FOOD PREFERENCES AND NUTRITION IN RURAL BANGLADESH

Mark M. Pitt*

I. Introduction

THE dietary choice of households near subsistence levels of nutrient intake is one of obvious policy importance. In many countries, such as Bangladesh, national goals are set in terms of nutritional intake and there is heavy intervention in the markets for foods. However, little is known about the manner in which food preferences vary with food expenditure and nutrient intake. The design of efficient programs to aid nutritionally deficient households in attaining minimal levels of nutrient intake requires information on all own- and cross-price elasticities for both target and non-target groups. The net effect of a food price subsidy on the consumption of food nutrients cannot be predicted without knowledge of the complete elasticity matrix. Results presented below demonstrate that substitution effects can be so strong that the subsidization of certain foods quite often reduces nutrient consumption.

In this study, demand equations for nine foods which allow for extremely flexible consumer price response are estimated from the individual budgets of 5,750 rural Bangladeshi households. Estimation at the household level is preferred because it more readily permits the incorporation of household composition variables into the demand analysis, such as household size, occupation and employment status, that are typically lost in aggregation. There is also a greater range and variation in expenditure levels than found in grouped data. This is of particular importance in the study of nutritional well-being as it is the poorest households which are of special interest. Moreover, the household sample provides sufficient degrees of freedom to estimate a simple varying parameter model which requires the estimation of 270 parameters.

Previous econometric analysis of income-class specific dietary choice has been limited and not altogether satisfactory. Pinstrup-Anderson, de Londono and Hoover (1976) estimated complete sets of price elasticities for different income strata using Frisch's scheme in order to study the impact of changes in relative prices on nutrient consumption. Their results are suspect because of the assumption of want independence necessary for this methodology to be valid. Alderman and Timmer (1980), who were also concerned with studying the relationship between food price policy and nutrient intake by income classes, econometrically estimated separate price coefficients for each income group by including slope dummy variables in their demand equations for rice and cassava in Indonesia. The inclusion of these dummy variables revealed surprisingly large differences in compensated price response across income groups. Although their results support the notion that poorer households respond differently to prices than the rich, the limitations of their data constrained them to consider only two foods and to specify changes in price response which are discontinuous with respect to income.[1]

The formulation and estimation of the food demand equations is discussed in section II below. Section III presents the results of the estimation and discusses the nutritional implications of movements in relative food prices and other exogenous variables. Section IV summarizes our findings.

II. Estimation Methods and the Selection of a Functional Form

Standard approaches of estimating demand systems are not appropriate when units of observation are individual households because of the

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* University of Minnesota.

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[1] Timmer (1981) elaborates on these results and the possibility of curvature in the Slutsky matrix.

problems that arise when the consumption of one or more goods is zero. As is well known, the application of the usual continuous variable estimation techniques would result in biased and inconsistent estimates because the random disturbances have nonzero means and are correlated with the exogenous variables. Moreover, dropping those households which do not consume at least one of the goods would severely reduce sample size and still result in inconsistent estimates. The limited dependent variable model of Tobin (1958) (tobit) provides a likely candidate for estimating demand equations in this case since it permits a positive probability of observing nonconsumption.

The stochastic model underlying tobit is given by the following relationship:

$$\begin{aligned} y_t &= X_t\beta + u_t \quad \text{if} \quad X_t\beta + u_t \geq 0 \\ &= 0 \quad \text{if} \quad X_t\beta + u_t < 0 \\ t &= 1, 2 \ldots N \end{aligned} \tag{1}$$

where N is the number of observations, y_t is the dependent variable, X_t is a vector of independent variables, β is a vector of unknown coefficients and u_t is an independently distributed error term assumed to be normally distributed with zero mean and variance σ^2. In order to not further complicate the maximization of the nonlinear tobit likelihood function it would be best to choose a functional form which is linear in the parameters. This immediately rules out a large number of demand systems, such as the quadratic and generalized translog, which are relatively flexible and have been estimated with household budget data (using cell means) by other investigators (Pollak and Wales, 1980). For demand systems which are linear in the parameters, the lack of a computationally tractable multivariate tobit estimator means that the adding-up and symmetry restrictions derived from demand theory cannot readily be imposed.[2]

In tobit demand analysis, certain functional forms are ruled out by theory. If expenditure or expenditure share is the dependent variable in a tobit demand model and if demand is inelastic, an increase in own-price necessarily implies an increase in the probability of consuming (positive) quantities of the commodity. Novshek and Sonnenschein (1979) have shown that such a response on the part of marginal consumers is inconsistent with neoclassical demand theory. The reason for this perverse response can be seen by noting that in the tobit model, the probability of consuming is given by the normal cumulative function evaluated at the expected value of the unobserved latent variable $y^*_t = X_t\beta + u_t$. As is well known, expenditure, and therefore $E(y^*_t)$, is an increasing function of own-price if demand is inelastic. In this case, the probability of consumption rises with own-price even though expected demand will normally fall.

