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Abstract

Low-cost food plans offer little guidance to persons with limited food budgets. Diets costing much less can be determined by linear programming methods applied to specified nutritional standards and selected palatability requirements. The wide discrepancy between the cost levels needs examination and explanation.

Key words: Low-cost diets; Linear programming application; Food consumption.

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When inflation surges ahead, as it has recently, the poor, the pensioned elderly, and many others become progressively worse off as their real incomes decline. Such persons seek ways of making their shrinking food dollar go further. They get little help from available "low-cost" plans. These diets merely give the costs, as of particular dates, for specified collections of foods but do not indicate what shifts might be made in consumption patterns to reduce costs further. The basic problem is "How much must be spent, and for what foods, to insure a diet satisfying physiological and cultural specifications of food consumption?" This paper is directed toward that question.

Linear programming methods are used extensively for determining low-cost animal rations. However, they are applied quite infrequently to human diets, despite the fact that expenditures are much greater in the latter case. Admittedly, different problems are encountered with feeding programs for human populations than with those for livestock. It is doubtful, however, that the differences preclude using the linear programming method. This technique is applied in the present analysis.

By merely stipulating minimum nutritive requirements we get a solution at the "absolute" subsistence level, which includes only six or seven of

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the cheapest foods in terms of nutrients. Such a diet is both inexpensive and a bit monotonous. It would be quite unacceptable to many American families. A more realistic problem is formulated by including various palatability requirements as additional constraints. This modification is made for our analysis.

The major findings of the analysis made for this paper may be summarized about as follows:

1. The monthly shopping list (see Table 5) includes a moderate variety of foods as required by the palatability requirements specified in Table 2.
2. This diet provides minimum requirements of calories, protein, calcium, iron and five vitamins. In fact, it supplies a substantial excess of three vitamins (see Table 1).
3. Expenditures for feeding a man and his wife are about $30-35 per month at prices prevailing in 1972-1973 (see Table 5).
4. This diet is only a third as expensive as the "low-cost" food plan prepared by professional dieticians in USDA. A discrepancy of this magnitude requires some explanation along the lines of the brief examination made later in the paper.

Methodology

Two couples were selected for this study. Professor Elder is retiring from the Agricultural Economics Department on a modest pension. He and his wife are in their mid-60's. His replacement is Mr. Younger, just completing his dissertation, and whose wife is pregnant with her first child. They are in their late 20's. Both couples are of average weight, in good health, and living independently as 2-person families under usual environmental conditions.[1/] It is assumed that both couples wish to minimize their food costs in accordance with the restrictions imposed by the linear programming technique. They are willing, however, to set up an extra food allowance for use whenever they entertain, as their guests may expect to be fed more lavishly than permitted by the economy diet determined here.

To minimize the cost of their diets, we need information about (1) the nutritive and cultural requirements to be met by the diets, (2) which foods are eligible for inclusion in the diets, and (3) the nutritive-cultural composition of these foods and their prices. Applying linear programming techniques to these data gives a solution. We minimize

$$\sum_{j=1}^{n} c_j X_j \quad \text{subject to} \quad \sum_{j=1}^{n} a_{ij} X_j \gtrless b_i \quad (i=1...m)$$

where X_j = amount of food j

c_j = price of food j

b_i = level specified by requirement i

a_{ij} = per-unit contribution of food j toward requirement i

Probably the linearity assumption is satisfied at least approximately. For example, two pounds of most foods cost twice as much as one pound and contribute twice the amount of each nutrient. This is particularly true if we assume that the participants do, in fact, endeavor to keep their food costs down by buying those packages which give low per-pound prices. However, some problems with linearity remain. Agricultural Handbook No. 8 [5, p. 166] indicates some of the factors that inhibit the utilization of certain nutrients.

Diet Specifications

Two standards are used for defining an acceptable diet. These set minimum nutritive requirements and minimum acceptable cultural components of food consumption for the diets to be determined.

