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KNOWLEDGE IS BETTER THAN MONEY: THE EFFECT OF THE FOOD STAMP PROGRAM ON NUTRIENT INTAKE

by

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Abstract

Does the Food Stamp program improve the nutrient intake of participants? An elaborate econometric model, based on nutritional theory, is used to determine whether the program is effective and to quantify its effects while controlling for selection bias. The data used in the study are from the Food Stamps Cashout Project and the Rural Income Maintenance Experiment.

The results concur with earlier studies. Adequate income is no guarantee of adequate nutrition. Increased income, whether from food stamps or from other sources, is associated with reduced nutrient intake, at least in the two data sets studied. Yet food stamps increase food consumption, and therefore the program serves to reduce hunger.

Even rudimentary knowledge of nutrition appears to increase nutrient intake considerable. It would appear therefore that a program to increase knowledge of what constitutes an adequate diet would effect the desired changes in the nutritional status of the poor.

KNOWLEDGE IS BETTER THAN MONEY: THE EFFECT OF THE FOOD STAMP PROGRAM ON NUTRIENT INTAKE

The purpose of the Food Stamp program is to increase the nutrient intake of the poor. According to the preamble of the law, the program is to "assure low-income households the opportunity to attain a nutritionally adequate diet through normal channels of trade by increasing their food purchasing power and by furnishing food purchasing assistance to all eligible individuals who apply for participation." (See U.S. Congress, Senate Committee on Agriculture, Nutrition, and Forestry, 1979.) The program arose with another purpose as well, to dispose of surplus commodities induced by agricultural subsidies. In 1973, Caro Luhrs of the U.S. Department of Agriculture stated:

> "We are interested in both [surplus food and nutritional problems] but we are the USDA. We purchase the food we distribute in any event. Some of the food we purchase is in surplus in this country, but much of the food we distribute is not. The fact that the USDA purchases and distributes non-surplus food certainly indicates that we are attending to nutritional problems." (Luhrs 1973, p. 1153)

The Food Stamp program (FSP) may be serving other purposes as well. It may make donors happy, especially those who would like to give food rather than money (see Thurow, 1974, and Giertz and Sullivan, 1977, for example). At the other extreme, a belief that food stamps can be substituted for cash in the budget combined with the fact that eligibility is based on income and deductions but not family structure can lead to its being considered a kind of negative income tax, hence favored by those who would place minimal restrictions on recipients.

This research is based on the assumption that whatever its purposes may be, the effect of the FSP on nutrient intake matters. The previous research has indicated that it is not very effective, but that research has not used the best econometric technique. This paper considers again the question of whether the FSP is effective, quantifies the effect, controls for selection bias, and evaluates the effect on nutritionally relevant intake. Controlling carefully for selection bias and nutritional theory concerning effective nutrient intake may or may not make a difference to the results, but it refines the estimates and may help to show what the program is really doing nutritionally.

The first part of the title refers to the fact that in raising nutrient intake, a little knowledge of nutrition is more effective than food stamps according to the empirical results.

The following sections present (1) a literature review, (2) nutritional and economic theory, (3) the econometric methodology, (4) the data, (5) the results from the old people, (6) the results from the rural people, (7) the policy implications, and (8) a summary.

Section 1. Literature Review

The studies of the nutritional effects of the Food Stamp program and similar programs are presented in Table 1. The Rural Income Maintenance Experiment is considered in one study. (In this paper, the effect of food stamps in that sample is estimated.) The Commodity Food Distribution Program is examined in three studies.

O'Connor, Madden, and Prindle (1976) examined the effects of the Rural Income Maintenance Experiment on nutrient intake. (This later appeared as O'Connor and Madden, 1979.) Madden and Yoder (1972) studied the effect of food stamps in two surveys in Bedford County and two surveys in Huntingdon County, Pennsylvania, and the effect of commodities in one survey in Bedford County. The results for commodities are report-

Table 1

Studies of the Nutritional Effect of the Food Stamp Program and Similar Programs

1	O'Connor, Madden, and Prindle (1976)	Rural IME	parts of NC and Iowa
2	Madden and Yoder (1972) (commodities)	1 survey	part of PA
	(food stamps)	4 surveys	parts of PA
3	Guthrie, Madden, Yoder, and Koontz (1972) (commodities)	1 survey	part of PA
4	Lane (1978) (commodities and food stamps)	1 survey	Kern Co., CA
5	Johnson, Burt, and Morgan (1981)	NFCS	national
6	Whitfield (1982)	1 survey	Tulsa, OK
7	Akin, Gilkey, Popkin, and Smith (1985)	NFCS	national
8	Butler, Ohls, and Posner (1985)	FSC	parts of NY, OR, and SC

Nutrient	1 NC	1 IA	2	3	4 CFDP	4 FSP	5	6	7 P	7 NP	8
Calories	+ **	- **	+	+ *	0	+ *	+ *	+	+	-	+
Protein	+	-	+ *	+	+ *	+ *		+ *	+	-	+
Calcium	+	-	+	+	0	+ *		-	+	+	+ **
Iron	+ **	+	+	-	+ *	+ *		+ *	+	+	+
Vitamin A	+	+	+	+ **	- *	+ *		- *	+	-	+
Thiamin (B1)	+	+	+	+	+ *	+ *					+
Riboflavin (B2)	+ *	+	+	+	0	+ *					+
Niacin	+	+	+	+	0	0					+
Vitamin C	+ *	+	+	- *	- *	- *		+ *			+
Phosphorous	+	+	-	-							
Pyridoxine (B6)									-	-	

Notes: * significant at the 5% level
** significant at the 10% level
Blank spaces indicate that a nutrient was not included in a study.
IME = Income Maintenance Experiment
NFCS = National Food Consumption Survey
CFDP = Commodity Food Distribution Program
FSC = Food Stamps Cashout

Effects in reference 2 are based on food stamps and are averages; in Huntingdon County several effects were negative, and in Bedford County all effects were positive, but none were significant except in the first two weeks after receipt. The results for the commodities are reported as reference 3.

Reference 4 shows means corrected for income devoted to food but not for any other characteristics. A figure of 0 is no effect as reported in the source, which reports only two significant digits in the statistics.

Reference 5 reports calories and summary measures only, obtaining significant (5% level) results in a summary measure based on seven nutrients.

P and NP under a reference refer to participants and non-participants; they estimate separate equations for each group. Coefficients relate to measures of participation. Food Stamp bonus has a negative effect on calories (non-significant); its effect on other nutrients is not reported.

ed separately in Guthrie, et al. (1972). Lane (1978) used a survey from Kern County, California, to study food stamps. Johnson, Burt, and Morgan (1981) used the same national survey, the National Food Consumption Survey, as Akin et al. (1985), but the first study employed only calories and summary measures, while the second reported results for individual nutrients, and used more sophisticated models. Whitfield (1982) used a survey from Tulsa to study food stamps. Butler, Ohls, and Posner (1985) studied food stamps using one of the data sets to be used in this paper, but with a different specification from the one here.

Unfortunately, Lane (1978) reports differences of means corrected only for income, not for any other economic or demographic variables, so the effects cannot be interpreted as being due to food stamps.

Conclusions from Akin et al. (1985) presented here are based on the estimated coefficients from the regressions they reported, and differ from the conclusions in the "Policy Implications" section of their article, which are based on the average behavior of participants, who differ in other respects from non-participants.

The conclusions drawn from Table 1 depend on the weighting applied to each study. Here we ignore Lane's study (number 4) and weight the others equally. The effect of the Food Stamp program is positive on most nutrients in most cases (55 of 68). Of these estimated effects, 10 are significant at the 5% level (8 positive), and 5 more come in at the 10% level (4 positive). Calories and Vitamin C are the most likely to be affected significantly, but neither is completely consistent across all studies. The appropriate conclusion seems to be that food stamps and similar programs have weak positive effects.

The only studies in the list which controlled for the endogenous or self-selected participation are the last two. Akin et al. find positive effects based on the estimated coefficients from their equations for participants and, usually, negative effects in their equations for eligible non-participants and ineligibles. The last study found positive results but coded participation as a dummy variable, ignoring the amount of food stamps received. This paper is an extended respecification and reestimation of that study. Thus the best estimates in a statistical sense are the weakest for the Food Stamp program.

The food stamps received by participants in the Rural Income Maintenance Experiment have not been analyzed before, so they allow a new assessment of the effect of food stamps.

Before turning to the theory, note that participants are different from non-participants, a finding of both Lane and Akin et al. However, the marginal effect of food stamps, not the differences between the groups, is the appropriate measure of the effect of the policy. That people divide themselves into groups is not to the credit of the program.

Section 2. Theoretical Considerations

Nutrients are not purchased directly in most cases; food is. Thus nutrient intake is affected by all economic and social factors which govern the consumption of food. Furthermore, nutrient intake is also governed by physiological factors related to the body. The demand for food is ultimately derived from the body's needs for nutrients to remain active at a chosen level. For most people, however, food serves social purposes as well. Finally, some people seek out nutrients directly, choosing foods not only to allay hunger for the moment but also to achieve nutritional goals directly. Thus, both economic and nutritional theory must be consulted in studying nutrient intake.

Section 2.1. Factors Affecting Nutrient Intake

Nutrient intake is a function of income, demography, geography, education, time, and the physical body.

Physical factors determine how much of each nutrient is required to carry out an activity or a life. Age, race, and gender may affect this, but the main readily observable factors related to nutrient needs for given physical activity are height and weight. Weight is apt to be highly endogenous to nutrient intake, height less so. Height is used here.

Income affects both the willingness and the ability to consume nutrients: the willingness through choices made to allocate the budget, the ability through the size of the budget. Food stamp bonuses accepted may affect nutrient intake as other income does, but there may also be differences. Much research has shown that a larger portion of food stamps than of other income tends to be used for food. The effect on nutrient intake could be greater than for other income if recipients buy nutritional food in their increased expenditures; it could be less, if a degree of compulsion is involved which results in inefficiency in turning dollars into nutrients.

Demographic factors--age, race, and gender--may affect nutrient intake for a variety of reasons, some of which are already listed. It would be difficult to guess what the net effect might be. However, another factor, living alone, probably reduces nutrient intake based on lessened interest in food or greater technical inefficiency in buying, storing, and cooking for one. Men who live alone (especially elderly men) may be particularly unsuited to domestic tasks, such as preparing food. Thus, they may be even less efficient in consuming nutrients.

Diets may differ over geographic regions, so one should control for geographical areas. Rural locations may be systematically different in ways that affect the willingness and ability to obtain nutrients.

Education is a major factor in models based on human capital, and the production of nutrients is a major output of the household production function. Two types of human capital are distinguished, general and specific. General human capital is measured by years of formal education. Specific human capital is measured by a key question on both surveys used here to measure knowledge of nutrition. The question in the Rural Income Maintenance Experiment is:

> Next I would like to ask your ideas about what foods and drinks a person should have to keep in good health. What things do you think a healthy person should eat or drink daily to be healthy? (Family Management Interview V, 1970, Part B, p. 29).

A similar question is asked in the Food Stamps Cashout survey: "What kinds of foods do you think a person should eat to maintain good health?" (Question 24, p. 117). In each case, the respondent could name any number of foods and the result was coded by counting the number of the four basic food groups represented. These are (1) fruits and vegetables, (2) bread and grains, (3) meat or high-protein substitutes, and (4) dairy products, especially milk.

Dining on the weekends may be different from dining on other days, because other behavior is quite different. Most people do less market work, for example, although the difference in rural areas may be smaller. Big meals may be planned or ordinary meals skipped. The effect of weekends is ambiguous.

Section 2.2. Effective Nutrient Intake

Effective nutrient intake may differ from total nutrient intake. Regular intake of nutrients is required to maintain good health. In order to provide guidance in dietary standards, the National Research Council of the United States publishes recommended dietary allowances (RDA's) defined for various combinations of age and sex (see Guthrie, 1975 on this point and others discussed here). The standards used for comparisons of foods and the percentages written on the sides of containers of food, are based on the largest requirements for healthy persons, the U.S. RDA (see Peterkin, 1977, and Souders, 1974). For example, iron is based on the needs of menstruating women, Vitamin D on the needs of growing teenagers, etc. Thus, for any person, some nutrients are not needed at the 100% level implied by the government standards. Aside from that, the RDA's are set so that almost every healthy person would have enough of all nutrients under them. When Guthrie et al. (1972) studied nutrient intake, they considered 67% to be the cutoff for nutritional deficiency. In this paper, 67% and 100% are used.