A functional form which is linear, does not incorrectly model the response of marginal consumers, and allows for flexibility in response to prices and other exogenous variables across expenditure groups is

$$\begin{aligned} y_i = \alpha_i + \beta_i \ln m + \Sigma_j\gamma_{ij} \ln p_j \\ + \Sigma_k\theta_{ik}c_k + \Sigma_t\delta_t s_t \end{aligned} \tag{2}$$

where y_i is physical consumption of the i^{th} good, m is real expenditure, p_j is the price of the j^{th} good, c_k is the k^{th} household characteristic, s_t is the t^{th} time period, and the α_i, β_i, γ_{ij}, θ_{ik} and δ_t are parameters to be estimated. Furthermore, the parameters β_i, γ_{ij}, and θ_{ik} themselves vary as follows:

$$\begin{aligned} \beta_i &= \beta_i^0 + \beta_i^m \ln m, \\ \gamma_{ij} &= \gamma_{ij}^0 + \gamma_{ij}^m \ln m, \\ \theta_{ik} &= \theta_{ik}^0 + \theta_{ik}^m \ln m. \end{aligned} \tag{3}$$

The data used for the estimation are taken from the tapes of the Household Expenditure Survey of Bangladesh 1973/74, the results of which are summarized in Bangladesh Bureau of Statistics (1978) and Rabbani and Hossain (1978). Only data from rural areas were used in the estimation. The surveys were carried out in four successive quarters beginning in 1973 III. Nine commodities are distinguished for the purpose of this research: rice, wheat flour, mustard oil, fish, onions, spices, pulses, fresh milk and potatoes.[3] These items constitute nearly 90% of

[2] Wales and Woodland (1978, 1980) estimate limited dependent variable models for systems of share equations by maximizing the likelihood function directly. This entails the evaluation of multiple integrals under the multivariate normal density function, a procedure which is only feasible when the number of goods is small. They estimate this multivariate model for the case of three goods.

[3] We have excluded non-food commodities from our demand analysis. In doing so we are assuming that foods are separable from nonfoods in the households' preference ordering. In addition, a similar assumption is made with respect to

total food expenditure, 95% of calorie intake, 93% of protein intake and no less than 80% of the intake of iron, thiamine, riboflavin and niacin by rural households in Bangladesh.

Prices are those of the village in which the household resides and have large variances as a result of seasonal supply variation and the spatial variation resulting from Bangladesh's difficult topography and poor transportation infrastructure. Approximately 800 villages were surveyed and the sample size for the estimation is 5,750.

The consumption and expenditure data are scaled to per capita terms in the estimation. This does not mean that all household members are assumed equivalent. Average household consumption is explicitly made a function of the c_k household composition variables in (2). Introducing expenditure in real rather than nominal terms in (2) and (3) is done for two reasons. First, it would not be sensible for parameters to vary with nominal expenditure, as this would represent money illusion on the part of consumers. Second, the use of real expenditure and nominal prices allows us to interpret the estimated price coefficients in a compensated response sense. In investigating the effect of price policy on nutrition, it is important that pure substitution effects be isolated as the sign of their effect on nutrition is unknown. The price index used to deflate expenditure is that used by Stone (1953), $\tilde{P} = \Pi_i p_i^{w_i}$ where the w_i are expenditure shares, which can be thought of as a general index of prices (Deaton and Meullbauer, 1980). Homogeneity of degree zero in prices is readily tested in (2) and (3) by restricting $\Sigma_j \gamma_{ij} = 0$.

Information on three household characteristics, household size, cultivator status and number of earners, is available. The variable *CULTIVATOR* has the value zero if cultivation is a source of income and one otherwise. Households cultivating only kitchen gardens or only supplying agricultural labor are not considered cultivators. The variable *EARNER* is the number of persons who bring "material return in cash or in kind for services rendered and/or for the use of land, property and capital" (Bangladesh Bureau of Statistics, 1978, page 4). Unpaid family workers are explicitly defined as earners. In practice this seemingly broad definition applied mostly to adult males. Data on the age and sex composition of households are not available. However, the *SIZE*, *CULTIVATOR* and *EARNERS* variables incorporate some information on household composition. It is more likely that additions to households are children and that earners are adults and probably male. *CULTIVATOR* picks up two distinct effects. First, as a demographic variable, it picks up any difference in food preferences between cultivator and noncultivator households resulting from the exertive labor of cultivators and any special nutritional requirements. Second, the *CULTIVATOR* variable adjusts for differences between ex-farm prices and the retail food prices of the data set. Households will consume more of a food which they produce since the relevant price to them, the ex-farm price, is less than the retail price as a result of marketing costs.[4]

food commodities which are not included in our set of nine because of data unavailability. The major groups excluded include meats, fruits and green vegetables, all of which are relatively unimportant in terms of total food expenditure. However, fruits and vegetables are important sources of vitamins A and C, and thus these nutrients are not considered in the discussion of results that follow.

III. Results

The parameter estimates, which are not reported here for reasons of space, are hard to interpret because the underlying parameters vary with per capita expenditure. Instead, after first discussing hypothesis tests, we will closely examine elasticities.

A. *Hypothesis Tests*

Table 1 presents test statistics for the null hypothesis that each of the underlying varying parameters of the demand equations is zero. Wald test statistics, which require only estimation of the unrestricted model, are presented because of the high computational costs of the more commonly used likelihood ratio test, which requires reestimation for each restriction.[5]

[4] It would be better if we had information on household cultivation specific to each food. Unfortunately, these data were not available.

[5] The Wald test statistic, W, is calculated as

$$(\hat{\theta} - \bar{\theta})'V(\hat{\theta})(\hat{\theta} - \bar{\theta})$$

where $\hat{\theta}$ is the vector of maximum likelihood parameter estimates which we are interested in testing, $(\hat{\theta} - \bar{\theta})$ are the restrictions to be tested, and $V(\hat{\theta})^{-1}$ is the covariance matrix of $\hat{\theta}$. Asymptotically, W has a χ^2 distribution with degrees of freedom equal to the number of restrictions in $(\hat{\theta} - \bar{\theta})$.