A diet is deemed physiologically adequate if it contains the "allowances" recommended by the National Research Council [1]. Their allowances specify minimum needs for maintaining good nutrition in healthy Americans living under present-day environmental conditions. They do not take into account losses in food preparation and of discards as table waste. The minimum levels for our two couples are limited to nine food elements (Table 1). Allowances for other minerals and vitamins are excluded because of the scarcity of information about amounts obtainable from various foods and for other reasons.

Attention must also be given to the need for variety in the diet, palatability of individual foods, use of certain items for prestige purposes, and other cultural aspects of food consumption. This diversity in the diet is forced by setting the 35 palatability requirements listed in Table 2. Most of these specify maximum limits on cheaper foods. Minimum consumption levels are set for eggs, meats, milk, fruits, and vegetables in order that these more expensive foods are included in the diet. In addition, exact amounts are specified for a few items. These requirements define one set of cultural standards. Another researcher is likely to select a different set. For example, palatability might be defined in terms of conformity to conventional patterns of food purchase. Of course, I cannot, and do not, claim that my standard is necessarily the most desirable one. It does, however, serve to make the linear programming problem more realistic by adding a second dimension to the diet specifications.

TABLE 1

Nutritive Adequacy of Low Cost Diets
for the Elders and the Youngers

Food element	Unit	Monthly Dietary Allowance a/		Diet's Adequacy, % of Allowance b/	
		Elders	Youngers	Elders	Youngers
Energy	calorie	126,000	150,000	100	100
Protein	gram	3,060	3,960	106	100
Calcium	milligram	48,000	60,000	100	100
Iron	milligram	600	840c/	105	100
Thiamin	milligram	66	81	147	137
Riboflavin	milligram	78	93	136	130
Niacin	milligram	840	990	113	106
Ascorbic acid	milligram	2,700	3,150	205	100
Vitamin A	int'l unit	270,000	300,000	100	138

a/ Designed for the maintenance of good nutrition of practically all healthy persons living in the U.S.A. under usual environmental conditions. Assumed weights are 128 pounds for women and 154 pounds for men.

b/ Amount provided by the low-cost diet expressed as a percent of the allowance recommended.

c/ Mrs. Younger is pregnant. Her need for additional iron cannot be met by ordinary diets. It is assumed she will use supplemental iron.

Source: Allowances are synthesized from: Food and Nutrition Board, National Research Council, "Recommended Daily Dietary Allowances," revision released October 1973.

TABLE 2

Palatability Requirements for Economy Diets

	Food item	Unit	Level
1	Coffee, instant, jar	10 oz.	1 exactly
2	Tea, instant	oz.	3 exactly
3	Catsup, bottle	14 oz.	1 exactly
4	Oil, cooking and salad	pt.	1 exactly
5	Salt a/	oz.	4 exactly
6	Sugar a/	lb.	2 to 5
7	Margarine a/	lb.	1 to 4
8	Shortening a/	lb.	2 or less
9	Kitchen aid b/	cents	75 exactly
10	Breadstuffs c/	pkg.	10 or less
11	Dough mixes 1 and 2	pkg.	8 or less
12	Dough mixes 3 and 4	pkg.	4 or less
13	Dough mix 5	pkg.	1.5 or less
14	Other cereals d/	cass.	15 or less
15	Macaroni/cheese and Spaghetti/meatballs	cass.	6 or less
16	Noodles/chicken and Noodles/tuna	cass.	6 or less
17	Beans, dry	lb.	6 or less
18	Rice	lb.	6 or less
19	Eggs a/	dz.	1 or more
20	Milk, total fresh equivalent e/	qt.	15 or more
21	Milk, evaporated, can	14-1/2 oz.	4 or less
22	Meat, total f/	lb.	8 or more
23	Chicken, fryer	lb.	6 or less
24	Liver	lb.	2 or less
25	Fruits, total fresh equivalent g/	lb.	30 or more
26	Bananas	lb.	12 or less
27	Juices, orange and tomato h/	can	8 or less
28	Vegetables, total i/j/	lb.	14 or more
29	Non-green vegetables i/	lb.	10 or more
30	Green vegetables j/	lb.	8 or less
31	Cabbage	lb.	4 or less
32	Carrots	lb.	4 or less
33	Onions, dry	lb.	5 or less

