Anne M. Thomson*

A CROSS-COUNTRY ANALYSIS OF CHANGING NUTRITION PATTERNS

At the present moment, a great deal of time and energy is being put into studying ways of increasing food production, and there are increasing numbers of Cassandra-style articles about impending world food shortages. It is essential that we try to increase our knowledge about the determinants of demand for food at the global level. The most obvious of these is the size and growth of population, but the determinant economists have placed most emphasis on is income. A number of studies have estimated the relationship between the demand for food and the level of income, using cross-country data; most notable are H. S. Houthakker's estimations in the early 1960s (*6*). However, in almost all of the estimations, the food variate is measured in expenditure terms. In the late 1950s, L. M. Goreux made some income elasticity estimates for food, both on a time series and on a cross-country basis, in which the food variate was measured in expenditure, calorie, and weight units. The sample of countries was almost entirely composed of Western industrialized nations so that the results are not nearly so broadly applicable as those of Houthakker.

An expenditure elasticity includes the effects of increases in quality as well as simple quantity increases. In a discussion of the new kinds of research needed on the world food situation, W. O. Jones points out that "Of all the misinterpretations of our tentatively formulated 'laws' of consumption, perhaps the most common is the confusion between consumption in calories and consumption or demand measured in value" (*7*, p. 271). Although expenditure elasticities give us some idea of what happens to the demand for food as income rises, they also include increased services and processing bought with the food. If we are interested in looking at the demand for food in relation to the question of possible food shortage and resultant malnutrition, we should use a more purely quantitative measure.

This paper also brings evidence to bear on the controversy over how to go about solving the problem of malnutrition. A number of articles have been written about whether direct intervention programs are the best method, or whether emphasis should be put on increasing economic growth, thus increasing income and thereby nutritional level (*8*, pp. 70–73). Alan Berg argues that the latter argument is dependent on a number of questionable assumptions, two of which are that an increase in per capita income of the poor leads to an increase in the

* The author is a doctoral candidate in the Food Research Institute.

amount they spend on food, and that this in turn leads to an improvement in nutrition. Although this study does not deal with the poor specifically, it does throw some light on the validity of these assumptions (*2*, p. 10).

The relationships estimated here are on a very general level. The underlying hypothesis is that as income in a country changes there is an accompanying change in certain broad indicators of nutritional status. Thus the estimation is based on a variant of an Engel curve. The analysis is based on a combination of time series and cross-country data, and four indicators of nutritional level are used—number of calories consumed per capita per day, grams of protein consumed per capita per day, percentage of protein from animal sources, and the starchy-staple ratio. Two of the indicators are largely quantitative measures: calories, the lack of which, below a certain level, will induce hunger feelings; and protein, which is necessary for body-building, growth, and cell replacement. Percentage of protein from animal sources and the starchy-staple ratio are qualitative measures. Animal protein intake is not a physiological necessity—the necessary amino acids can be obtained from a proper mixture of vegetable proteins—but in many countries, especially in the developed countries, animal protein is preferred, partly for cultural reasons and also because it tends to be a more efficient source of protein in consumption, though not in production. The starchy-staple ratio measures the percentage of calories consumed that come from cereals, starchy roots, and starchy fruits. A diet with a high starchy-staple ratio may be nutritionally adequate, especially if augmented with pulses, but for reasons of taste it is generally reckoned to be inferior. Bennett's law states that the starchy-staple ratio is inversely correlated with income (*1*, pp. 216–22).

The latter two variables will also be related to the price structure. Animal protein, in most countries, is an expensive form of protein. It is also an inefficient way to feed a population. For every calorie ingested from beef, many times more have been ingested by livestock in the form of feedstuffs. Cereals and starchy roots, on the other hand, tend to be the cheapest form of calories in almost all countries. The main exceptions to this are in populations of hunters and gatherers, or primitive pastoralists, who now form a very small percentage of the world population. To bring in price explicitly would have seriously restricted the number of countries used in the estimation and also brought in a bias toward developed countries in the data. Thus, in the absence of using price as a separate variable, one would expect that price sensitivity in the income elasticities would be picked up by these variables.

A priori, we might expect certain relationships among the variables. Engel's law states that as income rises, the proportion of income spent on food decreases, i.e., the income elasticity for food is less than one. On the other hand, caloric consumption need not be related to income directly, once physiological requirements are met. It is likely, however, to be influenced by various noneconomic variables, such as education, which are themselves correlated with income. Except for caloric content, the nutrients in food seem not to inspire feelings of want or satiety in humans, though "meat hunger" is frequently reported and it may be a physiological need for protein, not commonly recognized. On the other hand, it may be no more than a craving for salt. One would expect a positive income elasticity for animal protein, if only because of quality factors.