TABLE 1.—TEST STATISTICS FOR THE DEMAND EQUATIONS

	Demand Equation								
	Rice	Wheat	Pulses	Fish	Mustard Oil	Onions	Spices	Milk	Potatoes
Coefficients:									
Rice[a]	126.45	49.66	42.88	8.92	12.57	9.59	62.38	3.40	15.73
Wheat[a]	131.01	73.60	2.24	0.92	7.52	6.54	6.45	12.31	14.04
Pulses[a]	60.45	13.38	77.40	66.93	0.43	19.97	4.22	15.50	1.83
Fish[a]	130.07	2.79	0.79	765.18	50.75	32.65	0.35	23.11	3.29
Mustard Oil[a]	123.02	47.45	17.70	29.27	174.82	1.79	29.68	0.62	0.12
Onions[a]	4.61	7.20	0.37	65.47	3.98	183.90	33.67	14.91	15.48
Spices[a]	24.83	13.65	57.98	11.92	36.46	13.42	928.71	5.29	20.68
Milk[a]	40.26	20.23	10.67	161.95	9.69	3.28	24.11	25.01	5.01
Potatoes[a]	25.39	9.56	14.59	25.42	1.42	0.59	17.29	0.21	78.11
Expend[a]	555.38	21.57	93.18	203.17	267.10	77.94	131.21	14.38	29.40
Size[a]	170.57	22.37	4.58	205.50	12.23	79.29	340.92	158.14	19.73
Earners[a]	13.53	26.16	16.14	9.19	7.96	1.78	0.27	21.52	13.55
Cultivator[a]	91.78	280.47	7.96	4.41	9.06	11.30	2.79	35.32	4.42
Seasons[b]	61.91	48.35	47.95	78.54	11.25	49.38	17.92	19.25	122.38
Other tests:									
Unvarying parameters[c]	724.42	96.73	125.66	440.79	369.97	135.64	201.22	57.88	41.77
Absence of price effects[d]	646.26	220.61	229.08	1183.76	309.36	270.09	1109.82	109.32	141.87
Unvarying price parameters[e]	111.49	79.16	17.41	119.75	126.67	46.71	56.83	26.35	8.44

[a] Wald test. Critical values with 2 degrees of freedom are $\chi^2(.05) = 5.99$ and $\chi^2(.01) = 9.21$.
[b] Wald test. Critical values with 3 degrees of freedom are $\chi^2(.05) = 7.81$ and $\chi^2(.01) = 11.34$.
[c] Likelihood ratio test. Critical values with 13 degrees of freedom are $\chi^2(.05) = 22.36$ and $\chi^2(.01) = 27.69$.
[d] Wald test. Critical values with 18 degrees of freedom are $\chi^2(.05) = 28.87$ and $\chi^2(.01) = 34.81$.
[e] Wald test. Critical values with 9 degrees of freedom are $\chi^2(.05) = 16.92$ and $\chi^2(.01) = 21.67$.

The test statistics of table 1 indicate a considerable degree of price response for all food commodities. Out of 81 estimated pairs of price coefficients, 60 are significantly different from zero at the 0.05 level and 55 are significant at the 0.01 level. Table 1 also provides test statistics for hypotheses incorporating larger numbers of parameters. The hypothesis that the parameters of the underlying model (2) do not vary with real expenditure is strongly rejected in every case. We test further whether all price coefficients are jointly zero and whether they do not vary with expenditure. The former hypothesis is rejected in every case and the latter in all cases except potatoes at the 0.05 level. In summary, the data strongly support the varying parameter specification of the model.

B. Demand Elasticities

In the tobit model (1), the expected value of the dependent variable y is given by

$$E(y) = \sigma z\, F(z) + \sigma f(z) \tag{4}$$

where $z = X\beta/\sigma$, $F(\ )$ is the normal cumulative distribution function and $f(\ )$ is the unit normal density (subscripts are omitted for simplicity). The elasticity of this expectation with respect to an argument x_i is

$$\epsilon_i = \frac{\partial E(y)}{\partial x_i}\,\frac{x_i}{E(y)} = \sigma(\partial z/\partial x_i)\, F(z) x_i/E(y). \tag{5}$$

This elasticity can be decomposed as

$$\epsilon_i = \frac{\partial F(z)}{\partial x_i}\,\frac{x_i}{F(z)} + \frac{\partial E(\tilde{y})}{\partial x_i}\,\frac{x_i}{E(\tilde{y})} \tag{6}$$

where $E(\tilde{y}) = E(y)/F(z)$ is the expectation of y for $y > 0$ (non-zero consumption), the first term on the right-hand side is the elasticity of the probability of consuming with respect to x_i, which will be referred to as the participation elasticity (ϵ_i^p), while the second term is the elasticity of the expected consumption of consuming households with respect to x_i, which will be referred to as the nonlimit consumption elasticity (ϵ_i^n).[6]

Results are presented below for two representative households. Both households have five members, one earner, and are cultivators. The high expenditure household, labeled "percentile 25," has a level of per capita food expenditure

[6] This elasticity decomposition is the same as that proposed by Thraen, Hammond and Buxton (1978). McDonald and Moffitt (1980) choose as an alternative decomposition the fraction of mean total response due to response above the limit.

greater than 75% of sample households, and the low expenditure household, labeled "percentile 90" has per capita food expenditure greater than 10% of sample households. The latter household represents the median level of food expenditure for the lowest 20% of households, a group with serious nutritional deficiencies, while the former household represents the median of the top 50% of food consumers, a group without serious nutritional deficiencies.