Section 4.3 of this paper discusses the problem of using one day's nutrient intake to measure nutritional status. Under conditions discussed there, one day provides an indicator of average nutritional attainment and can be used to generate distributions over a population.

All nutrient data in this paper are divided by the appropriate RDA's: those for men and women over the age of 50 in the Food Stamp Cashout data, the total RDA of the family concerned in the Rural Income

Maintenance Experiment. The variable so defined is called the nutrient adequacy ratio (NAR). All the analysis is done in terms of the NAR's, rather than in terms of the actual quantity of nutrient consumed. The NAR may be analyzed untruncated or truncated at various levels, but it is in any event the best measure of dietary intake of one nutrient. When the NAR's of a variety of nutrients are computed, truncated at an appropriate level, and averaged, the result is the mean adequacy ratio (MAR).

Section 3. Econometric Methodology

The basic idea is to use regression analysis, but there are complications implied by nutritional theory and econometric theory. The first implies a truncated nutritional outcome, and the second implies the endogeneity of participation and the total bonus received, which may be considered a problem of selection bias. Were it not for these matters, the estimation could begin and end with ordinary least squares estimation of regressions of nutrient RDA's on variables representing the factors described in the previous section. Here the complications are described, then the solution, namely, method of moments estimation.

Section 3.1. Truncation of Effective Nutrient Intake

The truncation of the nutrient intake at a specified percentage of the RDA is implied by nutritional theory, because nutrients do not substitute for each other in general, but that does not necessarily invalidate the use of regression. The usual solution in cases of truncated regression, a tobit model, is inappropriate here, because the untruncated data are available as well as the measure of effective nutrition. As long as the normally distributed regression model applies, the most efficient procedure is to estimate the relationship between untruncated nutrient intake and the explanatory variables, then apply the estimated coefficients to formulae expressing the expected values of the properly truncated amounts of nutrient intake. Appendix A, "The Tobit Framework in the Analysis of Nutrient Intake Data," discusses this point in detail.

Section 3.2. Transformation of the Estimated Parameters

The estimated regressions are transformed into estimated probabilities of attaining an adequate diet and expected effective nutrition. Each explanatory variable's estimated marginal impact on each of these is calculated. The mean adequacy ratio or MAR is the mean of the truncated NAR's. It is calculated as are the marginal impacts of the explanatory variables on it. The best summary measure of the effect of an explanatory variable on the diet is found as the marginal impact of the variable on the MAR. Note that the MAR, the average of a number of truncated variables, has a complex distribution, but it can be analyzed by regressing each untruncated NAR on appropriate variables and working with the resulting truncated normal distributions. The MAR is discussed more below.

Section 3.3. Selection Bias

The matter of selection into the program refers to the fact that people choose to be in the Food Stamp program, and the unobserved or random aspects of the decision can be correlated with nutrient intake. People motivated to join the program may tend to seek higher or lower levels of nutrients, other things equal. Two problems arise. The first is that the most important coefficient in the nutrient equations for purposes of policy is that on food stamp bonus received, but that variable is endogenous and must be treated as such; some kind of instrumental variable must be found. Unlike many cases of endogenous variables, however, one is immediately at hand: potential food stamp bonus. Potential bonus does not affect nutrient intake; only money accepted can be spent. Potential bonus, therefore, does not belong in the nutrient equation. It is certainly correlated with actual bonus, however, and unless people behave strategically to become eligible because they are consuming nutrients, potential bonus is uncorrelated with the disturbance in the nutrient equation. Thus, there is an instrumental variable for bonus received.

Correcting for selection bias entails estimating a participation equation. That equation receives little attention here, since the FSC results are discussed in detail in other papers (Butler and Schoenman, 1986, and Butler, 1986).

The second problem is that the expectation of the disturbance in the nutrient equation is not zero given the participation status (in or out of the program), or equivalently the actual bonus received (positive or zero). This problem can be handled with the usual Heckman correction (Heckman, 1976), but the lambda term representing the expected value of the disturbance in the nutrient equation given the participation status is endogenous, which cannot be ignored if the correct standard errors are to be obtained. Another instrumental variable is needed. In the case of the Food Stamps Cashout data set, assets are used; they affect participation but not nutrient intake, because once income of all types is given, the source of practically all spending for food is specified. Objections are possible, but the connection between assets and the food budget seems too tenuous to maintain. In the Rural Income Maintenance Experiment data set, various tries netted nothing which could effectively identify lambda. Unmanageable multicollinearity resulted in minuscule t-values for everything. Thus those results are presented uncorrected for selection bias. Note that the exercise of estimating bonus amounts, reported in Appendix D, found no evidence of selection bias in this case. Akin et al. (1983) argued that separate equations should be estimated for participants and non-participants. We examine results from such an exercise at the end of Section 5.

Section 3.4. Estimation of the Mean Adequacy Ratio

The mean adequacy ratio (MAR) presents particularly interesting econometric problems. The MAR is the mean of a number of truncated dependent variables, so that the MAR follows a very complex mixed distribution. It cannot be analyzed correctly by regressing it on explanatory variables, because it is truncated, leading to biases of the sort encountered in tobit models. Even given that the untruncated regressions are estimated then modified to generate estimated NAR's, a multivariate regression with selection bias correction is required, followed by computation of NAR's, their average (the MAR), and the correct standard errors. Here we describe the steps in the process.

First, the untruncated regressions generate estimates of the effects of the explanatory variables on the NAR's, and the residual variances. All of these have variances and covariances; the residuals and the coefficients are uncorrelated, however, because that follows from regressions with normally distributed dependent variables. Second, the analytical formulae expressing the expected values of the truncated NAR's (and other functions of interest) are estimated as functions of the parameters. These are functions of both the coefficients and the residual variances. The variances of the truncated NAR's are found by pre and post multiplying the variance-covariance matrix of the parameters by the first derivatives of the nonlinear formulae with respect to the parameters. Third, the MAR is an average of the NAR's and requires all of the variances and covariances from all of the equations. The same is true of the marginal impacts of the explanatory variables on the MAR. The formulae are listed in Appendix B.

Section 3.5. The Method of Moments

Estimating a multivariate regression with a selection bias correction and endogenous bonus amount (zero if you do not accept food stamps) is not feasible by maximum likelihood, because it entails a multivariate normal integral (here, a ten- or eleven-variate normal). The method of moments is used instead. For details of the theory, see Hansen (1982). The expected values of the dependent variables given the explanatory variables are required. Then the fact that the actual bonus amount is endogenous is handled by using an instrumental variable. Assets squared are used here. Assets are strongly related to participation but not related to nutrient intake. The method of moments estimation is discussed further in Appendix C.

The result of using the method of moments is that the estimation is not fully efficient, but it is feasible and generates specifiable variances, and it deals with all of the problems discussed above.

Section 4. The Data Sets

Two data sets are used in the analysis of this paper: the Food Stamps Cashout data set and the Rural Income Maintenance Experiment data set. In the following subsections, each project and the characteristics of the sample generated are discussed.

The dependent variable in this paper, nutrient intake, cannot be measured by direct questions. Thus discussion of this variable, in both data sets, is deferred to a third subsection, where the technique used, the twenty-four-hour recall survey, is described along with other methods used in empirical nutrition.

Section 4.1. The Food Stamps Cashout Project and Data

The SSI/Elderly Food Stamps Cashout Project operated from April 1980 to August 1981 in six sites in New York, South Carolina, and Oregon. The basic reference describing the project is Blanchard et al. (1982). Barber, Hilton, and Ohls (1982) describe the public use file. All of the information in this section is drawn from those sources. Individuals were interviewed in the following demonstration sites, in which cash was substituted for food stamps in payments to the elderly and to persons receiving SSI: parts of Monroe County (Rochester), New York; parts of Darlington and Dillon Counties, South Carolina; and Mutnomah County (Portland), Oregon. Food stamps were provided as usual in comparison sites in Albany County, New York; parts of Marlboro and Lee Counties, South Carolina; and Lane County (Eugene), Oregon. The response rate of households not entirely elderly was terrible, so the sample and the analysis were ultimately restricted to the elderly.

The following questions motivated the FSC project. How does switching from food stamps (coupons) to cash affect program administration costs? What characteristics of the participants, as a group, change under cashout? What effect does cashout have on participation? Does switching to cashout decrease the Food Stamp program's effect on food expenditure and nutrient intake? How do FSP staff and participants feel about the change?

Both telephone interviews and interviews in person were used. Persons were drawn not only from the records of the Food Stamp program, to locate participants, but also from the Master Beneficiary Record of the Social Security System. Sampling weights based on the mode of interviewing and the source of the person were calculated.

A long and complex interview was required to determine the eligibility and the sources of income of the persons in the sample. A subset of those who were eligible were re-interviewed to determine their food consumption and a few other items, such as psychological scales and height and weight. Altogether, 2203 individuals were interviewed with some degree of success to the end of the food intake survey. Owing to missing data, 1867 of them were adjudged to have "good data" for analysis; of these, 1542 persons were ultimately used in the analysis in this paper, the difference being that some persons were missing variables desired for this paper.

Table 2 shows the means of the data of those persons used. The FSC data are weighted in that table and everywhere else in this paper. The sample is 34% Black, 33% male, has an average of 7 years of education, mostly lives alone (81%), is concentrated in South Carolina (54%), and lives 6.3 miles from the nearest food stamp office. The average nutrition score is 2.1 out of 4 food groups represented. On average, the persons sampled have $343 in income per month, $320 in assets,

Table 2

Summary Statistics of Food Stamps Cashout Data
(weighted based on sampling)

	Mean	Standard Deviation	Minimum	Maximum
Age minus 65	8.185	5.785	0	34
Black	0.3426	0.4748	0	1
Male	0.3304	0.4706	0	1
Education (years)	6.968	3.830	0	18
Lives alone	0.8077	0.3943	0	1
Site:				
NY Demonstration	0.0684	0.2524	0	1
NY Comparison	0.1102	0.3131	0	1
SC Demonstration	0.2380	0.4259	0	1
SC Comparison	0.3078	0.4646	0	1
OR Demonstration	0.1212	0.3264	0	1
OR Comparison	0.1544	0.3613	0	1
Non-food stamp income (monthly)	342.7	110.3	0	1095
Out daily	0.6368	0.4809	0	1
Out weekly	0.2600	0.4386	0	1
Male - alone	0.1760	0.3808	0	1
Distance to food stamp office (miles)	6.266	7.551	0	70
Knowledge of nutrition	2.1191	1.0680	0	4
Interviewed about a weekend	0.2445	0.4330	0	1
Assets	320	511	0	6010
Height (inches)	64.566	3.855	48	77
Rural	0.2646	0.4413	0	1
Potential bonus (monthly)	32.91	24.47	10	183
Actual bonus (monthly)	17.02	23.05	0	147
Participation	0.5022	0.5003	0	1
Nutrient adequacy ratios (percentages)				
Calories	64.79	32.72	2.54	326.82
Protein	104.61	67.97	2.98	646.07
Calcium	56.66	41.43	1.04	583.95
Iron	82.07	46.01	3.80	501.30
Vitamin A	97.99	117.57	0.00	1022.78
Thiamin	90.31	48.86	0.00	709.00
Riboflavin	92.03	52.53	0.00	568.57
Niacin	81.08	50.70	0.44	474.46
Vitamin C	115.82	127.95	0.00	1034.75

Sample Size: 1542

and could receive $33 in food stamps per month. Their nutrient intakes are generally below the RDA, and they show great variation in Vitamin A and Vitamin C.

In the course of estimation, eight persons who attained an intake of any nutrient over 12 times the RDA (1200%) of Vitamin A, Vitamin C, or riboflavin were eliminated from the sample, because their variation was interfering with the calculation of NAR's and marginal impacts. They were individually raising the variances of nutrient intake, were inconsistent with the normality assumption, and were materially changing the results of the extensions of the model.