TABLE 2

Footnotes

a/ In addition to amounts used as ingredients in dough mixes and pasta casseroles.

b/ Includes various unspecified items such as vinegar, mustard, spices, sauces, etc.

c/ Count 1 pkg. = 1 pkg. dough mix, 3 loaves bread, and 4 pkgs. (12 oz.) corn flakes.

d/ Count 1 cass. = 1 pasta casserole, 1 lb. dry beans or rice, and 2.5 lbs. potatoes.

e/ Count 1 qt. = 1 qt. whole milk, 1 can evaporated milk, 0.2 lbs. dry milk, 0.33 pt. cottage cheese, and 0.25 lb. processed cheese plus the dry milk used as ingredient counted at 1 qt. = 2.5 pkgs. dough mix 1 or 2, 0.8 pkg. dough mix 3 or 4, 1.25 pkgs. dough mix 5, 2.5 casseroles macaroni/cheese, and 2 casseroles noodles/chicken or noodles/tuna.

f/ Count 1 lb. = 1 lb. bologna, frankfurters, hamburger or liver, 1.33 lbs. chicken, chuck roast or picnic ham, 4 cans (4 oz.) sardines, 2.5 cans (6-1/2 oz.) tuna, 1 casserole spaghetti/meatballs, 1.33 casserole noodles/chicken, and 2.5 casseroles noodles/tuna.

g/ Count 1 lb. = 1 lb. apples, bananas or oranges, 0.67 can (6 oz.) frozen orange juice, and 0.5 can (No. 2-1/2) apricots, peaches or fruit cocktail.

h/ Count 1 can = 1 can (6 oz.) frozen orange juice and 0.5 can (46 oz.) tomato juice.

i/ Count 1 lb. = 1 lb. carrots, dry onions or green peppers, 0.83 can (No. 303) beans or peas, 0.67 can (No. 2-1/2) tomatoes, and 0.4 can (46 oz.) tomato juice.

j/ Count 1 lb. = 1 lb. cabbage or greens, 1 pkg. (10 oz.) frozen broccoli, and 1 can (No. 2-1/2) spinach.

Source: Assumed for L.P. program

The Foods

Americans select from 5-10,000 food items in each supermarket. Only a few of these items need be selected as potential foods for this study. Some foods are much more expensive than others (e.g., steak vs. hamburger) in terms of nutritive values per dollar spent. These will not appear in the solution, and so can be excluded from consideration. Some foods are offered in a wide variety of brand names, package sizes, styles, etc. Only the ones cheapest in terms of nutrient values need be included.

Some items are cheap sources of certain nutrients but are used chiefly as ingredients rather than being consumed directly—e.g., flour, baking powder, yeast, etc. The linear programming solution probably would contain these ingredients in quantities other than the proportions desired by the housewife for her meal preparations. This problem can be overcome by combining the ingredients to form composite foods. Table 3 gives recipes for the nine combinations used.

Five dough mixes are specified. Each combines three pounds of flour with the other listed ingredients. These recipes are designed for making bread and pan rolls (Mixes 1 and 2), biscuits and muffins (Mixes 3 and 4), and sweet rolls (Mix 5). Whole wheat flour is used in Mixes 2 and 4; all-purpose wheat flour in the other three mixes. Four pasta casseroles are used. The ingredients included merely provide essentials for average recipes. It is assumed the housewife will add seasonings (and possibly other ingredients) according to her preferences.