Table 2 presents estimates of own-price and expenditure elasticities for these two representative households. Differences in elasticities between the two representative households are quite striking. For example, the wheat and mustard oil uncompensated own-price elasticities are −0.72 and −0.09, respectively, for the poor household compared with −0.06 and −0.72 for the richer one. In six of nine cases, the poorer household is more sensitive to changes in own-prices. The only uncompensated own-price elasticities to rise in absolute value with total expenditures are those of mustard oil, fish and onions. These results are qualitatively the same for compensated own-price elasticities. Note that the compensated elasticity for rice is substantially smaller than the uncompensated elasticity, reflecting its large share in budgets.

The participation component of own-price elasticities ranges considerably across foods and representative households. For example, in the low expenditure household, participation response accounts for 82% of the total potato own-price elasticity and is greater than non-limit response in six of nine cases. In contrast, participation response for rice is effectively zero for the high expenditure household and is dominated by non-limit response in six of nine cases. These differences reflect the greater probability of consuming more diverse goods at higher levels of expenditure.

The expenditure elasticities found in table 2 vary significantly across foods and with total expenditure level. Wheat, only recently consumed in substantial quantities, is a very inferior foodgrain for both representative households. The highest expenditure elasticities are for milk, potatoes and mustard oil. The only expenditure elasticities which do not rise with total per capita expenditure are rice, wheat and milk. The fish, milk and onions expenditure elasticities differ the most between low and high expenditure households.

Table 3 presents the entire uncompensated cross-price elasticity matrices for our two representative households. The absolute values of 24 out of 72 cross-price elasticities of the percentile 90 household exceed 0.250, suggesting the

TABLE 2.—OWN-PRICE AND EXPENDITURE ELASTICITIES

	Uncompensated Own-Price Elasticities			Compensated Own-Price Elasticities			Expenditure Elasticities		
	ϵ_{ii}	ϵ_{ii}^{p}	ϵ_{ii}^{n}	ϵ_{ii}	ϵ_{ii}^{p}	ϵ_{ii}^{n}	ϵ_{im}	ϵ_{im}^{p}	ϵ_{im}^{n}
Percentile 25 Expenditure									
Rice	−0.83	−0.00	−0.83	−0.26	−0.00	−0.26	0.94	0.00	0.94
Wheat	−0.06	−0.03	−0.03	−0.09	−0.05	−0.04	−0.24	−0.13	−0.11
Pulses	−0.51	−0.11	−0.40	−0.47	−0.10	−0.36	1.04	0.22	0.82
Fish	−0.97	−0.33	−0.63	−0.89	−0.30	−0.58	1.02	0.35	0.67
Mustard Oil	−0.72	−0.15	−0.57	−0.66	−0.14	−0.52	1.31	0.27	1.04
Onions	−0.60	−0.23	−0.37	−0.59	−0.22	−0.37	0.69	0.26	0.43
Spices	−0.65	−0.09	−0.55	−0.62	−0.09	−0.53	0.74	0.11	0.63
Milk	−0.25	−0.13	−0.11	−0.20	−0.11	−0.09	1.91	1.04	0.87
Potatoes	−0.96	−0.66	−0.30	−0.94	−0.65	−0.29	1.88	1.29	0.58
Percentile 90 Expenditure									
Rice	−1.30	−0.09	−1.21	−0.57	−0.04	−0.53	1.19	0.08	1.11
Wheat	−0.72	−0.37	−0.35	−0.73	−0.38	−0.35	−0.10	−0.05	−0.05
Pulses	−0.68	−0.35	−0.33	−0.64	−0.33	−0.31	0.84	0.43	0.41
Fish	−0.66	−0.36	−0.30	−0.62	−0.34	−0.28	0.50	0.28	0.23
Mustard Oil	−0.09	−0.05	−0.04	−0.05	−0.03	−0.02	1.03	0.58	0.45
Onions	−0.49	−0.24	−0.25	−0.49	−0.24	−0.25	0.09	0.05	0.05
Spices	−0.76	−0.27	−0.49	−0.74	−0.27	−0.47	0.47	0.17	0.30
Milk	−1.08	−0.85	−0.23	−1.02	−0.80	−0.22	2.52	1.98	0.54
Potatoes	−1.68	−1.37	−0.32	−1.66	−1.35	−0.31	1.61	1.31	0.30

significance of substitution in response to price interventions. Many of the cross-price elasticities vary with expenditure to the point of changing signs. For example, an increase in the price of wheat will result in a large increase in milk consumption by poor households (ϵ milk, wheat = 0.495) but a fall in milk consumption by wealthier households (ϵ milk, wheat = −0.192). Of key importance to policy makers in Bangladesh are the larger than unity elasticities of demand for wheat with respect to the price of rice. The prices of rice and wheat, the primary food grains of Bangladesh, are heavily influenced by government intervention, and as the negative expenditure elasticities of wheat suggest, wheat is consumed in larger *absolute* quantities by lower expenditure households. This evidence suggests that wheat may have the characteristics desired for a cost-effective food subsidy program. This point will be further discussed below.