Section 4.2. The Rural Income Maintenance Experiment and Data

The Rural Income Maintenance Experiment (RIME) was one of four experiments in negative income taxes. The others were the New Jersey, Seattle/Denver, and Gary negative income tax experiments. The RIME collected data in Manson, Iowa, and Warsaw, North Carolina, from summer 1969 to September 1973. The information in this section comes from Setzer et al. (1976). The interviews pertinent to this paper are Family Management Interview V (September 1970) and XIII (September 1972).

The primary purpose of the RIME was to measure the effects of a negative income tax on income and work responses of the recipients, in this case the response of farmers in particular. Other effects studied included those on nutrition, consumption, health, geographic mobility, asset holding, psychological well-being, marital dissolution, and the behavior of children. The rural administration of a negative income tax was examined.

In this case, nutrition was measured for the entire family; the RDA of all members was added together and divided into the nutrient intake of all members. Nutrient data were collected twice, and nutritional knowledge was measured once, in the Family Management Interview V. Unfortunately, nutrition data from Iowa for the first interview have been lost owing to computer error. The sample consists of 799 observations from North Carolina and 254 from Iowa. There may be two observations of a family in North Carolina.

Table 3 reports the unweighted means of the data. None of the RIME analysis reported here uses weights. The members of the sample average 48 years of age and 8 years of education. Blacks constitute 47% of the sample. Only 8% participate in the Food Stamp program, and many may be ineligible. Information as to deductions and assets used in one's business (here, usually farming), is not available, so a formal determination cannot be made of eligibility. The average nutrition score is 2.9 out of 4. Except for calcium, the diets are usually adequate, and the NAR's are truncated at 999.99% by the number of digits allocated in the data set. We do not know whether anyone exceeds that number (993.62 is the maximum observed).

Section 4.3. Measuring Nutrient Intake

Nutrient intake is measured by determining the foods consumed by an individual or a group, then converting those foods into nutrients using computer programs of the U.S. Department of Agriculture based on U.S. Department of Agriculture (1975), which was originally called Agricultural Handbook No. 8. More than 2000 categories of food, cooked and uncooked, can be analyzed. The problem is to determine what foods

Table 3

Summary Statistics of Rural Income Maintenance Experiment Data
(unweighted)

	Mean	Standard Error	Minimum	Maximum
Age of head of household	47.747	18.151	19	92
Black head of household	0.4687	0.2490	0	1
Education (years)	8.069	1.057	0	19
Lives alone	0.0693	0.0645	0	1
Site:				
NC	0.7581	0.1834	0	1
Iowa	0.2419	0.1834	0	1
Non-food stamp income (monthly)	153.8	25.6	0	1876.7
Knowledge of nutrition	2.8520	1.1109	0	4
Interviewed about a weekend	0.1300	0.1131	0	1
Assets	707	183	0	16812
Date:				
Quarter 3 (September 1970)	0.3539	0.2287	0	1
Quarter 11 (September 1972)	0.6461	0.2287	0	1
Used food grown at home	0.4583	0.2483	0	1
Children in the household	1.8140	3.3867	0	9
Adults in the household	2.4877	1.9804	0	8
Elderly in the household	0.2552	0.3058	0	3
Potential bonus (estimated by a regression)	95.59	61.24	-449	+553
Actual bonus	9.95	21.66	0	553
Participation	0.0806	0.0741	0	1
Nutrient adequacy ratios (percentages)				
Calories	105.48	27.09	0.00	536.98
Protein	156.82	61.33	0.00	704.97
Calcium	72.73	27.66	1.12	605.02
Iron	115.91	64.90	3.17	968.17
Vitamin A	128.62	207.26	0.00	993.62
Thiamin	167.19	120.62	11.46	888.87
Riboflavin	141.81	88.66	7.22	693.97
Niacin	153.73	104.16	10.44	946.89
Vitamin C	163.56	253.04	0.00	979.97
Phosphorous	135.51	55.84	1.96	836.69

Sample Size: 1054

people consume, and how much. The following discussion is based on Pearl (1979), with other sources as noted.

Two major types of surveys are used to determine individual food consumption: the list-recall method and the diary method. In the list-recall method, an interviewer obtains from a respondent a list of foods consumed recently. The list is categorized by type; a respondent is asked whether she or he consumed any of a group, and if so, is asked about the specific foods within the category. A recall survey asks the respondent, with prompting by a trained interviewer, to name all foods consumed within a period of time; the twenty-four-hour recall survey is the most popular period and is used in both data sets in this paper. We discuss this method further, after mentioning other possibilities. Weekly recall entails remembering and reporting more foods than the corresponding one-day method. Food frequency methods inquire how often various foods are consumed, rather than what was consumed lately.

Diary techniques require the respondent to record what she or he eats for one or more days. The quality of the data declines rapidly, however. One general problem with any technique which involves extended observation is the possibility of altered behavior. Diaries may be manipulated to avoid excess work in recording or to avoid embarrassing data, as well. Schnakenberg, Hill, and Kretsch (1978), who studied military personnel who could be observed while eating, used a combination of twenty-four-hour recall and extended diaries, 14 days or more, to try to obtain better data. They found, however, significant decreases in quality of data, with underreporting increasing noticeably. Gersovitz, Madden, and Smikilas-Wright (1978) compared twenty-four-hour recall and seven-day diary techniques for elderly respondents who were independently observed. They found that the recall data tended to overstate the low end and understate the high end of the distribution of consumption, perhaps biasing toward zero the estimates of the effect of a policy intervention, such as food stamps. The diary technique showed rapid deterioration of the information during the seven days.

Pearl (1979) flatly states that the twenty-four-hour recall survey cannot be used to determine distributions of nutrient intake. The problem is that one sees a cross section of individuals but wants a time series to assess the quality of the diet. Suppose everyone has good and bad days, but consumes 100% of the appropriate RDA's on average. Then the cross section is of no use, and there is no nutritional problem. The quality of time series data (diaries or seven-day recall surveys) is apparently inferior. Rather than discarding any hope of assessing the effect of food stamps on the quality of the diet or struggling with large and growing downward biases in time series data, one can use twenty-four-hour recall data with regression models. These assess accurately the average quality of the diet and the effect of various factors on that average quality.

The observed distribution of dietary quality is the one desired for analysis of a population only if everyone looks the same every day, i.e., the correlation of individual nutrient intake over time is +1.0. If that correlation across time, conditional on the explanatory variables, is zero, then all families, conditional on the explanatory variables, have the same mean. That is, all differences are explained by the systematic factors in the regressions. In that case, the distribution of nutrient intake could be inferred correctly, since it would depend only on observable factors.

The only evidence available from either data set to bear on this problem is that derived from the two observations of North Carolina families in the RIME. The correlation coefficients of the nutrient intake in the original data and the proportion of the variance explained by regression are as follows:

Nutrient	Correlation Coefficient	R^2
Calories	0.135	0.050
Protein	0.159	0.115
Calcium	0.097	0.136
Iron	0.110	0.037
Vitamin A	0.073	0.032
Thiamine	0.134	0.029
Riboflavin	0.119	0.087
Niacin	0.107	0.035
Vitamin C	0.117	0.076
Phosphorous	0.097	0.080

All of the correlations are significantly different from zero (with 475 North Carolina families in the original data, a correlation of 0.008 would be significantly different from zero). However, they are not large. For the RIME data, distributions of nutrient intake could be derived from the distributions of the explanatory variables. No data exist to consider this question for the FSC data, however, and in the extensions of the models, we shall consider a hypothetical person of average characteristics. No data set has combined extensive socioeconomic data with a diary technique to allow evaluation of the effect of the Food Stamp program on nutrient intake.

Section 5. Results from Food Stamps Cashout

The results in this section are presented first for the regressions which were estimated, then for the probability of an adequate diet, then for the NAR's and MAR. Brief discussion of the participation equation follows.

Nine nutrients are analyzed from the FSC data set: calories, protein, calcium, iron, Vitamin A, thiamine, riboflavin, niacin, and Vitamin C. Each is regressed on a set of 20 variables representing the factors identified in the theory section above. The 180 coefficients resulting are not presented, but Table 4 shows the signs and statistical significance of the coefficients.

Age does not have a consistent pattern of effects. Blacks have sometimes greater, sometimes smaller nutrient intake. No pattern emerges for males versus females. Education always increases nutrient intake, consistent with human capital theory, and the effect is significant in most cases. Living alone always reduces nutrient intake, but rarely is the effect significant. No effect of cashout, substituting cash for food stamps, is evident. The demonstration sites, where cash was used, have 11 positive and 16 negative effects; the comparison sites, where food stamps were used, have 10 positive and 8 negative effects. (A comparison site is the omitted category.) Income other than food stamps always has a negative effect, several times significant. Greater mobility outside the house usually has a positive effect, and sometimes the effect is significant. Males living alone are not detectably different, other things equal. Knowledge of nutrition has a positive effect every time and a significant effect all but one time. Weekend intake of nutrients is always smaller, and several times significantly so.

Table 4

Signs and Significance of the Coefficients in the FSC Results

	Calories	Protein	Calcium	Iron	Vitamin A	Thiamine	Riboflavin	Niacin	Vitamin C
Constant	+	+ *	+	+	+	+ *	+ **	+	+ *
Age-65	-	+ *	-	-	-	-	+ **	- **	- **
Black	-	-	-	-	+ *	- *	-	+	+
Male	- **	-	+	+	-	+	+	-	+
Educaton	+	+	+ *	+	+ *	+ *	+ *	+ *	+ *
Lives alone	-	- *	-	-	-	-	-	- **	-
Site:									
NY Demo	+	+	-	+ *	- *	+	+	+	+
NY Comp	+	-	+	+ *	-	+ *	+ *	+	-
SC Demo	-	- *	- *	-	- *	+	- *	- *	-
SC Comp	+	- *	-	+	- *	+	-	+	-
OR Demo	+	- **	-	+	+ *	-	-	-	-
Non-FS Income	-	- *	-	-	-	- *	- **	-	-
Out Daily	+	+	-	+	+ *	+ *	-	+ **	+
Out Weekly	+	+	+	+	+	+	+	+ **	-
Male-alone	+	+	-	+	-	-	-	+	-
Knowledge	+ *	+ *	+ **	+ *	+ *	+ *	+ *	+ *	+
Weekend	-	- *	-	- *	-	- *	- **	-	- *
Height	+ *	+ *	+ *	+ *	+	+	+	+	-
Rural	-	+	-	+ *	-	+ *	+	+	-
Actual Bonus	- *	- *	-	-	-	- **	-	-	- *
Lambda	+	+	-	+ **	+	+ *	+	+ *	+ *

*significant at the 5% level
**significant at the 10% level

Taller people consume more nutrients. Rural location usually increases nutrient intake. Actual food stamp bonus always reduces nutrient intake.

To recapitulate the major factors, education, mobility, and knowledge of nutrition increase nutrient intake, while the food stamp bonus, other income, and weekends decrease nutrient intake.

Table 5 displays the estimated coefficients and standard errors of the selection bias corrections. The effect of program selection is positive 8 times out of 9, and significant in four of those cases. That implies that the unmeasured or random effects on nutrient intake are positively correlated with participation. People who join the program for unmeasured reasons tend to like nutrients for the same unexplained reasons.

Table 6 reports the estimated probability of an adequate diet and the nutrient adequacy ratio (NAR) for a person with characteristics given by the mean of the explanatory variables in the FSC data set, for limits equal to the RDA and two-thirds of the RDA. Calories, calcium, and niacin are particularly likely to be inadequate; protein and riboflavin are most likely to be adequate. The NAR is the percentage of the maximum effective nutrient intake attained. That ranges from about 75% (protein) to about 53% (calcium). Concerning calcium, Guthrie (1975, pp. 125-126) states that

> it is apparent from various studies of dietary intake that many persons in the United States fail to meet this standard.... The inadequate intake in calcium in the diets of older women is of special concern because of the increased likelihood of osteoporosis [absorption of bone, resulting in excessively porous tissue (Webster's 1983)] in this group.