Nutritive values are taken mainly from two USDA publications [5, Table 2; 6, Table 1]. The former gives the "Nutrients in the edible portion of one pound of food as purchased" and hence makes no deductions

TABLE 3

Composite Recipes for Dough Mixes and Pasta Casseroles

Ingredient	Unit	Dough mix 1 & 2	Dough mix 3 & 4	Dough mix 5
Flour a/	lb.	3.00	3.00	3.00
Shortening	lb.	.10	.50	.40
Sugar	lb.	.10	.15	.40
Dry milk	lb.	.07	.24	.14
Salt	T.	1.20	1.00	.50
Eggs	ea.	.75	2.50	4.00
Yeast	ea.	1.33		2.50
Baking powder	oz.		1.15	
Weight per pkg. b/	lb.	3.44	4.24	4.43

Ingredient	Unit	Spaghetti & Meatballs
Spaghetti	lb.	0.50
Hamburger	lb.	1.00
Tomatoes, can	No. 2-1/2	.50
Tomato paste, can	6 oz.	1.00
Parmesan cheese	oz.	1.00
Onion	ea.	1.00
Pepper	ea.	1.00
Salt	T.	.67
Weight b/ c/	lb.	3.04

Ingredient	Unit	Noodles & chicken	Noodles & tuna
Noodles, egg	lb.	0.50	0.50
Chicken	lb.	.50	
Tuna, can	6.5 oz		1.00
Dry milk	lb.	.10	.10
Shortening	T.	1.00	1.00
Weight b/ c/	lb.	1.13	1.03

Ingredient	Unit	Macaroni & cheese
Macaroni	lb.	0.50
Amer. cheese	lb.	.50
Dry milk	c.	.50
Margarine	c.	.25
Flour	c.	.25
Salt	T.	.17
Weight b/ c/	lb.	1.28

a/ Use all-purpose flour (enriched) for mixes 1, 3, and 5 and whole wheat flour for mixes 2 and 4.

b/ Count: 1 lb. salt = 24 T.
1 egg = 1.5 oz.
1 yeast = 0.6 oz.
1 lb. shortening = 36 T.
1 can tomatoes = 20 oz. (drained weight)
1 onion = 0.25 lb.
1 pepper = 0.20 lb.
1 c. dry milk = 0.15 lb.
1 c. margarine = 0.50 lb.
1 c. flour = 0.273 lb.

c/ Weight of pasta casseroles excludes any seasonings and other ingredients that may be added--e.g., cayenne pepper, mushrooms and bread crumbs.

Source: Prepared for use in analysis.

for losses of vitamins during preparation and cooking. The other lists the "Nutritive values of the edible parts of foods," often on a cooked as well as uncooked basis.[2/]

Annual 1972 retail prices reported by BLS [3] for Los Angeles-Long Beach and San Francisco-Oakland were averaged using weights of 2 and 1, respectively. However, many cheap foods rich in nutrients are excluded from the BLS list. Additional foods are represented by prices prevailing in 1973 at Davis, California, stores. Although adjustments were made to improve comparability, the set of prices is not entirely satisfactory. Their use can be defended on the basis that the solution obtained serves to indicate the magnitude of the discrepancy between costs of economy diets determined by linear programming techniques and costs of usual low-cost diets.

Nutritive values and prices for the five dough mixes and four pasta casseroles are the sums of those for the ingredients in each composite food. About 50 other individual foods were considered for potential inclusion in the economy diet. A lump sum of 75 cents is included for "kitchen aids", i.e., to cover the cost of spices, mustard, and other table-use items. Table 4 lists the foods, their prices, and their nutrient composition.

Results

Monthly expenditures are $34.20 by Mrs. Younger and $28.60 by Mrs. Elder to buy the foods listed in Table 5. These levels are determined, of course, by the dietary specifications adopted for the analysis. Altering the physiological and cultural composition will, or at least may, change the amount spent. Instead of attempting a sensitivity analysis only a general indication is presented.