METHODOLOGY

The methodology used in this paper is based on that used by Richard Weisskoff to measure price elasticities, combining time-series data for a number of countries, resulting in cross-country equations (*9*, pp. 325–26). It is also similar to the methodology used by Houthakker (*5*). The basic model is as follows:

$$C_{jt} = a_1 E_{jt}^{b_1} \tag{1A}$$

$$P_{jt} = a_2 E_{jt}^{b_2} \tag{2A}$$

$$A_{jt} = a_3 E_{jt}^{b_3} \tag{3A}$$

$$S_{jt} = a_4 E_{jt}^{b_4} \tag{4A}$$

where C = caloric intake,
P = protein intake,
A = animal protein intake,
S = starchy-staple intake,
E = total per capita consumption expenditure,

and j refers to country, t to time period, and all intakes and expenditures are expressed in per capita terms.

Taking the calorie equation, we then get

$$\log C_{jt} = a_1 + b_1 \log E_{jt}. \tag{1B}$$

First differences are then taken over time series for individual countries, giving

$$D\log C_{jt} = b_1\, D\log E_{jt}. \tag{1C}$$

Then the mean value over the total time period is formed.

$$\overline{D\log C_j} = b_1\, \overline{D\log E_j} \tag{1D}$$

Weisskoff then estimates two overall equations: what he calls the short-term, within-countries equation

$$D\log C_{jt} - \overline{D\log C_j} = b_1\, (D\log E_{jt} - \overline{D\log E_j}) \tag{1E}$$

and the long-term, between-countries equation

$$\overline{D\log C_j} = b_1\, \overline{D\log E_j}\text{, the same as } D_1. \tag{1F}$$

The first picks up the short-term effects of expenditure changes, whereas the second picks up the long-term effects. Because of problems with the reliability of the data, which will be discussed in greater detail below, and also on *a priori* grounds, only the long-term equation was estimated in this paper. An overall conservatism in food habits and the very generality and broadness of the concepts involved led to the belief that the relationships would not be sensitive to short-term effects, i.e., that it was basically a long-term relationship that was being examined.

One can go through a similar derivation for total protein, percentage of animal protein, and starchy-staple ratio, which lead to estimating equations as follows:

$$\overline{D\log P_j} = b_2\, \overline{D\log E_j}, \tag{2F}$$

$$\overline{D\log A_j/P_j} = (b_3 - b_2)\, \overline{D\log E_j}, \tag{3F}$$

$$\overline{D\log S_j/C_j} = (b_4 - b_1)\, \overline{D\log E_j}. \tag{4F}$$

Two adaptations of this model are also tested. Population growth (N) is brought in as an explicit variable, as a proxy for changes in the age distribution (a country with a high rate of population growth will tend to have a younger population). Also a dummy variable is used to test for differences in slope between developed and less developed countries.

Thus the equations tested here are of the form:

$$\overline{D\log C_j} = b_1 \overline{D\log E_j} + c_1 \overline{D\log N_j},$$

where N_{jt} is the population in country j over time period t, and

$$\overline{D\log C_j} = b_1 \overline{D\log E_j} + b_1{}' \overline{D\log E_j{}^1},$$

where $E_j{}^1$ is set equal to zero for developed countries and equal to E_j for underdeveloped countries.

There are both advantages and disadvantages to the use of this model. The most obvious disadvantage is that it constrains the expenditure elasticity to be constant, since the form used is the double-log functional form. In general, the semi-log functional form has been more popular in econometric studies of food, as this gives an income elasticity that declines as income rises. However, the double-log form is necessary if the variables are to be regressed in the form of rates of change, and this helps circumvent the problem of comparability of purchasing power of income between countries. A transformation of income to dollar terms fails to deal with the possibility, and probability, of different price levels, so if the regression were to be done using absolute levels as opposed to rates of change it would be necessary to include some kind of price index—a very difficult task, considering the paucity of statistics for some of the countries used in the study. The lack of data also prevented other relevant variables, such as education level and relative prices, being explicitly used in the analysis, so the implicit assumption is that their effect did not change over the time period considered. Data from 35 countries were used[1] and most areas of the world were represented, with the exception of Africa, where suitable data were not available.