C. *Nutrient Price Elasticities*

The demand elasticities of table 3 provide information on the response of food intake to any change in food prices but do not directly provide information on the resulting intake of food nutrients. Although the subsidization of a food will increase its consumption, we cannot predict the sign of the change in nutrient intake. If substitution is strong, and we have shown that it is, and the foods being substituted for are important sources of nutrients, the net effect of a subsidy on nutrient intake may be negative. Information on the response of nutrient intake to any change in food price is contained within the matrix of *nutrient price elasticities*, whose elements ϕ_{nj} are calculated as

$$\phi_{nj} = \frac{\Sigma_i a_{ni} \epsilon_{ij} E(y_i)}{\Sigma_i a_{ni} E(y_i)} \qquad (7)$$

where a_{ni}[7] is the quantity of nutrient n per unit of food i, and ϕ_{nj} is the elasticity of nutrient n with respect to food price j. We will refer to (7) as the uncompensated nutrient price elasticity, and will define ϕ^*_{nj} as the compensated price elasticity calculated by replacing ϵ_{ij} with ϵ^*_{ij} in (7) above.[8]

Table 4 presents matrices of ϕ_{nj} for the two representative households. Since these are uncompensated elasticities, it is expected that most

[7] The a_{ni} were taken directly from Gopalan et al. (1974).

[8] Calculating nutrient elasticities in this manner seems clearly preferable to the procedure adopted by Alderman and Timmer (1980). They estimated a separate regression having calories as a dependent variable with prices, income and other exogenous variables as regressors. Such an approach is uncalled for since all the parameters of the true calorie–price relationship are completely identified from the individual demand equations.

TABLE 3.—UNCOMPENSATED PRICE ELASTICITIES

	Quantity of								
Percentile 25 Expenditure	Rice	Wheat	Pulses	Fish	Mustard Oil	Onions	Spices	Milk	Potatoes
Price of:									
Rice	−0.832	1.079	−0.157	−0.914	−0.586	−0.088	0.107	−0.868	−0.295
Wheat	0.003	−0.063	−0.084	−0.083	−0.218	−0.181	−0.155	−0.192	−0.516
Pulses	−0.175	0.348	−0.512	0.511	−0.094	0.297	0.065	0.344	0.093
Fish	0.002	0.044	−0.114	−0.967	0.072	−0.261	−0.068	0.057	−0.150
Mustard Oil	0.131	−0.624	−0.183	−0.381	−0.716	0.009	−0.264	−0.045	−0.095
Onions	−0.032	0.099	0.005	0.310	−0.082	−0.599	0.144	−0.280	−0.336
Spices	−0.003	−0.133	0.116	0.047	0.091	0.088	−0.648	0.019	0.144
Milk	−0.088	−0.151	−0.030	0.507	0.069	−0.070	0.131	−0.246	−0.028
Potatoes	0.046	−0.061	−0.174	−0.265	−0.016	0.002	0.146	−0.020	−0.963
Percentile 90 Expenditure									
Price of:									
Rice	−1.301	1.061	0.364	−0.351	−0.894	0.117	0.076	−1.326	−0.266
Wheat	0.011	−0.719	−0.169	−0.016	0.021	−0.117	−0.024	0.495	−0.552
Pulses	−0.121	0.330	−0.679	0.310	−0.078	0.104	0.024	0.118	0.172
Fish	0.019	0.095	−0.071	−0.660	−0.060	−0.026	−0.019	0.058	−0.390
Mustard Oil	0.026	0.064	−0.493	−0.220	−0.094	0.148	0.018	−0.299	0.027
Onions	−0.067	0.189	0.002	0.348	−0.104	−0.489	0.022	−0.440	−0.543
Spices	−0.005	−0.134	0.248	0.109	−0.080	−0.040	−0.759	0.080	0.388
Milk	0.050	−0.332	0.256	0.478	−0.106	0.105	0.065	−1.084	0.439
Potatoes	0.162	−0.334	−0.283	−0.410	0.122	0.078	0.195	−0.154	−1.684

will have negative signs. The greatest (in absolute value) uncompensated calorie price elasticity for the calorie-deficient percentile 90 household is for rice. This is not surprising since rice is the leading source of this nutrient. Wheat, a much less important food than rice in terms of expenditure share, nevertheless has the largest absolute nutrient price elasticity for protein, both minerals and two of the three vitamins. Moreover, only it and potatoes have uniformly negative rows of nutrient elasticities for the low expenditure household. That is, the uncompensated subsidization of wheat or potatoes will increase the net intake of all of the nutrients of table 4. The wheat price row is also negative for the high expenditure household.

Positive elasticities have the interesting implication that an uncompensated increase in the price of that food will *increase* consumption of a particular nutrient. A row of positive elasticities implies that an increase of that food price will increase the consumption of *all* nutrients. The onion price row has this property for the 90th percentile household. Onions would seem a likely candidate for this attribute because they are a high-cost source of nutrients. However, spices are an even higher cost source of nutrients (in most cases) and yet the spice row is negative for all nutrients except calcium. Although substituting equivalent values of spices with other foods almost always leads to an increase in total nutrient intake, spice cross-price effects are such that an increase in its price still results in a net fall in nutrient intake.

There are important differences in nutrient price elasticities between the two expenditure groups. Note the substantial difference in the magnitude of the elements of the rice price row relative to the elements of the wheat price row between the two representative households. Uncompensated changes in wheat prices have much larger effects on the nutrient intake of the 90th percentile household than on the 25th percentile household, while the opposite is true for rice prices. This reflects both the much larger share of wheat and smaller share of rice in the nutrient intake of the poorer households, and differences in the relative sizes of demand elasticities. The cases of calcium, thiamine and riboflavin illustrate these inter-household differences well.