Table 4

Price and Nutritive Value of Potential Foods for the Economy Diet

Food [a/]	Unit	Price cents	Energy 10 calories	Protein gram	Calcium 10 mg	Iron 0.1 mg	Thiamine 0.01 mg	Riboflavin 0.01 mg	Niacin 0.1 mg	Ascorbic acid mg	Vitamin A 100 IU
1 Sugar, granulated	lb.	13.9	175								
2 Shortening	lb.	30.0	400								
3 Oil, cooking and salad	pt.	55.0	400								
4 Margarine	lb.	33.4	325	4	9						150
* Flour, all-purpose, enriched	3 lbs.	38.4	495	143	22	390	600	360	480		
* Flour, whole wheat	3 lbs.	42.4	453	180	56	450	747	162	591		
* Macaroni or spaghetti	lb.	25.0	167	57	12	130	400	170	270		
* Noodles, egg	lb.	54.0	176	58	14	130	400	170	270		10
5 Dough mix 1 pkg.	3.44 lbs.	59.7	572	161	71	409	627	458	503	2	11
6 Dough mix 2 pkg.	3.44 lbs.	63.7	530	198	105	469	774	260	614	2	11
7 Dough mix 3 pkg.	4.24 lbs.	87.2	784	196	380	424	651	591	490	8	39
8 Dough mix 4 pkg.	4.24 lbs.	91.2	742	233	414	484	798	393	601	8	39
9 Dough mix 5 pkg.	4.43 lbs.	98.5	783	194	118	454	666	590	525	5	38
10 Bread, white, enriched	lb.	27.0	122	39	38	113	113	45	109		
11 Corn flakes pkg.	12 oz.	30.7	140	28	6	56	154	28	70		
12 Nuts	lb.	150.0	240	75	34	150	156	69	204		4
13 Potatoes, white	lb.	9.8	28	8	3	22	39	14	54	73	
14 Beans, dry	lb.	30.2	160	105	66	357	190	90	90		
15 Rice, white	lb.	19.6	168	30	11	135	205	15	162		
16 Macaroni and cheese, casserole	1.28 lbs.	81.6	231	100	210	99	233	249	148	2	54
17 Noodles and chicken, casserole	1.13 lbs.	57.2	134	74	68	96	226	224	224	3	26
18 Noodles and tuna, casserole	1.03 lbs.	79.2	168	90	67	88	223	182	326	3	17
19 Spaghetti and meatballs, casserole	3.13 lbs.	136.7	245	132	57	278	297	218	420	217	102
20 Eggs, large (24 oz.)	dz.	48.7	96	72	32	132	60	180			71
21 Milk, dry, nonfat	lb.	80.0	163	160	586	27	160	807	40	33	100
22 Milk, evaporated, can	14.5 oz.	20.5	63	33	115	5	18	156	9	5	15
23 Milk, whole, 3-1/2% fat	qt.	27.5	64	36	115	4	28	164	8	8	14
24 Cheese, cottage, creamed	pt.	45.5	170	36	28	10	10	108	4		70
25 Cheese, American processed, pkg.	8 oz.	58.1	84	56	158	24	8	96	0		28