Table 5

Selection Parameters in the FSC Results

Equation	Coefficient	Standard Error	t-value
Calories	0.198736	0.177328	1.121
Protein	0.266541	0.263163	1.013
Calcium	-0.038910	0.194475	-0.200
Iron	0.329678	0.172217	1.914**
Vitamin A	0.390510	0.300184	1.301
Thiamine	0.566412	0.230606	2.456*
Riboflavin	0.340658	0.208687	1.632
Niacin	0.631228	0.262821	2.402*
Vitamin C	0.619499	0.260921	2.374*

*significant at the 5% level
**significant at the 10% level

Table 6

Probability of an Adequate Diet and Nutrient Adequacy Ratios (NAR's) from the FSC Data

	Limit of 66 2/3%		Limit of 100%	
Nutrient	Prob. Adequate	NAR	Prob. Adequate	NAR
Calories	0.476472 0.033257	0.530582 0.013938	0.133462 0.018195	0.626629 0.022960
Protein	0.712356 0.020077	0.544860 0.012500	0.527171 0.022805	0.752237 0.019485
Calcium	0.400976 0.034015	0.452665 0.021109	0.138156 0.019730	0.538167 0.030217
Iron	0.635521 0.023184	0.555781 0.010313	0.343398 0.022729	0.718765 0.018132
Vitamin A	0.609519 0.017024	0.356532 0.025929	0.492916 0.017305	0.540396 0.030774
Thiamine	0.690476 0.020542	0.572178 0.008958	0.419320 0.022564	0.757907 0.016234
Riboflavin	0.690349 0.021608	0.565167 0.010137	0.438036 0.023908	0.754000 0.017777
Niacin	0.614104 0.024178	0.532170 0.012553	0.351754 0.023512	0.692929 0.020564
Vitamin C	0.651876 0.016441	0.372257 0.027673	0.550008 0.016305	0.572763 0.032337
MAR		0.498022 0.011166		0.661582 0.016943

Note: Standard errors of the estimates are shown below the estimates.

Although the probability of attaining the RDA in calories is very unlikely, the NAR is not small, so it appears that the probability of being very low or very high is small in that case.

The best measure of the effect of an explanatory variable on the diet is the marginal impact on the MAR, which Table 7 reports for the FSC data set. Each year of education raises the MAR about 0.6 percentage points. The MAR is lower in South Carolina, other things equal, by 3.2 percentage points in the comparison site and 4.6 percentage points in the demonstration site, and demonstration sites in general have no clear effect. The average non-food stamp income is $343 per month. A change of $30 per month would reduce the MAR by 0.6 percentage points. Getting out of the house daily increase the MAR by 2.6 percentage points. Knowledge of nutrition ranges from 0 to 4, and the effect on the MAR of a change of 4 full points is 8.3 percentage points. Weekends lower the MAR by 3.1 percentage points. Finally, the actual bonus received reduces the MAR by 1.5 percentage points per $10 of bonus. The average entitlement is $33 in the FSC sample.

Table 8 shows the correlations of the residuals from the nine nutrient equations. All correlations are positive, so that unmeasured sources of variation in nutrient intake are positively correlated across all nutrients. The correlations are distinctly lower between Vitamin C and the others and between Vitamin A and the others. The largest correlation is 0.7452, between riboflavin and calcium. The smallest correlation is 0.2482, between Vitamin C and protein.

Table 9 shows the participation equation. People who are older, have more years of education, live alone, have higher non-food stamp income or are offered a greater amount of food stamps, get out of the

Table 7

Marginal Impacts of the Explanatory Variables in the FSC Data Set
Mean Adequacy Ratio Based on 66 2/3% and 100% of the RDA

	Basis of the Nutrient Adequacy Ratio	
	66 2/3%	100%
Constant	0.2743* 0.1185	0.4207* 0.1901
Age minus 65	-0.0002 0.0008	-0.0002 0.0128
Black	0.0018 0.0129	-0.0017 0.0199
Male	-0.0110 0.0424	-0.0190 0.0672
Education (years)	0.0058* 0.0019	0.0087* 0.0029
Lives alone	-0.0682 0.0420	-0.1098 0.0667
NY Demonstration Site	-0.0006 0.0216	0.0039 0.0338
NY Comparison Site	0.0237 0.0189	0.0417 0.0295
SC Demonstration Site	-0.0458* 0.0169	-0.0687* 0.0264
SC Comparison Site	-0.0317** 0.0182	-0.0420 0.0283
OR Demonstration Site	0.0027 0.0186	0.0001 0.0284
Non-Food Stamp Income ($1000)	-0.2047** 0.1093	-0.3285** 0.1757
Out Daily	0.0257** 0.0150	0.0390** 0.0234
Out Weekly	0.0133 0.0158	0.0224 0.0245

Table 7 (continued)

	Basis of the Nutrient Adequacy Ratio	
	66 2/3%	100%
Male-Alone	-0.0189 0.0426	-0.0233 0.0669
Knowledge of Nutrition	0.0207* 0.0049	0.0323* 0.0073
Weekend	-0.0315* 0.0100	-0.0476 0.0156
Height	0.0203 0.0148	0.0344 0.0231
Rural	0.0037 0.0132	0.0100 0.0206
Actual Bonus ($100)	-0.1461* 0.0569	-0.2251* 0.0923

*significant at the 5% level
**significant at the10% level

Note: Standard errors of the estimates are shown below the estimates.

Table 8

Correlation of the Residuals from the FSC Nutrient Equations

	Calories	Protein	Calcium	Iron	Vitamin A	Thiamine	Riboflavin	Niacin	Vitamin C
Calories	1.000	0.6786	0.5958	0.7285	0.3500	0.6980	0.6820	0.6339	0.2873
Protein	0.6786	1.000	0.4768	0.6356	0.2826	0.5560	0.6000	0.6854	0.2482
Calcium	0.5958	0.4768	1.000	0.4011	0.2815	0.4730	0.7452	0.2782	0.2669
Iron	0.7285	0.6356	0.4011	1.000	0.3962	0.6984	0.6212	0.6708	0.2543
Vitamin A	0.3500	0.2826	0.2815	0.3962	1.000	0.3178	0.4701	0.3428	0.4260
Thiamine	0.6980	0.5560	0.4730	0.6984	0.3178	1.000	0.6549	0.6350	0.3854
Riboflavin	0.6820	0.6000	0.7452	0.6212	0.4701	0.6549	1.000	0.5958	0.3224
Niacin	0.6339	0.6854	0.2782	0.6708	0.3428	0.6350	0.5958	1.000	0.2788
Vitamin C	0.2873	0.2482	0.2669	0.2543	0.4260	0.3854	0.3224	0.2788	1.000

Table 9

Estimated Probit Model of Participation in the FSC Data

	Estimated Coefficient	Standard Error	t-value
Constant	2.8556	0.4833	5.9088*
Age minus 65	-0.0114	0.0053	-2.1584*
Black	0.1143	0.0855	1.3363
Male	-0.1716	0.3198	-0.5366
Education (years)	-0.3672	0.1085	-3.3844*
Lives alone	-0.7725	0.3217	-2.4013*
Sites:			
NY Demonstration	0.0166	0.1275	0.1306
NY Comparison	0.0171	0.1165	0.1466
SC Demonstration	-0.3145	0.1092	-2.8815*
SC Comparison	-0.1020	0.1211	-0.8421
OR Demonstration	0.1814	0.1075	1.6865**
Non-food stamp income ($1000)	-3.8073	0.6972	-5.4611*
Out daily	-0.2090	0.0924	-2.2628*
Out weekly	-0.0783	0.0998	-0.7846
Male-alone	0.0826	0.3316	0.2491
Distance (miles)	-0.8822	0.0547	-1.6124
Knowledge of nutrition	0.0189	0.0288	0.6551
Assets ($10000)	-2.7754	0.8683	-3.1964*
Rural	-0.0922	0.0960	-0.9607
Potential bonus ($100)	-0.6494	0.1758	-3.6935*

*significant at the 5% level
**significant at the 10% level

house daily, or have more assets are less likely to participate. There is no consistent effect of the sites on participation; two demonstration sites (where cash was substituted for food stamps) have significant effects, one in each direction relative to the omitted comparison site. The negative effect of bonus amount offered can be interpreted as stigma; see Butler (1986) and Butler and Schoenman (1986).

Akin et al. (1985) argued that separate equations should be estimated for participants and non-participants. In response to that, we estimate the model, including all of the equations in the multivariate regression and the computations of probabilities of an adequate diet, NAR's, and the MAR, for the participants only. The resulting regression coefficients and marginal impacts on the MAR truncated at the RDA and two-thirds of the RDA are presented in Table 9-A for knowledge of nutrition, the actual bonus, and lambda, the correction for selection bias. The results may be compared with those in Tables 4, 5, and 7.

Knowledge is always significant (rather than 8 out of 9 cases) this time. Actual bonus reduces nutrient intake in every case as before, with a somewhat different pattern of significance. Selection bias appears to be less strong, being significant in only two cases. Comparing Tables 7 and 9-A shows that the estimated effects of knowledge of nutrition and actual bonus on the MAR are absolutely larger in both cases. Using the RDA as the limit, the effect of knowledge is 4.2 percentage points versus 3.2 before. The effect of a bonus of $33 is -8.6 percentage points versus -7.4 before. (Note that the coefficients and effects of the bonus are stated per $100.) Estimating the effects on participants alone leads to the same conclusions, but the estimated effects are larger.

Table 9-A

Results Using Participants Only in the FSC Data

Coefficients in Regressions:	Knowledge	Actual Bonus ($100)	Lambda
Calories	0.041545*	-0.231302	0.261957
	0.020254	0.224791	0.460640
Protein	0.102832*	-0.528510*	0.684638
	0.023773	0.259907	0.520380
Calcium	0.055442*	-0.134674	-0.057301
	0.022253	0.225255	0.428726
Iron	0.634823*	-0.361786	0.452027
	0.215529	0.232756	0.459275
Vitamin A	0.108308*	-0.366649	0.407474
	0.037905	0.289125	0.607434
Thiamine	0.076355*	-0.544920*	0.656156
	0.023405	0.264917	0.519281
Riboflavin	0.073796*	-0.399525*	0.394055
	0.023269	0.256853	0.483565
Niacin	0.064829*	-0.625574*	1.072810**
	0.021931	0.279040	0.580430
Vitamin C	0.067741**	-1.123900*	0.856943**
	0.039114	0.316154	0.567980
Effect on MAR:			
66 2/3%	0.0286*	-0.1839*	
	0.0108	0.0702	
100%	0.0416*	-0.2608*	
	0.0139	0.1115	

*significant at the 5% level
**significant at the 10% level

Since non-participants have no actual bonus, one cannot estimate an effect of bonus amount on their nutrient intake.

Section 6. Results from the Rural Income Maintenance Experiment

The results are presented first for the regressions, then for the probability of having an adequate diet, then for the NAR's and the MAR.

Ten nutrients are analyzed from the RIME data set: calories, protein, calcium, iron, Vitamin A, thiamine, riboflavin, niacin, Vitamin C, and phosphorous. Each is regressed on a set of 15 variables representing the factors identified in the theory section. The 150 coefficients resulting are not presented, but Table 10 shows the signs and significance of the coefficients.

Age has a positive effect in half of the equations, but only positive effects are significant. Blacks always have higher nutrient intake, other things equal, and significantly so in four of ten cases. Living alone (which is less common in the rural population than in the elderly population studied by the FSC) has a small negative effect. Living in North Carolina (as opposed to Iowa) has a negative effect in nine of ten equations, five of these effects being significant. Higher income reduces nutrient intake in most cases, but never significantly. Nutritional knowledge increases intake of eight of the ten nutrients, significantly in five cases. Weekends have no consistent pattern of effects. Diets seemed to be a little worse in 1970 (as opposed to 1972). Eating food produced at home has a slight positive effect. Children have a positive effect on most nutrients, but never a significant effect. The greater is the number of adults and the greater the number of elderly, the less adequate is the diet, and those effects

Table 10

Signs and Significance of the Coefficients in the RIME Results

	Calories	Protein	Calcium	Iron	Vitamin A	Thiamine	Riboflavin	Niacin	Vitamin C	Phosphorous
Constant	+ *	+ *	+ *	+ *	+ *	+ *	+ *	+ *	+ *	+ *
Age	−	−	+	+	+ *	−	−	−	+ **	−
Black	+ *	+ *	+	+	+ *	+	+	+	+ *	+
Education	−	−	−	−	−	+	+	+	+ *	−
Lives alone	−	− *	−	−	−	−	+	−	−	−
Lives in NC	−	−	− *	−	− *	−	− *	+	− *	− *
Non-FS Income	−	−	−	−	−	−	−	+	−	−
Knowledge	+ *	+ *	+	+ **	−	+	+ *	+ *	−	+
Weekend	−	+ *	−	−	+	−	+	+	−	−
Q3--1970	+	−	−	+	− **	+	−	+	− *	−
Homefood	+ **	+ *	−	+	−	+	+	+	−	+
Children	+	+	+	+	+	−	+	−	+	+
Adults	− *	− *	− *	− **	− *	− *	− *	− *	− *	− *
Elderly	− **	− *	− *	−	− *	− **	− *	−	− *	− *
Actual bonus	−	− *	−	−	−	+	−	+	−	−

*significant at the 5% level
**significant at the 10% level

hold in every case, with all adult effects and most elderly effects being significant. Actual food stamp bonus reduces the nutrient intake in most cases, but significantly in only one case.