Information on pure substitution effects are required for designing cost effective target group-oriented food programs (Selowsky, 1979), yet little is known about them at the household level. The compensated nutrient price elasticities tell us the net effect of pure substitution on the intake of the various food nutrients, perhaps induced by a price subsidy program. While the sign of income effects on nutrient intake is most likely positive for nutritionally deficient households, the sign of pure substitution is not easily predicted.

TABLE 4.—UNCOMPENSATED NUTRIENT PRICE ELASTICITIES

Percentile 25 Expenditure	Protein	Fat	Carbohydrate	Calories	Calcium	Iron	Thiamine	Riboflavin	Niacin
Rice	−.418	−.588	−.549	−.529	−.536	−.165	−.214	−.281	−.474
Wheat	−.037	−.129	−.014	−.026	−.099	−.034	−.036	−.050	−.020
Pulses	−.048	.071	−.115	−.091	.196	−.027	−.049	−.047	−.089
Fish	−.102	−.153	−.002	−.024	−.301	−.028	−.003	−.003	−.007
Mustard Oil	−.097	−.372	.016	−.029	−.206	−.153	−.121	−.114	−.018
Onions	.019	−.005	−.018	−.012	.021	.017	−.005	−.023	−.010
Spices	−.006	.037	−.015	−.011	.012	−.035	−.027	−.023	−.020
Milk	−.035	.064	−.092	−.074	.060	−.081	−.100	−.106	−.090
Potatoes	−.037	−.062	.017	.004	−.110	−.022	−.018	−.019	.004
Percentile 90 Expenditure									
Rice	−.191	−.441	−.553	−.484	−.087	.129	.055	.009	−.394
Wheat	−.261	−.112	−.203	−.210	−.177	−.391	−.373	−.329	−.254
Pulses	.016	.056	−.011	−.000	.105	.088	.067	.028	.025
Fish	−.028	−.147	.034	.016	−.198	.036	.048	.043	.035
Mustard Oil	−.044	−.099	.017	.002	−.135	.001	.002	−.030	.019
Onions	.062	.048	.005	.016	.105	.080	.060	.046	.026
Spices	−.015	−.015	−.034	−.032	.024	−.060	−.053	−.045	−.042
Milk	−.028	−.012	−.050	−.048	.021	−.127	−.131	−.134	−.072
Potatoes	−.118	−.106	−.001	−.026	−.249	−.151	−.134	−.129	−.043

If income effects are positive, compensated nutrient price elasticities will be larger than their uncompensated counterparts. This is true in every case in tables 4 and 5. As should be expected, the compensated nutrient price elasticities for rice, the most important food expenditure item of both representative households, differs the most from the uncompensated elasticities.

The elasticities associated with onions are, of course, all positive in the compensated matrix as they were in the uncompensated matrix. The row of ϕ^*_{nj} associated with pulses is also positive. This is somewhat surprising since pulses are an important and inexpensive source of protein in the Bangladeshi diet and have been considered favorably on nutritional grounds by the government in its deliberations on price policy. These results argue that compensated decreases in the price of pulses will in fact reduce the nutrient intake of the nutritionally deficient population.

For policy makers intent on using selective food price subsidies as a means of attacking malnutrition, it is the negative elasticities of table 5 that are of key importance. Subsidization will augment calorie consumption in the cases of only four of the nine foods—rice, wheat, milk and potatoes. In the case of protein, only for wheat, mustard oil, milk and potatoes will this be true. The compensated subsidization of wheat has a greater positive effect on both calorie and protein intake than proportionately equivalent subsidies on any of the other foods. It is interesting to note that potatoes are second only to wheat in its subsidy induced effects on protein consumption. This is surprising since potatoes are a more expensive source of protein per unit of expenditure than all other foods except spices in our sample. Indeed, the cost of protein derived from potatoes is over eleven times greater than protein derived from wheat or pulses. Its large and negative protein price elasticity compared with the positive protein elasticity of pulses indicates the importance of studying substitution and the errors that can arise by using cost per unit of nutrient provided as the criterion by which nutrition oriented price policy is formulated.

The results of table 5 make it clear that pure substitution effects make rice, the preferred food grain, a foodstuff whose compensated subsidization would reduce the consumption of most food nutrients. Treating fat and carbohydrate as components of calories, note that lower rice prices will reduce the intake of all food nutrients by the low expenditure household except for a very small gain in calories. The magnitude of the reductions in protein, calcium, iron, thiamine and riboflavin intake are quite large—all of these elasticities are above 0.3. In contrast, wheat would seem an ideal candidate if subsidization is de-