* Cheese, Parmesan, pkg.	8 oz.	98.0	84	62	210	21	2	90	1		26
26 Sardines, can	4 oz.	28.1	35	24	40	40	2	18	5		2
27 Tuna, can	6.5 oz.	43.3	53	45	1	20	7	16	187		2
28 Chicken, fryers, ready-to-cook	lb.	42.5	38	57	4	59	20	117	171		23
29 Beef, chuck, whole	lb.	81.7	98	72	4	107	31	64	172		2
30 Bologna sausage	lb.	120.8	138	55	3	82	72	98	120		
31 Frankfurters	lb.	86.8	140	57	3	86	71	90	122		
32 Ham, picnic	lb.	64.2	106	62	4	93	258	69	146		
33 Hamburger, beef, regular	lb.	71.2	122	81	4	122	35	72	195		2
34 Liver, beef	lb.	87.0	64	90	4	295	116	1479	616	140	1990
35 Perch, white	lb.	87.2	41	88	0	27	27	77	79		
36 Oranges	lb.	17.7	16	3	14	13	33	13	13	166	1
37 Orange juice, frozen, can	6 oz.	25.0	36	5	8	9	68	11	28	360	16
38 Tomato juice, can	46 oz.	37.0	26	12	10	126	69	40	109	224	112
39 Tomatoes, can	No. 2-1/2	35.1	19	8	5	45	45	26	64	154	81
* Tomato paste, can	6 oz.	15.0	14	6	5	60	33	20	53	82	56
40 Catsup, bottle	14 oz.	20.0	42	8	9	31	36	25	64	61	55
41 Apples	lb.	26.1	24	1	3	13	12	8	3	16	1
42 Bananas	lb.	15.3	26	3	2	22	14	18	22	31	1
43 Broccoli, frozen, pkg.	10 oz.	32.9	6	7	14	18	15	30	13	143	65
44 Cabbage	lb.	11.8	10	5	20	16	22	20	13	192	5
45 Greens	lb.	23.5	12	13	57	96	39	80	37	332	282
46 Pepper, green	lb.	46.2	8	5	3	26	28	30	20	476	2
47 Carrots	lb.	18.0	16	4	14	26	22	20	22	29	409
48 Onions	lb.	14.4	16	6	11	21	14	15	8	42	
49 Beans, green, can	No. 303	23.0	9	4	16	58	14	20	14	20	14
50 Peas, green, can	No. 303	26.0	33	18	10	84	46	26	44	44	22
51 Spinach, can	No. 2-1/2	29.0	17	19	80	176	11	79	22	90	540
52 Apricots, hvy. sirup, can	No. 2-1/2	45.0	82	8	10	30	19	23	34	38	169
53 Fruit cocktail, hvy. sirup, can	No. 2-1/2	49.0	73	4	9	38	19	11	49	19	14
54 Peaches, hvy. sirup, can	No. 2-1/2	38.0	75	4	4	30	8	22	52	26	41
55 Coffee, instant, jar	10 oz.	140.0	37		51	159		59	868		
56 Tea, instant, jar	3 oz.	129.0	25		1	14		81	76		
* Salt, table	lb.	5.0			115						
* Baking power, can	30 oz.	56.0	88	1	5375						
* Yeast "pkg." of 12	7.2 oz.	72.0	18	25	3	100	145	337	229		