To recapitulate the major factors, the more adults and the more elderly there are in the household, the less adequate the diet is, but Blacks have higher nutrient intake. Other factors have much less effect. Apparently small Black households have the highest nutrient intake, large white ones the lowest.

Table 11 reports the estimated probability of an adequate diet and the NAR for a household with characteristics given by the means of the explanatory variables in the RIME data set, for limits equal to the RDA and two-thirds of the RDA. As in the FSC data, calcium is least likely to be adequate. The NAR ranges from about 51% of the maximum effective intake (calcium) to about 89% (protein). The MAR is very close to the figures from the FSC, but the range of NAR's is much greater.

The somewhat peculiar results for Vitamin C arise from the large variance of Vitamin C consumption in the RIME data--the mean is 164% of the RDA, the standard error 253%. Such huge variation leads to much of the distribution of actual intake being beyond the effective maximum. Thus, the NAR attained may be surprisingly small.

Again, the best measure of the effect of an explanatory variable on the diet is the marginal impact on the MAR, which Table 12 reports for the RIME data set. Blacks have higher nutrient intake by 3.9 percentage points of the MAR. Residents of Iowa exceed those of North Carolina by 9.7 percentage points. Diets in 1970 were below those of 1972 by 5.5 percentage points. An extra child, adult, or elderly person changes

Table 11

Probability of an Adequate Diet and Nutrient Adequacy Ratios (NAR's) from the RIME Data

	Limit of 66 2/3%		Limit of 100%	
Nutrient	Prob. Adequate	NAR	Prob. Adequate	NAR
Calories	0.764437 0.010812	0.592364 0.005513	0.540534 0.012261	0.811420 0.009125
Protein	0.869757 0.010572	0.614376 0.006739	0.760903 0.012259	0.887297 0.010492
Calcium	0.528570 0.012302	0.358551 0.017465	0.373630 0.012504	0.508706 0.020151
Iron	0.730715 0.012394	0.534873 0.011364	0.578736 0.012349	0.753825 0.015075
Vitamin A	0.610701 0.015705	0.627903 0.085316	0.551671 0.013145	0.256570 0.089044
Thiamine	0.821447 0.013977	0.561172 0.014821	0.730898 0.014026	0.820484 0.019376
Riboflavin	0.794740 0.012780	0.561282 0.011831	0.676495 0.012855	0.807251 0.015906
Niacin	0.791866 0.014007	0.540822 0.015887	0.692059 0.013609	0.788708 0.020303
Vitamin C	0.653950 0.019273	0.099494 0.099654	0.602478 0.015874	0.308962 0.104942
Phosphorous	0.799793 0.012043	0.575151 0.009611	0.667754 0.012516	0.820688 0.013513
MAR		0.450088 0.026623		0.676391 0.028418

Note: Standard errors of the estimates are shown below the estimates.

Table 12

Marginal Impacts of the Explanatory Variables in the RIME Data Set
Mean Adequacy Ratio Based on 66 2/3% and 100% of the RDA

	Basis of the Nutrient Adequacy Ratio	
	66 2/3%	100%
Constant	0.4074* 0.1049	0.5846* 0.1295
Age (years)	0.0147 0.0117	0.0162 0.0145
Black	0.0387* 0.0174	0.0513* 0.0215
Education (years)	-0.0008 0.0039	-0.0013 0.0480
Lives alone	-0.0357 0.0391	-0.0504 0.0495
North Carolina	-0.0975* 0.0364	-0.1277* 0.0453
Other Income ($1000)	-0.1153 0.1029	-0.1438 0.1288
Knowledge of nutrition	0.0101 0.0121	0.0174 0.0149
Weekend	0.0036 0.0237	0.0041 0.0290
Quarter 3, 1970	-0.0549 0.0424	-0.0637 0.0522
Home-produced food	0.0048 0.0251	0.0113 0.0310
Children	0.0286 0.0250	0.0350 0.0309
Adults	-0.0272* 0.0100	-0.0373* 0.0123

Table 12 (continued)

	Basis of the Nutrient Adequacy Ratio	
	66 2/3%	100%
Elderly	-0.0574* 0.0203	-0.0755 0.0251
Actual Bonus ($100)	-0.4127 0.3286	-0.5104 0.4081

*significant at the 5% level
**significant at the 10% level

Note: standard errors of the estimates are shown below the estimates.

the MAR by 2.9, -2.7, and -5.7 percentage points. An extra $10 of food stamp bonus lowers the MAR by 4.1 percentage points. Only 8% of the persons in the RIME received food stamps, and those who did received an average of $123 in food stamps ($9.95/0.0806; see Table 3).

Table 13 shows the correlations of the residuals in the ten nutrient equations using RIME data. In contrast to the FSC results, the correlations are sometimes small and sometimes negative. The highest correlation is that between Vitamin A and Vitamin C, 0.8081, just a bit larger than the correlation of 0.8059 between calories and protein. The correlation of residuals of Vitamin A and Vitamin C in the FSC data was 0.4260, rather low. Perhaps the difference arises from the use of fruits and vegetables by rural as opposed to elderly people. At the low end, three nutrients have negative correlations with niacin, the largest of these being -0.1517.

Table 14 shows the coefficients in the participation equation. Note that this equation is not restricted to eligible households, so the coefficients do not assess the factors influencing eligibles to join the Food Stamp program. Rather they measure the effect of various factors on the entire process of becoming eligible and deciding to participate. Households whose heads are younger or male, or which contain more adults or elderly, are less likely to participate in the Food Stamp program. More children, living in Iowa, and being asked in 1972 lead to a greater probability of participation. Assets are a considerable deterrent, probably acting through the eligibility requirements. An equation for potential bonus was estimated, since the data

Table 13

Correlations Between the Residuals from the Nutrient Equations in the RIME Data

	Calories	Protein	Calcium	Iron	Vitamin A	Thiamine	Riboflavin	Niacin	Vitamin C	Phosphorous
Calories	1.0000	0.8059	0.5286	0.4868	0.4018	0.4187	0.4900	0.3459	0.3895	0.7499
Protein	0.8059	1.0000	0.5599	0.4768	0.4069	0.3600	0.5284	0.3733	0.4089	0.8045
Calcium	0.5286	0.5599	1.0000	0.2461	0.7665	0.0675	0.4366	-0.1517	0.7506	0.7709
Iron	0.4868	0.4768	0.2461	1.0000	0.2499	0.5088	0.5327	0.4990	0.2586	0.4706
Vitamin A	0.4018	0.4069	0.7665	0.2499	1.0000	0.1215	0.4130	-0.0981	0.8081	0.4888
Thiamine	0.4187	0.3600	0.6752	0.5088	0.1215	1.0000	0.7086	0.6771	0.1395	0.3125
Riboflavin	0.4900	0.5284	0.4366	0.5327	0.4130	0.7086	1.0000	0.6462	0.3741	0.5545
Niacin	0.3459	0.3733	-0.1517	0.4990	-0.0981	0.6771	0.6462	1.0000	-0.0872	0.2700
Vitamin C	0.3895	0.4089	0.7506	0.2586	0.8081	0.1395	0.3741	-0.0872	1.0000	0.4832
Phosphorous	0.7499	0.8045	0.7709	0.4706	0.4888	0.3125	0.5545	0.2700	0.4832	1.0000

Table 14

The Participation Equation Estimated from the RIME Data

	Estimated Coefficient	Standard Error	t-value
Constant	-1.3122	0.6949	-1.8883**
Age of head of household	0.2426	0.1028	2.3597*
Black head of household	0.1157	0.1755	0.6594
Male head of household	-0.3428	0.1842	-1.8607**
Education (years)	0.1452	0.2967	0.4894
Lives alone	-0.1296	0.3315	-0.3908
Lives in NC	-0.5335	0.2189	-2.4369*
Non-food stamp income ($1000)	-2.3135	1.6598	-1.3938
Assets ($10000)	-1.0600	0.2636	-4.0219*
Quarter 3, 1970	-0.6199	0.1932	-3.2076*
Food produced at home	-0.0865	0.1524	-0.5675
Number of children	0.2131	0.1037	2.0539*
Number of adults	-0.1754	0.0746	-2.3503*
Number of elderly	-0.3882	0.2491	-1.5586
Estimated potential bonus ($100)	0.0409	0.3566	0.1146

*significant at the 5% level
**significant at the 10% level

set did not contain such information. That equation is described in Appendix D. The estimated bonus amount has practically no effect.

Section 7. Implications for Policy

Food stamps appear to be ineffective in raising nutrient intake, and knowledge of nutrition appears to be effective in doing so, except for Vitamin C. Many parallels can be found with the results of Whitfield (1982), who used a different data set from the two used here but found very similar results. First a few other matters are discussed, then the effects of food stamp bonus, then knowledge of nutrition.

Blacks and whites or men and women can differ in their nutrient intake, even after controlling for a variety of other factors. In the FSC data, the elderly Blacks and whites were essentially identical after controlling for other factors. Males had slightly worse diets, by 1.1 percentage points in MAR. In the RIME data, the Blacks had significantly better diets, by 3.9 percentage points in MAR. In comparison, Whitfield's (1982) results indicated that, other things equal, Blacks had diets higher in some and lower in other nutrients, the net being -3.8 percentage points in MAR (the average of the six effects reported in Whitfield's Table 2). Whitfield found that males had better diets by 8.9 percentage points. Note that Whitfield did not truncate the NAR's and the means of the NAR's ranged from 0.795 to 1.164, so that many of the people in the sample were beyond the effective nutrient level, so his figures are biased upward. The independent effect of gender and race on nutrient intake is not clear here.

Viewing the Food Stamp program as a nutrient program is not supported by the data. Table 15 collects the effects of the actual food stamp bonus on the NAR's. The effect is, on average, negative in both

Table 15

Effects of Actual Bonus on NAR's Truncated at 0.67 and 1.00
(Effects per $100 of Bonus)

	Truncation at 0.67				Truncation at 1.00			
Data Set:	FSC		RIME		FSC		RIME	
Nutrient	Effect	Std. Error	Effect	Std. Error	Effect	Std. Error	Effect	Std. Error
Calories	-0.1665*	0.0715	-0.09493	0.1454	-0.2756*	0.1277	-0.1852	0.2837
Protein	-0.2586*	0.0579	-0.08747	0.1274	-0.4252*	0.1006	-0.1606	0.2338
Calcium	-0.1422	0.1148	-0.7354	0.5354	-0.2045	0.1706	-0.9770	0.7108
Iron	-0.0779	0.0536	-0.09201	0.3487	-0.1403	0.0997	-0.1439	0.5157
Vitamin A	-0.1764	0.1115	-1.538	0.994	-0.2291	0.462	-1.772	1.144
Thiamine	-0.0917**	0.0472	0.04714	0.3001	-0.1721**	0.0922	0.07105	0.4532
Riboflavin	-0.0755	0.0534	-0.07932	0.2466	-0.1371	0.0998	-0.1250	0.3888
Niacin	-0.0524	0.0686	0.1669	0.2485	-0.0881	0.1172	0.2469	0.3672
Vitamin C	-0.2736**	0.1038	-1.535	1.055	-0.3536*	0.1355	-1.764	1.210
Phosphorous			-0.1779	0.2169			-0.2953	0.3597
MAR	-0.1461*	0.0569	-0.4127	0.3286	-0.2251*	0.0923	-0.5104	0.4081

Note: The average food stamp bonus is $73 and $123 in the FSC and RIME.