TABLE 5.—COMPENSATED NUTRIENT PRICE ELASTICITIES

Percentile 25 Expenditure	Protein	Fat	Carbohydrate	Calories	Calcium	Iron	Thiamine	Riboflavin	Niacin
Rice	.065	.102	−.061	−.029	.126	.201	.184	.201	−.011
Wheat	.056	.003	.080	.070	.028	.036	.040	.042	.069
Pulses	−.013	.122	−.079	−.055	.244	−.000	−.020	−.011	−.055
Fish	−.033	−.054	.068	.047	−.206	.024	.054	.066	.060
Mustard Oil	−.061	−.322	.052	.008	−.157	−.126	−.092	−.079	.016
Onions	.030	.011	−.007	−.001	.036	.026	.004	−.012	.001
Spices	.028	.086	.019	.024	.059	−.009	.001	.011	.013
Milk	−.015	.093	−.071	−.053	.088	−.066	−.083	−.086	−.070
Potatoes	−.027	−.047	.027	.015	−.096	−.014	−.010	−.008	.014
Percentile 90 Expenditure									
Rice	.201	.041	−.061	−.011	.308	.403	.362	.365	.045
Wheat	−.186	−.020	−.109	−.119	−.102	−.339	−.314	−.261	−.170
Pulses	.045	.092	.025	.035	.135	.108	.090	.054	.057
Fish	.028	−.078	.105	.084	−.142	.075	.092	.094	.097
Mustard Oil	−.015	−.063	.053	.037	−.106	.021	.025	−.004	.052
Onions	.071	.059	.016	.027	.114	.086	.067	.054	.036
Spices	.013	.019	.000	.001	.052	−.041	−.032	−.020	−.011
Milk	−.011	.008	−.029	−.027	.038	−.115	−.118	−.118	−.054
Potatoes	−.109	−.096	.009	−.016	−.240	−.145	−.127	−.121	−.033

sired because all of its compensated nutrient price elasticities are of the correct sign and have the largest magnitudes for every nutrient except calcium. Treating carbohydrates as a component of calories, potatoes also have a row of negative nutrient elasticities.

Pure substitution effects on nutritionally better off households are quite different. The wheat price row of ϕ^*_{nj} for the percentile 25 household is now uniformly positive. That is, a compensated wheat subsidy will reduce the intake of all nutrients for this household. This complete change in signs reflects both the smaller share of nutrients derived from wheat by this household and the large differences in own- and cross-price compensated elasticities between high expenditure and low expenditure households.

D. Nutrient Expenditure Elasticities

The nutritional effect of incremental food expenditure can be summarized by the nutrient expenditure elasticity ϕ_{nm}, defined as

$$\phi_{nm} = \Sigma_i a_{ni} \epsilon_{im} E(y_i) / \Sigma_i a_{ni} E(y_i). \quad (8)$$

Table 6 provides estimates of ϕ_{nm} for both representative households. The vector of ϕ_{nm} for the percentile 90 household consists of elements which are all less than unity. That is, increments in food expenditure result in less than proportionate increments in the consumption of all nutrients. In choosing foods, poorer households put more emphasis on meeting perceived nutritional needs than on taste. These households choose foods which are inexpensive sources of nutrients, for example, obtaining the bulk of their protein from vegetable sources. At higher levels of expenditure, households substitute for foods desired on "taste" grounds even though this may mean obtaining nutrients at higher average cost. This is seen clearly in the data on cost of nutrients consumed found in table 6. The percentile 25 household spent 22% more per gram of protein, 15% more per calorie and as much as 44% more per milligram of iron than did the percentile 90 household. Of course, if this household had consumed foods in the same proportions as the 90th percentile household, its consumption of these nutrients would be higher by these same percentages. Recall that both households face the same set of prices so that these cost of nutrient differences represent only differences in diet.

TABLE 6.—NUTRIENT EXPENDITURE ELASTICITIES AND THE COST OF NUTRIENTS CONSUMED

	Nutrient Expenditure Elasticity		Cost of Nutrients Consumed by Percentile 25 Household ÷ Cost of Nutrients Consumed by Percentile 90 Household
	Percentile 25	Percentile 90	
Protein	0.79	.64	1.22
Fat	1.13	.79	0.97
Carbohydrate	0.80	.81	1.15
Calorie	0.82	.78	1.15
Calcium	1.08	.65	1.06
Iron	0.60	.45	1.44
Thiamine	0.65	.50	1.38
Riboflavin	0.79	.58	1.25
Niacin	0.76	.71	1.21

The small size of the nutrient expenditure elasticities of the percentile 90 household may be rather surprising. The nutrient intake of this household is significantly below requirements and yet nutrient elasticities are as low as 0.45 and none is higher than 0.78. The implication is that even very poorly nourished households can improve nutrition by altering their diet. For example, highly subsidized wheat flour is a much cheaper source of protein, calories, calcium and iron, and of all other nutrients identified in this study. Substitution of wheat flour for rice will have a dramatic impact on nutritional status. At the extreme, if the 90th percentile household consumed nothing but wheat flour their consumption of protein and calories would rise by 110% and 77%, respectively, and they would exceed the minimum nutritional requirements for protein, iron, thiamine, riboflavin and niacin. To achieve an equivalent rise in calories by augmenting total food expenditure given the existing pattern of food preferences would require it to more than double. A tripling of expenditure would be necessary to get the same increase in protein intake. Thus, even for the very malnourished, substitution among foods can improve nutritional status more dramatically than the largest imaginable income transfer program.

IV. Summary

A number of lessons emerge for policy makers concerned with designing target group oriented food programs. First, disaggregation by income class is essential because the poor respond very differently to changes in prices and total expenditure. It is these differences in response which suggest that it may be possible to target interventions toward poor households. Second, substitution effects are strong and cannot be ignored in formulating policy. In Bangladesh, there are many instances where subsidization of foods would result in absolute declines in nutrient intake because of cross-price effects. A related point is that although households obviously benefit nutritionally from substituting low cost sources of nutrients for high cost sources, cost per unit of nutrient is a poor and often misleading guide in identifying candidates for subsidization. For example, subsidization of pulses, the lowest cost source of protein in Bangladesh (along with wheat), would result in a net decline in protein consumption by poor households. Third, supplemental income may not be as effective at augmenting nutrient intake as programs which induce substitution for foods which are low cost sources of nutrients. Nutrient elasticities with respect to total food expenditure were found to be surprisingly small for low income households.