The data were taken from three sources. For caloric intake, protein, animal protein, and the starchy-staple ratio, they came from a collection of food balance sheets published by the Food and Agriculture Organization (FAO) from 1956 to 1971. For population figures, the United Nations (UN) demographic yearbooks were used. Total private expenditure at constant prices was derived from the UN yearbooks of national accounts statistics. With respect to the latter figures, for some countries, e.g., India, where private consumption figures were not available, total national income figures were used, under the assumption that private consumption expenditure was a constant percentage of national income. This may lead to some error in estimation but is unlikely to introduce a consistent bias. However, to leave these countries out would have biased the sample toward developed countries.

The division of countries into the developed and less developed was fairly arbitrary. A group of countries seemed to be in the middle of the spectrum:

[1] Argentina, Australia, Austria, Belgium-Luxembourg, Brazil, Canada, Ceylon, Chile, China (Taiwan), Colombia, Denmark, Finland, France, Germany, Greece, Honduras, India, Ireland, Israel, Italy, Japan, Netherlands, Norway, Pakistan, Paraguay, Peru, Philippines, Portugal, Spain, Sweden, Syria, United Kingdom, United States, and Uruguay.

Ireland, Israel, Greece, Portugal, and Spain. From a nutritional viewpoint, the first two were put with the developed countries and the others with the less developed. The data were taken for the time period 1949–66. As food balance sheets for the latter half of this period were in the form of three-year averages, the data for the whole period were converted to this form. This gave a maximum of six observations for each country. No country was included for which there were not at least three observations. The aggregate observation from which the final equation was estimated was the mean of rates of change observations which varied in number from two to five.

Before presenting the results of these regressions, something should be said about the adequacy of the food balance sheet data used. Food balance sheets are divided into two sections: the supply side which has as its components production, gross imports and exports, and changes in stocks; and the utilization side, composed of feed and seed use, industrial use, and waste, thereby arriving at net food supply. As Helen Farnsworth points out, even for the dozen or so countries with highly developed statistical services, many of these figures are "guesstimates," especially for fruits and vegetables (*3*, pp. 183, 184). This is particularly true of the figures for feed and seed use, and waste. For the less developed countries, where non-marketed foods are much more important, these problems are much greater. Often, import and export figures are the only ones with any reliability, as agricultural production figures are frequently arrived at from estimates of crop areas, multiplied by estimates of crop yield, without any means of being cross-checked. The final stage of the calculation, turning physical quantities of foods available into nutrient levels, also contains a great deal of guesswork, as Farnsworth illustrates with the case of manioc and manioc flour in Nigeria (*3*, p. 190). In spite of these caveats, figures from food balance sheets were used on the assumption that, by using three-year averages and by looking, not at specific commodities, but at broad nutrient measures, the growth rates derived from these had some validity.

RESULTS

Although the model indicates that there should be no constant term, the computer package program used for estimation requires a constant term to give a meaningful coefficient of multiple determination. A constant term was therefore estimated, which provided some test of the validity of the model. As can be seen, a significant constant term only appeared in the equations with the starchy-staple ratio and total protein, and then was only −0.01, indicating that the form of equation specified was justified in this respect. The results, estimated by ordinary least-squares regression, are as in Table 1, where D indicates the dummy variable for differential slope.

If we look at equations (1) through (4) in Table 1, where the rate of change of caloric intake is the dependent variable, we see that personal consumption expenditure (E) has very little explanatory power. The expenditure elasticity from the first equation is 0.12—very low, as would be expected—and is significant at the 5 percent level. Population growth has some additional effect when added in the second equation, but when the dummy slope variable is added this dis-

TABLE 1.—ELASTICITY COEFFICIENTS: PROTEIN-CALORIE CONSUMPTION, TOTAL EXPENDITURES, DEGREE OF DEVELOPMENT, AND RATE OF POPULATION GROWTH*