*significant at the 5% level
**significant at the 10% level

data sets investigated here. The implication is that the nutritional status of the poor would be higher without food stamps. In the RIME data, the effects are mostly insignificant, and in the FSC data, they are mostly significant. In any event, the conclusion cannot be favorable to the program. The Food Stamp program can certainly be supported as a negative income tax or an anti-hunger program, since it provides income, and recipients buy more food.

The effect of knowledge of nutrition, measured by a crude test, naming foods in various food groups as being needed on a regular basis for good health, is strong in both data sets. Table 16 collects the effects of nutritional knowledge on the NAR's. In this connection, Whitfield (1982) found similar results. The major exception is, remarkably, the same in all three sets of results--the NFCS (Whitfield's), RIME, and FSC. It is Vitamin C. The effect of knowledge on Vitamin C consumption is negative in the FSC and NFCS and small and insignificant in the RIME. Most Vitamin C comes from fruits and vegetables, 94% according to Guthrie (1975, p. 245). The only other nutrient substantially depending on fruits and vegetables is Vitamin A (Guthrie, 1975, p. 314). The RIME results show negative effects of knowledge only on Vitamin A and Vitamin C. However, the effect is positive and significant on Vitamin A in the NFCS and the FSC. Since Vitamin A comes only 50% from fruits and vegetables, while the rest comes from meat, milk, fats, and oils, possibly the other foods are masking the effect. Vitamin C is a mystery at this point.

It is impossible to compare the cost of attaining nutritional objectives by raising knowledge or by increasing food stamp allotments, since the estimated effect of food stamps is negative. However, policy

Table 16

Effects of Nutritional Knowledge on NAR's Truncated at 0.67 and 1.00

	Truncation at 0.67				Truncation at 1.00			
Data Set:	FSC		RIME		FSC		RIME	
Nutrient	Effect	Std. Error	Effect	Std. Error	Effect	Std. Error	Effect	Std. Error
Calories	0.02201*	0.0610	0.01166*	0.00510	0.03643*	0.00977	0.02275*	0.00990
Protein	0.03059*	0.00577	0.01198*	0.00463	0.05028*	0.00901	0.02200*	0.00839
Calcium	0.01806*	0.00974	0.01316	0.01905	0.02597*	0.01387	0.01749	0.02532
Iron	0.01826*	0.00466	0.01997**	0.01158	0.03290*	0.00811	0.03124**	0.01801
Vitamin A	0.03672*	0.01129	-0.02319	0.03901	0.04769*	0.01456	-0.02671	0.04490
Thiamine	0.01855*	0.00392	0.01477	0.00993	0.03481*	0.00694	0.02226	0.1490
Riboflavin	0.01582*	0.00426	0.01676**	0.00843	0.02871*	0.00754	0.02642*	0.1317
Niacin	0.02129*	0.00464	0.02601*	0.00963	0.03576*	0.00744	0.03849*	0.01407
Vitamin C	0.00503	0.01030	-0.00580	0.03793	0.00651	0.01332	-0.00666	0.04357
Phosphorous			0.01598*	0.00774			0.02653*	0.01276
MAR	0.02070*	0.00486	0.01013	0.01213	0.03323*	0.00735	0.01738	0.01494

Note: Knowledge of nutrition ranges from 0 to 4 with means of 2.1 and 2.9 in the FSC and RIME.

*significant at the 5% level
**significant at the 10% level

which aims at increasing the nutritional status of the poor population should apparently concentrate on increasing basic nutritional knowledge.

Section 8. Summary and Conclusions

James Tobin (1970), in a discussion of various programs to decrease inequality in society, discussed the Food Stamp program.

> The society's propensity to give assistance to the poor in kind rather than in cash is most clearly evidenced by the political popularity of food stamps and housing subsidies.... The intent is to increase the consumption of these necessities of life by the poorly nourished and poorly housed....
>
> Paternalism is presumably the motive for assisting poor people with food vouchers rather than generalized purchasing power. But the actual and proposed systems do not live up to the rationale, which would imply compulsory nutrition in the manner of compulsory education. Given the fungibility of stamps and foods, the plans do not even insure adequate diets for their beneficiaries. And, although based on the premise that adequate income is no guarantee of adequate nutrition, income-conditioned food vouchers do nothing to insure adequate nutrition for those whose incomes make them ineligible. In short, food vouchers are just an inferior currency, and taxpayers' funds would be better spent in general income assistance. (pp. 274-275) [He then asserts that the obligation to protect children is independent of source of income.]

Following other papers which have reported the effect of food stamps on nutrient intake, in this paper we examine the effect with an elaborated model reflecting econometric and nutritional theory. The results support some of the points raised by Tobin, and oppose others. Adequate income is no guarantee of adequate nutrition; increased income, either in food stamps or otherwise, is associated with reduced nutrient intake in two data sets, a sample of elderly people in the Food Stamps Cashout Project and a sample of rural people in the Rural Income Maintenance Experiment. Yet, food stamps are not "just an inferior currency." They expand purchases of food more than ordinary income, as has been shown in studies of that topic (for example, Benus, Kmenta and Shapiro, 1976, and Blanchard et al., 1982). Perhaps as a part of the same phenomenon, food stamps seem to have a more deleterious effect on nutrient intake than ordinary income in both data sets.

The results suggest that even rudimentary knowledge of nutrition can increase nutrient intake considerably. Education in years has no effect in one data set (the elderly) but substantial effects in the other (the rural). If a program could increase knowledge, it appears that it could effect the desired changes in nutritional status of the poor.

Should there be, then, a Food Stamp program? If taxpayers wish to be paternalistic, and they do not want to provide general assistance, the FSP is succeeding, in part. The evidence does not support the FSP as a nutrition program. But it is not quite a negative income tax, either. Given its effects on food consumption, it is probably best described as an anti-hunger program. Perhaps the best policy conclusion is that the FSP does reduce hunger, but nutrition is a harder problem.

Appendix A

The Tobit Framework in the Analysis of Nutrient Intake Data

Nutritional theory asserts that exceeding the necessary level of daily intake of one nutrient does not substitute for failing to obtain the necessary level of another. It follows that proper nutrition requires attaining at least 100% of the standard for each of a number of nutrients, not an average of 100% over all. In practice the Recommended Daily Dietary Allowances (RDA) of the Food and Nutrition Board are taken in studies of nutritional intake to be the standard (Food and Nutrition Board, 1968). These allowances are defined by age and sex of the person whose diet is to be evaluated, and they are defined for a range of vitamins and minerals.

In evaluating the nutrient intake of a person or household, the physical food intake is converted into amounts of specific vitamins and minerals, then divided by the appropriate RDA to obtain a percentage, called the nutrient adequacy ratio (NAR). Given a number of NAR's, the mean adequacy ratio (MAR) is the average of the NAR's, each being truncated at 100% before averaging. The NAR or MAR becomes the object of the analysis.

As O'Connor, Madden, and Prindle (1976, p. 26) note in a preliminary version of O'Connor and Madden (1979), "the impact of the program on the NAR variables truncated at 100 percent seems to be the relevant question from a policy standpoint." The implicit conclusion drawn, that the truncated NAR should be regressed on the explanatory variables to be used, is incorrect. In fact, truncating then regressing results in biased (systematically wrong) coefficients for the question of interest, namely: What is the effect of race, sex, income, etc., on the

NAR given that it does not "count" to go over 100%? Lane (1978) found one consistent (correct with a large sample) method to analyze the data, but then used only one regressor, thus not controlling for others, such as sex, race, age of household head, etc. As the title suggests, the tobit framework is emphasized here, but ordinary regression of the untruncated NAR's with some additional mathematical results is adequate in most cases.

To emphasize the points: analytical objectives and statistical means to obtain them must be considered separately. The analytical objective to be accomplished is analyzing NAR's or the MAR of a sample of persons or households, given that exceeding 100% of the RDA is not nutritionally useful. The statistical means to attain that objective is not regression of the truncated NAR on regressor variables; that gives the wrong answer.

Section 1 introduces and discusses the tobit model. Section 2 shows that, although tobit appears to be needed here, it is not, and a simpler solution is provided. Section 3 discusses a method of dealing with nutrient intake data which are truncated and cannot be restored for regression.

In what follows, we assume there are ten nutrients, but nothing important would change if there were more or fewer.

1. The Tobit Model

Introduced to economics by Tobin (1958) and definitively explained by Amemiya (1973), the tobit model concerns a continuous variable truncated above or below a limit. The original example was consumer durable purchases (cars, refrigerators), which cannot go below zero and frequently are exactly zero. The concept of a potential amount of purchase is introduced: this may be negative, but if it is, no purchase (not a negative purchase) is observed. As a second example, the number of hours of market work per period is a function of socioeconomic variables and the wage rate compared to the monetized rewards of staying out of the labor market (housework, leisure, volunteer activities, etc.). The preferred amount of hours of market work may be any positive or negative amount, but zero is observed if the preferred amount is negative. Finally, the NAR may be any amount; it is distributed continuously, with no "barrier" at 100%.[1] The implicit variable "effective nutrient intake" takes the value 100% if the NAR takes a value greater than 100%, however. Statistically, these three examples are interchangeable. The upper bound on truncated NAR's is equivalent to the lower bounds on consumer durables and market hours worked because: (1) Derivations do not depend on where the bound is; the formulas change little; (2) if an explicit lower bound at zero is wanted, 100 plus the negative of the NAR can be used.

Consider a regression model, $Y_t^* = X_t\beta + \varepsilon_t$, ε_t distributed $N(0,\sigma^2)$, where Y^* is potential purchases or market hours or actual NAR in the previous examples.

This framework was assumed in all the literature cited above.

Now define a truncated version of Y_t^*, called Y_t, thus:

$$Y_t = l_t, \qquad Y_t \geq l_t, \text{ i.e., } \varepsilon_t \geq l_t - X_t\beta,$$

$$Y_t = Y_t^*, \qquad Y_t^* < l_t, \text{ i.e., } \varepsilon_t < l_t - X_t\beta, \tag{1}$$

---

[1]Of course it cannot be negative, but income, weight, and other non-negative variables have long been modeled this way; as long as the mean is far (many standard deviations) from zero, all is well.

where l_t is the limit value which may differ across observations, although it rarely does in practice.[2]

What, in terms of the above model (1), do we seek to find by statistical analysis? The marginal impact on the expected value of Y_t^*, $E(Y_t^*)$, of a change in X is given by β, but that does not take into account the truncation. (Nevertheless, since β may be estimated by ordinary regression of Y^* on X it would be good to find a way to use it.) In behavioral terms that ignores the fact that the increase in NAR could be from 110 to 120, rather than from 80 to 90. The marginal impact on the expected value of Y_t, $E(Y_t)$, of a change in X is analyzed as follows; the expected value of Y_t is

$$E(Y_t) = E(Y_t^* | Y_t^* < l_t)Pr(Y_t^* < l_t) + l_t Pr(Y_t^* \geq l_t) \tag{2}$$

where Pr denotes probability. Now

$$\begin{aligned} Pr(Y_t^* < l_t) &= Pr(\varepsilon_t < l_t - X_t\beta) \\ &= Pr(\frac{\varepsilon_t}{\sigma} < \frac{l_t - X_t\beta}{\sigma}) \end{aligned}$$

$$Pr(Y_t^* < l_t) = \Phi(\frac{l_t - X_t\beta}{\sigma}) \tag{3}$$

where Φ denotes the standard normal cumulative density function (cdf) and the result follows from ε's being normally distributed. Similarly,

$$Pr(Y_t^* \geq l_t) = 1 - \Phi(\frac{l_t - X_t\beta}{\sigma}) = \Phi(\frac{X_t\beta - l_t}{\sigma}), \tag{4}$$

---

[2]As long as l_t is a known constant $l_t - Y_t^*$ may be analyzed to obtain a normally distributed variable truncated at zero.

which follows from the identity: $\Phi(a) + \Phi(-a) = 1$. Note $E(Y_t^* | Y_t^* < l_t)$ must be determined.

$$E(Y_t^* | Y_t^* < l_t) = E(X_t\beta + \varepsilon_t | \varepsilon_t < l_t - X_t\beta)$$

$$= X_t\beta + E(\varepsilon_t | \varepsilon_t < (l_t - X_t\beta)).$$

The mean of a truncated normal variable (ε_t) may be found by direct integration,

$$E(Y_t^* | Y_t^* < l_t) = X_t\beta + \sigma\phi\left(\frac{l_t - X_t\beta}{\sigma}\right) / \Phi\left(\frac{l_t - X_t\beta}{\sigma}\right), \qquad (5)$$

where ϕ is the standard normal probability density function (pdf), the deviative of the cdf. Note that $E(Y_t^*) = X_t\beta$ and that truncating large values reduces the mean.

