Central region are presented in Table 5. Aggregate state consumption indices vary from 5.0 for North Dakota to 104.6 for Illinois. The state consumption index reflects primarily the effects of population density on total broiler meat consumption among the states. Thus, a very populous state such as Illinois is estimated to consume 4.6 percent more broiler meat than a weighted average consumption for the U.S. Per capita consumption for states in the North Central region in 1980 are estimated to be lower than the U.S. average. The per capita consumption index reflects the relative position of per capita broiler meat consumption among states in the North Central region as compared with the U.S. average.

Per capita consumption index estimated by Raunikar et al. for 1965 is also shown in Table 5 for purpose of comparison. It is noted that per capita consumption index for states in the North Central region

Table 5. Estimated Aggregate and Per Capita Broiler Meat Consumption Indices, and Per Capita Consumption by Product Form in the North Central Region, U.S., 1980.

State	Aggregate	Per capita		Per capita consumption 1980		
	1980 relative to U.S. average	1980 relative to U.S. average	1965 relative to U.S. average[a]	Whole broilers	Broiler parts	Total
	- - -Index (U.S. = 100)- - -			- - - - - - lbs.- - - - - -		
Illinois	104.6	85.7	94.0	31.4	11.5	42.9
Indiana	47.6	81.2	85.0	30.4	10.2	40.6
Iowa	25.0	80.3	82.0	30.6	9.7	40.3
Kansas	20.3	80.3	85.0	29.7	10.5	40.2
Michigan	83.2	84.1	88.0	31.7	10.4	42.1
Minnesota	33.9	77.8	82.0	29.1	9.9	39.0
Missouri	45.4	86.4	91.0	32.8	10.5	43.3
Nebraska	13.0	77.6	82.0	29.0	9.9	38.9
North Dakota	5.0	72.4	74.0	27.6	8.6	36.2
Ohio	98.8	85.6	88.0	32.1	10.8	42.9
South Dakota	5.6	75.4	76.0	29.4	8.4	37.8
Wisconsin	38.6	76.8	82.0	28.7	9.8	38.5

[a]Compiled from Raunikar et al.

are estimated to be lower in 1980 than in 1965. This suggest that while per capita consumption among states in the North Central region has been increasing over the past decades, their rates of increase in per capita consumption of broiler meat have been relatively lower than other states in the U.S. Results of this study indicate that per capita consumption of broiler meat in Missouri, Illinois, Ohio and Michigan are the highest among states in the North Central region. Similar results were shown in Raunikar et al.

Conclusion

The objective of the study was to develop estimates of broiler meat demand for specified geographic markets in the U.S. for 1980. Although projections of market demand to years beyond 1980 are of definite interest, procedures to be used for demand projections have not been completely developed. This study utilizes available information in 1980 as a benchmark to illustrate the procedure used for development of demand estimates among spatially delineated markets.

The procedure necessary to develop estimates for the markets required basic information on factors influencing demand and spatial detail on the socioeconomic characteristics of the studied market areas. Demand relationships were estimated based on the 1977-78 USDA NFCS data. Data on the population and characteristics of the population were developed from the 1980 Census of Population.

Demarcations of the differing geographic markets were defined by the 50 states plus the District of Columbia. Consumption indices for broiler meat were estimated for each state to reflect the relative consumption position of each state as compared with the national

average. Results of the study suggest that considerable spatial variation in broiler meat consumption among states in the U.S. The study shows that the North Central region is a deficit region in broiler meat production, and consumption of broiler meat among states in the region were generally lower than the U.S. average.

Only limited information on broiler meat consumption is available to examine the validity of the estimates presented in this study; however, estimates from this study appear to be in agreement with previous studies. It should be noted that results of this study are subject to the limitation of data and estimation procedures. In particular, since the analysis is based on cross-sectional data of household consumption and characteristics, factors such as supply and price variations are not explicitly considered. Thus, it should be emphasized that the study only provides insights with respect to implications resulting from changes in a few key variables such as income and population size and composition. Nevertheless, results of the analysis provide additional information and guidelines for decision-makers concerning production, processing and distribution of broiler meat products, and development of marketing strategies for promoting broiler meat consumption among various spatial markets in the U.S.

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