a/ Numbered foods are used directed as potential foods. Those denoted by * are used only as ingredients.

Source: Prices are those reported for 1972 (metropolitan Los Angeles and San Francisco) as supplemented by other prices gathered later by the author--see text for explanation.

Nutritive values are almost entirely from [4, 5].

TABLE 5

Monthly Shopping Lists for Mrs. Elder and Mrs. Younger

Food	Unit	Price, cents	Mrs. Elder Amount	Mrs. Elder cost	Mrs. Younger Amount	Mrs. Younger cost
Sugar	lb.	13.9	6.20	$ 0.86	6.65	$ 0.92
Shortening	lb.	30.0	4.77	1.43	5.22	1.57
Margarine	lb.	33.4	4.00	1.34	4.12	1.37
Oil, cooking and salad	pt.	55.0	1.00	.55	1.00	.55
Sugar-fats group				$ 4.18		$ 4.41
Flour, all-purpose	lb.	12.8	30.00	3.84	29.87	3.82
Flour, whole wheat	lb.	14.1			.19	.03
Noodles, egg	lb.	54.0	3.00	1.62	3.00	1.62
Macaroni	lb.	25.0			.46	.11
Rice	lb.	19.6	.71	.14	6.00	1.18
Cereal group				$ 5.60		$ 6.76
Milk, dry	lb.	80.0	5.20	4.16	5.96	4.77
Milk, evaporated, can	14-1/2 oz.	20.5			4.00	.82
Cheese, processed, pkg.	8 oz.	58.1			.93	.54
Milk group				$ 4.16		$ 6.13
Chicken, fryer	lb.	42.5	7.67	3.26	3.00	1.28
Hamburger	lb.	71.2			3.50	2.49
Eggs	dz.	48.7	2.21	1.08	2.61	1.27
Meat group				$ 4.34		$ 5.04
Bananas	lb.	15.3	12.00	1.84	12.00	1.84
Oranges	lb.	17.7	9.33	1.65		
Orange juice, frozen, can	6 oz.	25.0	5.78	1.44	4.42	1.10
Peaches, canned	No. 2-1/2	38.0			5.69	2.16
Fruit group				$ 4.93		$ 5.10
Onions	lb.	14.4	5.00	.72		
Carrots	lb.	18.0	2.22	.40		
Tomato juice, canned	46 oz.	37.0	1.11	.41		
Peas, canned	No. 303	26.0			8.33	2.17
Spinach, canned	No. 2-1/2	29.0			3.67	1.07
Cabbage	lb.	11.8	4.00	.47	.33	.04
Catsup, bottle	14 oz.	20.0	1.00	.20	1.00	.20
Vegetable group				$ 2.20		$ 3.48
Coffee, jar	10 oz.	140.0	1.00	1.40	1.00	1.40
Tea, jar	3 oz.	129.0	.33	.43	.33	.43
Yeast	ea.	6.0	8.00	.48	9.75	.59
Baking powder	oz.	1.9	4.60	.09	4.60	.09
Salt	lb.	5.0	.71	.03	.68	.03
Kitchen aids	cent			.75		.75
Miscellaneous group				$ 3.18		$ 3.29
GRAND TOTAL				$28.59		$34.21

Table 1 indicates, as should be expected, that variations in the nutritive requirements will be positively correlated with changes in expenditures. This relationship, however, is not equally pronounced for the different nutrients. The correlation is strongest for calories and calcium, and somewhat weaker for protein and iron. In other words, raising or lowering requirements for these four nutrients, at least by moderate amounts is likely to alter expenditures almost proportionately.

Vitamins present a different situation. Thiamin and riboflavin are supplied amply, and their requirements can be reduced without limit, or raised by a third without affecting the solution. Niacin is in a similar situation, except that requirements need be increased much less before the solution is altered. Table 1 seems to indicate that either vitamin A or ascorbic acid may be a real bottleneck. Examination of the detailed data (not given here) indicates contrariwise. The relative amounts of these two vitamins can be altered substantially by a small change in expenditures for the fruit-vegetable group, and with limited effect on the amounts of the other seven nutrients.

Changing the palatability requirements (Table 2) has a direct expenditure effect because of the way these requirements were set. For example, the linear program solution includes meat, milk, and eggs at the minimum consumption levels specified for these more expensive foods (in terms of nutrients). Quite obviously, changing these specifications would affect expenditures to almost the same extent. Similarly, maxima were specified for cheaper foods rich in nutrients. Changing the levels specified would alter expenditures also, but in the opposite direction. Thus, permitting the inclusion of more sugar, fats, and bananas would decrease monthly costs of the diet, whereas restricting their consumption would increase expenditures.

Mrs. Younger spends 20 percent ($5.60) more than Mrs. Elder almost entirely because her market basket must contain 19 percent more calories. The small additional increment is due to higher requirements for protein, calcium, and iron, which are 30, 25 and 40 percent, respectively, above Mrs. Elder's. As indicated in Table 5 expenditures are increased much more for some foods than for others.

Implications

The results of any statistical analysis are only as reliable as the information used. Admittedly, the input data lack the accuracy desired. Possibly the nutritional coefficients are the most accurate. However, even these need to be reexamined closely since they may not reflect satisfactorily the nutrient values actually absorbed, or at least eaten, by the average person. A better basis for specifying palatability requirements is needed to replace my arbitrary cultural standard. The prices used are the most suspect input data. It might have been better to use a series of official prices. However, for reasons indicated above, BLS prices were supplemented by those collected subsequently by the author. This blend may not represent comparable prices, particularly in view of the fact that food prices varied sharply during the period to which the analysis was applied.