Finally substituting (3), (4), and (5) into (2)

$$E(Y_t) = X_t\beta\Phi\left(\frac{l_t - X_t\beta}{\sigma}\right) - \sigma\phi\left(\frac{l_t - X_t\beta}{\sigma}\right)$$

$$+ l_t\Phi\left(\frac{X_t\beta - l_t}{\sigma}\right)$$

and the object we seek is[3]

---

[3]Note that $d\Phi(a)/da = \phi(a)$ and $d\phi(a)da = -a\phi(a)$.

$$\frac{dE(Y_t)}{dX_t} = \beta\Phi(\frac{l_t - X_t\beta}{\sigma}) - \frac{\beta}{\sigma}(X_t\beta)\phi(\frac{l_t - X_t\beta}{\sigma})$$

$$- \frac{\beta}{\sigma}\ \sigma[\phi(\frac{l_t - X_t\beta}{\sigma})][\frac{l_t - X_t\beta}{\sigma}] + l_t\ \frac{\beta}{\sigma}\ \phi(\frac{X_t\beta - l_t}{\sigma})$$

$$\frac{dE(Y_t)}{dX_t} = \beta\Phi(\frac{l_t - X_t\beta}{\sigma}). \tag{6}$$

This has an intuitive interpretation. The effect of X on Y is β if Y is at the limit and 0 otherwise. The probability that Y is at the limit is $\Phi(\frac{l_t - X_t\beta}{\sigma})$. Thus (6) represents an average.

Formula (6) shows again that β is not the parameter we seek. However, if β and σ were estimated, for example by ordinary regression of untruncated NAR's on X, then $\beta\Phi((l_t - X_t\beta)/\sigma)$ could be evaluated directly by computation.

Suppose instead of using the plan in the last paragraph that Y is regressed on X. This is inefficient because it fails to use all the available information about Y^* to estimate β, but does it give the right answers? Regression gives the best linear approximation to the relationship between X and Y, so to evaluate what happens take another look at $E(Y_t)$.

$$E(Y_t) = X_t\beta\Phi(\frac{l_t - X_t\beta}{\sigma})$$

$$- \sigma\phi(\frac{l_t - X_t\beta}{\sigma}) + l_t\Phi(\frac{X_t\beta - l_t}{\sigma}). \tag{7}$$

It is not clear that linear regression on X_t, which appears nonlinearly in every term, will produce the desired result. The next section shows that it may work out, and in any case β and σ may be estimated.

2. What to Do With Truncated Data

Suppose the tobit model under consideration cannot be untruncated to estimate β and σ and evaluate $\beta\Phi(\frac{l_t - X_t\beta}{\sigma})$. This is normally the case with wage and hours data or with consumer durable purchases. Then to recover β and σ, maximum likelihood estimation (MLE) must be employed. Fortunately, many computer packages now exist to estimate tobit models. After a brief discussion of how these work, a deeper investigation into what happens if linear regression is employed will follow.

The likelihood function for a sample of T observations of which T_1 are not at the limit and T_2 are at the limit, is as follows.

$$(L = \prod_{t=1}^{T_1} \frac{1}{\sqrt{(2\pi\sigma^2)}} e - \tfrac{1}{2}(\frac{Y_t - X_t\beta}{\sigma})^2)(\prod_{t=1}^{T_2} \Phi(\frac{X_t\beta - l_t}{\sigma})). \quad (8)$$

The first product involves the normal probability density function (pdf) and the second involves the normal cumulative distribution function (cdf), because it reflects the probability of being over the limit. The log likelihood is

$$L^* = -\frac{T_1}{2}\ln(2\pi)\frac{T_1}{2}(\ln\sigma^2) - \tfrac{1}{2}\sum_{t=1}^{T_1}(\frac{Y_t - X_t\beta}{\sigma})^2$$

$$+ \sum_{t=1}^{T_2} \ln\Phi(\frac{X_t\beta - l_t}{\sigma}). \quad (9)$$

The derivatives of this function are tractable. Maximization of L^* leads to the MLE.

Suppose ordinary regression is applied to truncated NAR's. The regression models used on nutrient intake data have done just that. What is being estimated?[4] Let μ^* and σ^* refer to the mean and variance of the underlying variable--potential purchases or NAR, for example--and Φ^* refer to the probability in the population that the limit will not be exceeded. Let ϕ^* be the value of the standard normal pdf corresponding to the value Φ^* of the standard normal cdf. Finally, if a joint normal distribution for the explanatory and dependent variables can be assumed,[5] the ordinary regression coefficients b tend to $\beta\Phi^*$. On the other hand, the effect of X on the expected value of Y taking truncation into account is $\beta\Phi[\frac{\mu^*}{\sigma}]$. The difference between σ^* and σ is that σ^2 is the variance of ε, the disturbance, while σ^{*2} is the variance of Y^*, and thus includes the additional variation arising from X. In addition, Φ^* is the unconditional probability that a value of Y^* will not exceed the limit while $\Phi[\frac{\mu^*}{\sigma}]$ is that probability conditional upon the mean values of X.

The ratio of the two sets of coefficients, both of which are scalar multiples of β, is:

$$\frac{\text{Ordinary Regression Coefficients}}{\text{Marginal Impacts}} = \frac{\Phi(\mu^*/\sigma^*)}{\Phi(\mu^*/\sigma)}. \qquad (10)$$

---

[4]This discussion draws heavily on Greene (1981).

[5]While this is frequently not true, it seems to work well both in tobit and other cases. See Greene (1981).

If a connection between σ^* and σ could be found, this could be evaluated. There is one: the variance of Y^* is related to the variance in ε by the ordinary R^2.

$$R^2 = 1 - \frac{V(\varepsilon)}{V(Y^*)} = 1 - \frac{\sigma^2}{\sigma^{*2}}. \qquad (11)$$

Thus the R^2 from a regression of Y^* on X is needed to generate, among other things, the R^2 from it. From (11),

$$\sigma = \sigma^*(1-R^2)^{0.5}.$$

Finally the factor by which the marginal impacts are multiplied to get the ordinary regression coefficients is

$$\Phi(\frac{\mu^*}{\sigma_*})/\Phi(\frac{\mu^*}{\sigma_*} \cdot \frac{1}{(1-R^2)^{0.5}}). \qquad (12)$$

The value of this fraction is one--there is no bias in interpreting ordinary regression coefficients as marginal impacts--if $\mu_* = 0$, that is, if half the underlying population is at the limit. (It is also true if M_* is large, but then the model is not effectively truncated.) It helps for this purpose if R^2 is small, which is an unusual state of affairs.

The following strategy is indicated: regress y^* on X; if $\Phi(\mu_*/\sigma_*)/\Phi((\mu_*/\sigma_*)/\sqrt{1-R^2})$ is near one, then the regression of y on X will be approximately equal to the marginal impacts.

If the data are truncated initially, and they cannot be restored in order to apply the analytical technique of calculating

$$\gamma = \beta\Phi(\mu_*/\sigma_*) \tag{13}$$

or the regression technique described above, the marginal impacts may still be calculated using MLE to get estimates of β and σ. Formula (13) can then be evaluated. Ordinary regression is more direct and easier if it is available.

The variances of the estimated marginal impacts must be found to evaluate the statistical significance of the various coefficients or to test hypotheses. Whatever estimation technique is used will generate variances for β and σ, while $\mu_* = \beta\bar{X}$, the estimated β vector applied to the means of the X's.

3. Estimation Involving the Mean Adequacy Ratio (MAR)

The mean adequacy ratio (MAR) is the mean of the truncated NAR's. The MAR is used as a summary statistic to evaluate the nutritional quality of a diet. By definition, it must lie between zero and one. To be zero, the food intake would have to be essentially zero (bread and water would be too much). To be one, the NAR for each of ten nutrients would have to be at least 100. In the Rural Income Maintenance Experiment sample 132 of 1302 sample points attained a MAR of 100.

Ordinary regression is quite inappropriate for the MAR. First, it is constrained not to exceed 100, and frequently is near 100. As noted earlier, such a constraint may be ignored if a limit, such as zero, in this case, is practically never approached. The probability of seeing an observation many standard deviations from the mean is almost nil, anyway. But if 99.9 or 100 can be attained in practice, a regression model suggests that 100.1 is only slightly harder to attain. Binding constraints of this type are denied in the regression framework. Second, the MAR has an underlying variable--an "untruncated MAR"--associated with it. Regression of the truncated version results in coefficients which do not reflect the effect of explanatory variables either on the underlying untruncated variable or on the underlying variable, given that it is not greater than 100.

The central question is: What is the effect of explanatory variables on the mean of a number of NAR's, given that pushing any of them over 100 does not count? Because there is no unambiguously defined sum to truncate, there is no variable clearly eligible for regression.

Fortunately no regression at all is needed, just some mathematical maneuvering. Let Y refer to the MAR and Y_1 to Y_{10} refer to the NAR's after truncation. Then

$$\frac{dY}{dx} = \frac{d\left(\frac{1}{10}\sum_{i=1}^{10} Y_i\right)}{dx} = \frac{1}{10}\sum_{i=1}^{10}\frac{dY_i}{dX}$$

and dY_i/dX was found above. To evaluate dY/dX, then, the ten marginal impacts dY_i/dX must be evaluated and added. The variance of the sum can be found as the sum of the variances and covariances of the individual marginal impacts, i.e.,

$$V\left(\frac{dY}{dX}\right) = \sum_{i=1}^{10}\sum_{j=1}^{10} \mathrm{Cov}\left(\frac{dY_i}{dX},\frac{dY_j}{dX}\right).$$

All of the necessary calculations can be done using the results of the regressions of untruncated NAR's on the explanatory variables.

The covariance between residuals from different equations is needed. This can be estimated using the vector of estimated residuals from all of the ten equations for individual nutrients.

Appendix B

Formulae to Compute the Marginal Impacts

The participation equation:

$$y_{t,N+1} = 1 \quad \text{if} \quad \underline{z}_t'\underline{\delta} + \varepsilon_{t,N+1} > 0,$$

$$y_{t,N+1} = 0 \quad \text{if} \quad \underline{z}_t'\underline{\delta} + \varepsilon_{t,N+1} \leq 0.$$

The nutrient equations:

$$y_{tj} = \underline{x}_t'\underline{\beta}_j + \varepsilon_{tj}, \quad j = 1, 2, \ldots, N.$$

and

N = number of nutrients

$t = 1, 2, \ldots, T$ persons

$$\underline{\varepsilon}_t \sim N(\underline{0}, \Sigma), \quad E(\underline{\varepsilon}_s\underline{\varepsilon}_t') = \Sigma, \quad s = t,$$

and

$$E(\underline{\varepsilon}_s\underline{\varepsilon}_t') = 0, \quad s \neq t,$$

$$\Sigma_{N+1,N+1} = 1.$$

Probability of participation:

$$\Pr(y_{t,N+1}=1) = \Phi(\underline{z}_t'\underline{\delta}).$$

$$\frac{\partial\Phi(\underline{z}_t'\underline{\delta})}{\partial\underline{\delta}} = \underline{z}_t\phi(\underline{z}_t'\underline{\delta})$$

$$\frac{\partial\Phi(\underline{z}_t'\underline{\delta})}{\partial\underline{z}_t} = \underline{\delta}\phi(\underline{z}_t'\underline{\delta})$$

$$\frac{\partial^2 \Phi(\underline{z}_t'\underline{\delta})}{\partial \underline{z}_t \partial \underline{\delta}} = \phi(\underline{z}_t'\underline{\delta})[I - \underline{z}_t'\underline{\delta}\ \underline{\delta}'\underline{z}_t]$$