Dependent variable	Expenditure	Development differential[a]	Population growth	Constant	R^2	Equation number
Calories	0.12			0.00	0.08	(1)
	(1.69)			(0.16)		
Calories	0.14		0.07	0.00	0.09	(2)
	(1.77)		(0.56)	(−0.34)		
Calories	0.05	0.15		0.00	0.17	(3)
	(0.60)	(1.84)		(0.34)		
Calories	0.05	0.14	0.01	0.00	0.17	(4)
	(0.58)	(1.72)	(0.11)	(0.11)		
Protein	0.22			0.00	0.13	(5)
	(2.36)			(−1.50)		
Protein	0.24		0.11	0.01	0.14	(6)
	(2.31)		(0.61)	(−1.41)		
Protein	0.08	0.26		0.00	0.28	(7)
	(0.85)	(2.55)		(−1.41)		
Protein	0.09	0.26	0.00	0.00	0.28	(8)
	(0.74)	(2.42)	(0.01)	(−0.83)		
Percent of animal protein	0.56			0.00	0.29	(9)
	(3.67)			(−0.06)		
Percent of animal protein	0.56		0.01	0.00	0.29	(10)
	(3.39)		(0.03)	(−0.06)		
Percent of animal protein	0.47	0.18		0.00	0.31	(11)
	(2.67)	(1.01)		(0.04)		
Percent of animal protein	0.45	0.19	−0.07	0.00	0.31	(12)
	(2.27)	(1.08)	(0.24)	(0.21)		
Starchy-staple ratio	−0.35			0.00	0.27	(13)
	(−3.48)			(−0.82)		
Starchy-staple ratio	−0.25		0.47	−0.01	0.46	(14)
	(−2.59)		(2.72)	(−2.70)		
Starchy-staple ratio	−0.52	0.34		0.00	0.46	(15)
	(−5.11)	(3.34)		(−0.61)		
Starchy-staple ratio	−0.42	0.28	0.35	−0.01	0.53	(16)
	(−4.00)	(2.85)	(2.17)	(−2.13)		

* See text for description of data. Figures in parentheses are t-values.

[a] To obtain the expenditure elasticity for the underdeveloped countries, the development differential has to be added to the elasticity shown under the expenditure column. The expenditure elasticity for developed countries is as shown.

appears, so this is probably what the population variable is picking up. The addition of the dummy variable brings out the fact that this elasticity is derived virtually totally from the underdeveloped countries included in the sample. This raises the elasticity to 0.20 for the less developed countries, i.e., $b_1 + b_1'$, whereas

b_1 is only 0.05 and is significant only at the 30 percent level. These results are not surprising. There is a physiological limit on the total intake of calories, and most of the countries in the sample—in particular the developed countries—have overall calorie intakes that are nutritionally adequate (at least 2,100 to 2,300 calories, in general). Only about six countries fall below this level and may be suffering from overall calorie deficiency. Of course, in many countries where total caloric supply is adequate, there will be areas and income levels where this is not so, and in these areas an increase in income may lead to a greater increase in caloric intake than the equations above suggest. The difference between the elasticities for developed and less developed countries is almost certainly related to the absolute level of income. A more appropriate specification might be with an elasticity which declines as income rises (though to do this one would have to overcome the purchasing power comparability problem). On the other hand, it could be argued that income is simply a conditioning and constraining factor, and that once a certain level of income has been reached, there is no clearly defined relationship between caloric intake and income. This is perhaps the more plausible explanation.

The total protein equations in Table 1 follow a similar pattern, with different coefficients (*5, 6, 7, 8*). The overall elasticity of 0.22 is shown to come from the less developed countries in the data set, which have a differential expenditure elasticity of 0.26. Again, population growth only made an impact before the differential slope was introduced. Because the number of grams of protein ingested is related to the amount of food consumed, though not as directly as with caloric intake, the same argument as above holds.

The animal protein equations follow a rather different pattern. As expected, there is a much higher income elasticity for animal protein than for protein or calories alone, because of the quality factors involved. Since the elasticity measured here is the elasticity of the ratio of animal protein to total protein, 0.56, the absolute value of the elasticity of animal protein is equal to this plus the elasticity of total protein, i.e., approximately 0.78. The population variable adds nothing to the explanatory power of the equation but does show some small signs of multicollinearity with the income variable. When, in equations (11) and (12), a differential elasticity format is used, we get a different pattern from the first two sets of equations, with the more significant figure being the overall elasticity, while the differential factor is significant only at the 20 percent level, with a value of 0.18. This implies a similar pattern of demand for animal protein, relative to total protein, in developed and underdeveloped countries. *A priori*, the elasticity for animal protein relative to total protein might be expected to vary with income. This may yet be the case. In this equation, we are dealing with a relative substitution of animal protein for vegetable protein, as opposed to the earlier equations, where there is little substitution effect. Thus, the omission of a relative price variable may distort the results. If the relative price of animal protein to vegetable were significantly lower in developed countries, the greater ease of substitution might mask an elasticity that declined with income. However, this could only be shown by further analysis which explicitly included price.

In equations (13) through (16) in Table 1, where the starchy-staple ratio is the dependent variable, we get the highest explanatory power and the most significant coefficients. Again the quality factor is probably the most important. In the first two equations we have a negative income elasticity. For the first time, the population variable has a highly significant coefficient, but it introduces some multicollinearity. When a differential elasticity factor is brought in, there is a very clear split between developed and less developed countries. In equation (15) the respective elasticities are −0.52 and −0.18. The introduction of the population variable changes these to −0.42 and −0.14. This is the kind of result which would be expected, given the importance of the starchy staples in the diet in most underdeveloped countries, and their general status as markedly inferior goods.