Nevertheless, the results are useful in focusing greater attention on the need for determining costs of economy diets more accurately. The solution secured here is compared with two other results.

An early study along the lines of this analysis was published in 1945 by George Stigler [2]. He considered cost at the absolute subsistence level in the sense that only nutritive values were used as constraints.[3/] Stigler compared his result with estimates made by competent dieticians and concluded that their diets cost two or three times as much as his.

Eliminating all palatability requirements reduces monthly expenditures by almost one-half--from $28.60 to $15.20 for Mrs. Elder and from $34.20 to $18.30 for Mrs. Younger. The resulting diets are comparable to Stigler's in austerity, and few people would recommend such diets for the American public. We might, however, be ready to recommend something similarly derived for use in countries where peasants live at the absolute poverty level and remain largely on the fringes of, or outside, the money economy.

The summer 1973 issue of Family Economics Review [4, p. 27] gives food costs for April 1973 at three cost levels. For the "low-cost plan" estimates are $77.40 and $102.80 for 2-person families of the same sex-age composition as the Elders and the Youngers. Costs for our diets are only 35 percent as much.[4/]

Why is the discrepancy so large? The use of different price data accounts for only a small part of the difference. Almost all of the discrepancy is due to the way the cultural aspects of food consumption is handled. For example, in their "low-cost plan" the dieticians include 40 percent more milk and cheese, 75 percent more eggs, and three times as much meat; they specify 40 percent less flour and baked goods and 60 percent less citrus and tomato products. The quantity differences are even larger when their "moderate-cost" and "liberal" plans are compared with the economy diets derived here.

My comments should not be misconstrued. I do not recommend that low-cost diets be determined solely by physiological requirements. Of course, cultural assumptions must be made whenever diet costs are estimated. It does seem reasonable, however, to expect an explicit statement of what standard is used for specifying palatability, variety, and prestige in the diet formulated. Also it would be well to have an approximation of how the composition and cost of the diet are changed by the addition of cultural aspects of food consumption.

Footnotes

1/ This assumption corresponds with that embodied in the dietary allowances used--see Table 2. Possibly Mr. Younger, as a new addition on a lower rung of the academic ladder, may be subject to abnormal environmental conditions.

2/ These estimates are presumed to be the best data available. They may, however, contain large margins of error for several reasons. Nutritive values are not even approximately homogeneous in many foods. They are affected by method of preparation, maturity, temperature, length of storage, etc. Nutrients cannot be wholly extracted from some foods, and the amount of waste during preparation and at the dinner table is unknown.

3/ This study, reported almost 30 years ago, used an experimental procedure "because there does not appear to be any direct method of finding the minimum of a linear function subject to linear conditions" [2, p. 310]. Applying linear programming to Stigler's data gives essentially the same quantities (except for substitution of cornmeal for some wheat flour) at a cost about three percent lower.

4/ Incidentally, costs for the "moderate-cost plan" and the "liberal plan" are $102.10 and $111.20 for Mrs. Elder and $131.10 and $159.20 for Mrs. Younger.

References

[1] National Research Council, Food and Nutrition Board, "Recommended Daily Dietary Allowances," revision released October 1973.

[2] Stigler, George J., "The Cost of Subsistence," Journal of Farm Economics, May 1945, pp. 305-314.

[3] U.S. Bureau of Labor Statistics, "Estimated Retail Food Prices by Cities," 1972 annual averages, 9 pp.

[4] U.S. Department of Agriculture, ARS, Consumer and Food Economics Institute, Family Economics Review, Summer 1973 issue, 28 pp.

[5] _____, ARS, Consumer and Food Economics Research Division, Composition of Foods, Agricultural Handbook No. 8 (Bernice K. Watt and Annabel L. Merrill), revised December 1963, 190 pp.

[6] _____, ARS, Consumer and Food Economics Research Division, Nutritive Values of Foods, Home and Garden Bulletin No. 72, revised August 1970, 41 pp.