Probability of a diet adequate in nutrient j:

$$A = Pr(y_{tj} \geq L_j) = \Phi(\frac{\underline{x}_t\underline{\beta}_j - L_j}{\sigma_j}),\ \sigma_j = \Sigma_{jj}^{0.5}.$$

$$\frac{\partial A}{\partial \underline{\beta}_j} = \frac{\underline{x}_t}{\sigma}\ \phi(\frac{\underline{x}_t'\underline{\beta}_j - L_j}{\sigma_j})$$

$$\frac{\partial A}{\partial \sigma_j} = -(\frac{\underline{x}_t'\beta_j - L_j}{\sigma_j^2})\phi(\frac{\underline{x}_t'\beta_j - L_j}{\sigma_j})$$

$$\frac{\partial A}{\partial \underline{x}_t} = \frac{\underline{\beta}_j}{\sigma}\ \phi(\frac{\underline{x}_t'\underline{\beta}_j - L_j}{\sigma_j})$$

$$\frac{\partial^2 A}{\partial \underline{x}_t \partial \underline{\beta}_j} = \frac{1}{\sigma_j}[I - \frac{1}{\sigma_j}(\frac{\underline{x}_j'\underline{\beta}_j - L_j}{\sigma_j^2})\underline{\beta}_j\underline{x}_t']\phi(\frac{\underline{x}_t'\beta_j - L_j}{\sigma_j})$$

$$\frac{\partial^2 A}{\partial \underline{x}_t \partial \sigma_j} = \frac{\underline{\beta}_j}{\sigma_j^2}[\frac{(\underline{x}_t'\beta_j)(\underline{x}_t'\beta_j - L_j) - \sigma_j^2}{\sigma_j^2}]\phi(\frac{\underline{x}_t'\beta_j - L_j}{\sigma_j})$$

Nutrient adequacy ratio of nutrient j:

$$NAR_j = \underline{x}_t'\underline{\beta}_j + (L_j - \underline{x}_t'\beta_j)\Phi(\frac{\underline{x}_t'\underline{\beta}_j - L_j}{\sigma_j}) - \sigma_j\phi(\frac{\underline{x}_t'\underline{\beta}_j - L_j}{\sigma_j})$$

$$\frac{\partial NAR_j}{\partial \underline{\beta}_j} = \underline{x}_t\Phi(\frac{L_j - \underline{x}_t'\beta_j}{\sigma_j})$$

$$\frac{\partial NAR_j}{\partial \sigma_j} = -\phi(\frac{\underline{x}_t'\underline{\beta}_j - L_j}{\sigma_j})$$

$$\frac{\partial NAR_j}{\partial \underline{x}_t} = \underline{\beta}_j \Phi(\frac{L_j - \underline{x}_t'\underline{\beta}_j}{\sigma_j})$$

$$\frac{\partial^2 NAR_j}{\partial \underline{x}_t \partial \underline{\beta}_j} = -\frac{1}{\sigma_j}\ \phi(\frac{L_j - \underline{x}_t'\underline{\beta}_j}{\sigma_j})\underline{\beta}_j \underline{x}_t' + I\Phi(\frac{L_j - \underline{x}_t'\underline{\beta}_j}{\sigma_j})$$

$$\frac{\partial NAR_j}{\partial \underline{x}_t \partial \sigma_j} = \underline{\beta}_j (\frac{\underline{x}_t'\underline{\beta}_j - L_j}{\sigma_j}) \phi(\frac{L_j - \underline{x}_t'\underline{\beta}_j}{\sigma_j})$$

Mean adequacy ratio

$$MAR = \frac{1}{N} \sum_{j=1}^{N} NAR_j$$

All derivatives are found from those of NAR_j.

Appendix C

The Specification of the Method of Moments Problem

Each of a set of equations, one for each nutrient, is specified:

$$Y_{jt} = \underline{X}_t'\underline{\beta}_j + \varepsilon_{jt}, \tag{1}$$

where j = 1 to N (nutrients) and t = 1 to T (persons). The disturbances are related as follows:

$$\begin{aligned} &E(\varepsilon_{jt}) = 0, \\ &E(\varepsilon_{jt}\varepsilon_{is}) = 0, \qquad s \neq t \\ &\qquad\qquad\quad\; \sigma_{ji}, \qquad s = t, \end{aligned} \tag{2}$$

and the ε's are joint normally distributed. Normality has no effect on the MOM problem but does affect the calculation of nutrient adequacy ratios and other extensions of the model.

The probability of participation is given by a probit model:

$$\begin{aligned} &Y_{t,N+1} = 1 \quad \text{if} \quad \underline{Z}_t'\underline{\delta} + \varepsilon_{t,N+1} > 0, \\ &Y_{t,N+1} = 0 \quad \text{if} \quad \underline{Z}_t'\underline{\delta} + \varepsilon_{t,N+1} \leq 0, \\ &\varepsilon_{t,N+1} \sim \text{i.i.d. } N(0,1). \end{aligned} \tag{3}$$

Although the probit disturbances are independent between individuals, they are not independent of the disturbances in the nutrient equation:

$$E(\varepsilon_{tj}\varepsilon_{t,N+1}) = \sigma_{j,N+1}, \qquad j = 1 \text{ to } N. \tag{4}$$

Formula (4) implies that selection bias may be present here. In particular,

$$E(Y_t \mid \underline{X}_t, \underline{Z}_t, Y_{t,N+1}) = \underline{X}_t'\underline{\beta}_j + \gamma_j \lambda_t + \eta_t, \tag{5}$$

where

$$\lambda_t = \frac{\phi(\underline{Z}_t'\delta)}{\Phi(\underline{Z}_t'\delta)} \quad \text{if} \quad Y_{t,N+1} = 1,$$

$$\lambda_t = -\frac{\phi(\underline{Z}_t'\delta)}{1 - \Phi(\underline{Z}_t'\delta)} \quad \text{if} \quad Y_{t,N+1} = 0, \tag{6}$$

and η_t is not normally distributed and is heteroscedastic but has a mean of zero.

The objective is to estimate $\underline{\beta}_j$, j = 1 to N, $\underline{\delta}$, and σ_{ji}, i = 1 to N, and j = 1 to N. In addition to (5), this expectation is used:

$$E(Y_{t,N+1}) = \Phi(\underline{Z}_t'\delta), \tag{7}$$

referring to the probit equation. Normality is used in specifying equation (7).

Although it is not mathematically required, all of the explanatory variables in the nutrient equations are the same, because it is hard to imagine a factor which would affect some but not all of the nutrients.

The orthogonality conditions specified for this problem are:

$$E[\underline{X}_t^{I'}(Y_{tj} - \underline{X}_t'\underline{\beta}_j - \gamma_j\lambda_t)] = \underline{0}, \quad j = 1 \text{ to } N;$$

$$E[\underline{Z}_t'(Y_{t,N+1} - \Phi(\underline{Z}_t'\delta))] = \underline{0}, \tag{8}$$

where $\underline{X}_t^{I'}$ refers to the instrumental variables (see below). The orthogonality conditions written as a vector are called $\underline{g}$. To estimate the variances and their variances and covariances, one needs $\underline{0} = \sum_{t=1}^{T} \underline{g}_t = \underline{0}$ by construction (to estimate $\underline{\theta}$)

$$V(\hat{\underline{\theta}}) = (D'W^{-1}D)^{-1},$$

$$D = \frac{\partial \underline{0}}{\partial \underline{\theta}} \quad \text{and} \tag{9}$$

$$W = V(\hat{\underline{0}}) = \sum_{t=1}^{T} \underline{g}_t \underline{g}_t'.$$

One of the explanatory variables is the actual food stamp bonus, which is important in that it is the main instrument of policy. However, the actual food stamp bonus received is endogenous, since it is the potential bonus times the participation dummy. Thus, an instrumental variable is needed for it. The potential food stamp bonus is used for this. The selection bias factor λ also needs an instrumental variable for which purpose assets squared is used. Assets are absent from the nutrient equation. Assets squared provides a lower variance for the parameters in general than assets do. All other variables act as their own instruments.

Here $\underline{\theta}$ is arranged thus:

$$\underline{\theta} = \begin{vmatrix} \underline{\beta}_1 \\ \underline{\beta}_2 \\ \vdots \\ \underline{\beta}_N \\ \underline{\delta} \end{vmatrix}, \tag{10}$$

$$D = \begin{vmatrix} I \times A & \underline{\gamma} \times B \\ \underline{0}' \times 0 & C \end{vmatrix}, \tag{11}$$

where

$$\underline{\gamma} = (\gamma_1, \gamma_2, \ldots, \gamma_N)' \tag{12}$$

$$A = -\frac{1}{T}\,\Sigma(\underline{X}_t^{I'}\,\underline{X}_t), \tag{13}$$

$$B = \frac{1}{T}\sum_{t=1}^{T} \underline{X}_t^{I'}\,\underline{Z}_t \lambda_t(\lambda_t + \underline{Z_t'\delta}), \tag{14}$$

$$C = \frac{1}{T}\sum_{t=1}^{T} Z_t' Z_t\, \phi(\underline{Z_t'\delta}). \tag{15}$$

Note that

$$W = \sum_{t=1}^{T} \underline{g_t g_t'} \tag{16}$$

is a large matrix (here 209 x 209), but it can be inverted by computer.

Then

$$V(\hat{\underline{\theta}}) = (D'W^{-1}D)^{-1}$$

$$= \left[\begin{vmatrix} I \times A' & \underline{0} \times 0 \\ \underline{\gamma}' \times B' & C \end{vmatrix}' W^{-1} \begin{vmatrix} I \times A & \underline{\gamma} \times B \\ \underline{0} \times 0 & C \end{vmatrix} \right]^{-1} \tag{17}$$

is calculated by computer, fortunately. The size of the matrices requires a lot of space and time to carry out the computation!

Note that D^{-1} can be written analytically:

$$D^{-1} = \begin{vmatrix} I \times A^{-1} & -\underline{Y} \times A^{-1}BC^{-1} \\ \underline{0}' \times 0 & C^{-1} \end{vmatrix}. \tag{18}$$

Appendix D

Potential Bonus Amount in the RIME Data

The potential food stamp bonus amount is not known in the RIME data except for those persons who receive food stamps. Inadequate data exist to determine the true potential amount for each family, since the determination involves deductions of various kinds, related to medical care and child care, for example, but especially business expenses, which could be substantial in the case of farmers. Medical expenses are not known, but a variety of indicators of the use of medical care can be used to proxy medical expenses. Asset limits, similarly, omit vehicles used in a business, so that even large assets might be omitted. To avoid all of these difficulties, we estimate a potential bonus amount based on the observed bonus of those who participate in the Food Stamp program, correcting the equation for selection bias using Olsen's method (see Olsen, 1980, for the method and Mitchell and Butler (forthcoming) for an extended example and a set of detailed instructions).

The resulting equation, from which estimated bonus amounts are derived, is stated as Table D-1. The estimate was not substituted for those persons who are receiving food stamps. Identification is achieved by including the income as a percentage of the poverty line, male head of household, assets, and knowledge of nutrition in the participation equation. Stigma may be greater for a male-headed household or a household whose income is greater relative to its poverty line; assets may make a family ineligible; knowledge of nutrition may encourage participation. None of the four variables affects the food stamp entitlement.

Table D-1

Equation to Estimate Potential Bonus Amounts in the RIME Sample

Explanatory Variable	Estimated Coefficient	Standard Error	t-value
Constant	64.325	209.146	0.308
Age	1.002	0.793	1.263
Black	-2.290	18.398	-0.124
Education	-1.544	2.409	0.641
Children	22.285	9.751	2.285*
Adults	11.370	9.257	1.228
Elderly	-24.974	20.291	-1.231
Lives alone	-32.870	23.193	-1.417
North Carolina	22.134	28.116	0.787
Quarter 3, 1970	-16.929	26.896	-0.629
Non-food stamp income ($100)	-3.297	0.937	-3.520*
Proxies for medical expenses			
Children sick	19.181	29.888	0.642
Doctor	24.039	13.535	1.776**
Hospital	0.699	1.047	0.667
Pharmacy	-1.444	5.033	-0.287
Outpatient	-2.293	4.175	-0.549
Home-produced food	-15.398	13.321	-1.156
Conditions treated	-0.036	11.327	-0.798
Probability of not participating	-99.345	273.652	-0.363
R^2 = 0.34803			

*significant at the 5% level
**significant at the 10% level

The estimated equation indicates that income affects the entitlement as well as visiting a doctor. The number of children is the only other significant variable. The evidence does not reject the hypothesis of no selection bias.

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