Some comment is necessary on the results with respect to the population variable. It was initially included as a proxy for changes in the age distribution of the population. However, further examination of the data shows that this may not be a very good proxy. In some countries, e.g., Australia, high population growth is a result of immigration, and the number of men of working age in the population is high. This has an opposite effect on nutritional requirements from that of a natural growth of population which would increase the number of children in the population. However, as equations (14) and (16) show, it does seem to be picking up some significant effects and the explanation of this may perhaps lie in changes in family size. If an increase in population growth means more families with a large number of children, this may mean that they spend more on necessities than would otherwise be the case, because of income constraints, thus giving rise to the positive coefficients seen in these equations. Also, in many societies, children are fed mainly on cereal products and starchy roots. The multicollinearity introduced may be due to the absence of any relative price variable. Three more equations were run, to try to elucidate further the findings above. The variables were all in terms of rates of growth (see Table 2).

Equation (17) in Table 2 was estimated to see if there was a separate income elasticity of demand for total protein, apart from the increase in protein that would go along, in general, with an increase in caloric intake. As would be expected, the rates of change of caloric intake and of protein intake were highly correlated (0.97). Only in underdeveloped countries did there appear to be any significant separate demand for protein, and this was expressed in an elasticity of 0.12. Equation (18) examined the relation between animal protein and total protein. The income elasticities were not dissimilar from those in equation (12), though the differential fell, indicating perhaps that there was a more significant relation between animal and total protein in underdeveloped countries than was shown in equation (18) as a whole, which indicated very little correspondence between the two rates of growth. Equation (19) was of a similar nature for starchy-staple ratio and total calories. This indicated that in the absence of any income effects, as total calories rise, the intake of starchy staples would fall. However, as intake of calories is connected with income also, this merely confirms the position of the starchy staple as an inferior form of food.

CONCLUSIONS

Much clearer results were obtained when measures including quality aspects were examined. This is due, to a large extent, to the sheer physiological constraints on the quantity of food ingested. It is possible that changes in family size had

TABLE 2.—ELASTICITY COEFFICIENTS: RELATIONSHIPS BETWEEN CONSUMPTION OF PROTEIN AND CALORIES*

	Protein	Percent of animal protein	Starchy-staple ratio
Expenditure (E)	0.04	0.44	−0.41
	(0.56)	(2.49)	(−3.84)
Development differential (D)[a]	0.12	0.10	0.33
	(1.65)	(0.52)	(3.26)
Calories	0.97		−0.34
	(6.30)		(−1.60)
Protein		0.30	
		(0.98)	
Constant	0.00	0.00	−0.01
	(−2.47)	(0.28)	(−2.15)
R^2	0.69	0.33	0.57
Equation number	(17)	(18)	(19)

* See text for description of data.
[a] See footnotes for Table 1.

some explanatory power with respect to nutrition pattern. The significant effect of grouping the data into underdeveloped and developed countries indicates that elasticities may vary with income, and therefore it might be interesting to introduce some measure of absolute income level into the analysis. It is unlikely, considering the wide variety of countries included, that the split is simply due to cultural factors. However, in addition to requiring a different specification of the relationship this would also require considerable thought on the problem of purchasing power comparability. Since quality relations with income are the most significant, a relative price indicator might also have considerable explanatory power. There could be difficulties in obtaining suitable data to form calorie and protein price indices for all the countries involved.

The elasticities estimated in this paper are much lower than the various elasticities estimated from food expenditure data. Houthakker (*6*) gives a figure of 0.35, M. Gilbert in a study of western Europe and the United States has a figure of 0.54 (*4*), and Goreux gives 0.68, compared with the calorie elasticity here of 0.12 and a protein elasticity of 0.22. When we include the much higher elasticities associated with animal protein and the starchy staples, the picture becomes clearer. Thus the evidence given in this paper for reasonably strong relationships between nutritional measures and income indicates that the use of elasticities in expenditure terms overestimates the rise in demand for total quantity of food as income rises. The more important effect is substitution between different groups of foods, an effect shown by elasticities, both in nutritional and expenditure terms.

However, this does indicate that there is some positive relationship between increases in income and nutritional intake at a national level. We cannot say definitely that this relationship will hold if we only consider the poorer strata of a society, and we certainly cannot conclude from this alone that an emphasis on general economic growth as opposed to direct nutrition intervention is justified, but it does uphold some of the assumptions necessary to make out an argument for the former.

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