Knowledge of the complete matrix of nutrient price elasticities would be extremely useful in designing nutrition-oriented food policy. Nutrient price elasticities summarize the net effect of food price changes on net nutrient intake. Examination of the matrix of nutrient price elasticities estimated for rural Bangladesh reveals wheat flour as an ideal candidate if it were decided to use subsidies to achieve nutritional objectives. The uncompensated and compensated elasticities of nutrients with respect to the price of wheat flour are uniformly negative and of large magnitude for a representative poor household. In addition, wheat flour possesses other attributes which, as noted by McCarthy (1975), tend to target subsidies towards the poor and thus increase cost-effectiveness. It constitutes a significant fraction of the consumption of the poor but little of the rich. Indeed, its demand elasticity with respect to total food expenditure is negative over the entire range of expenditure studied. Furthermore, poor consumers are much more responsive to its own-price than are wealthier consumers. Rogers and Levinson (1976) document that wheat flour, in particular pre-ground wheat flour, has these same attributes in Pakistan and that its subsidization is effectively being targeted towards nutritionally deficient households.

REFERENCES

Alderman, Harold, and C. Peter Timmer, "Food Policy and Food Demand in Indonesia," *Bulletin of Indonesian Economic Studies* 16 (Nov. 1980), 83–93.

Bangladesh Bureau of Statistics, *A Report on the Household Expenditure Survey of Bangladesh, 1973–74*, Dacca, 1978.

Deaton, Angus, and John Muellbauer, *Economics and Consumer Behavior* (Cambridge: Cambridge University Press, 1980).

Gopalan, C., B. E. Sasthri, and S. Balasubraminiam, *The Nutritive Value of Indian Foods* (Hyderabad: Indian National Institute of Nutrition, 1974).

McCarthy, Desmond, "Consumption Planning in Pakistan: Preliminary Analysis of Some Options," International Nutrition Program, MIT, 1975.

McDonald, John F., and Robert A. Moffitt, "The Uses of Tobit Analysis," this REVIEW 62 (May 1980), 318–321.

Novshek, William, and Hugo Sonnenschein, "Marginal Consumers and Neoclassical Demand Theory," *Journal of Political Economy* 87 (6) (1979), 1368–1376.

Pinstrup-Anderson, Per, Norha Ruiz de Londono, and Edward Hoover, "The Impact of Increasing Food Supply on Human Nutrition: Implications for Commodity Priorities in Agricultural Policy Research," *American Journal of Agricultural Economics* 58 (May 1976), 131–142.

Pollak, Robert A., and Terrence J. Wales, "Comparison of the Quadratic and Translog Demand Systems with Alternative Specifications of Demographic Effects," *Econometrica* (Apr. 1980), 595–612.

Rabbani, A. K. M. Ghulam, and Shadat Hossain, *Rural and Urban Consumption Patterns in Contemporary Bangladesh* (Dacca: Bangladesh Bureau of Statistics, 1978).

Rogers, Beatrice Lorge, and F. James Levinson, "Subsidized Food Consumption Systems in Low Income Countries: The Pakistan Experience," International Nutrition Program Discussion Paper 76-1, MIT, 1976.

Selowsky, Marcelo, "Target Group Oriented Food Programs: Cost Effectiveness Comparisons," *American Journal of Agricultural Economics* 61 (1979), 988–994.

Stone, J. N. R., *The Measurement of Consumers' Expenditure and Behavior in the United Kingdom* (Cambridge: Cambridge University Press, 1953).

Thraen, C. S., J. W. Hammond and B. M. Buxton, "Estimating Components of Demand Elasticities from Cross-sectional Data," *American Journal of Agricultural Economics* 60 (Nov. 1978), 674–677.

Timmer, C. Peter, "Is There 'Curvature' in the Slutsky Matrix?," this REVIEW 63 (Aug. 1981), 395–402.

Tobin, James, "Estimation of Relationships for Limited Dependent Variables," *Econometrica* 26 (Jan. 1958), 24–36.

Wales, T. J., and A. D. Woodland, "A Limited Dependent Variables Model for a System of Share Equations, with an Application to Meat Consumption," Discussion Paper No. 78-32, Department of Economics, University of British Columbia, 1978.

———, "A Random Preferences Model for the Estimation of Consumer Demand Systems with Binding Nonnegativity Constraints," manuscript, University of British Columbia, 1980.

LINKED CITATIONS

Food Preferences and Nutrition in Rural Bangladesh
Mark M. Pitt
The Review of Economics and Statistics, Vol. 65, No. 1. (Feb., 1983), pp. 105-114.
Stable URL:
http://links.jstor.org/sici?sici=0034-6535%28198302%2965%3A1%3C105%3AFPANIR%3E2.0.CO%3B2-Z

[Footnotes]

[6] **Estimating Components of Demand Elasticities from Cross-Sectional Data**
C. S. Thraen; J. W. Hammond; B. M. Buxton
American Journal of Agricultural Economics, Vol. 60, No. 4. (Nov., 1978), pp. 674-677.
Stable URL:
http://links.jstor.org/sici?sici=0002-9092%28197811%2960%3A4%3C674%3AECODEF%3E2.0.CO%3B2-C

References

Marginal Consumers and Neoclassical Demand Theory
William Novshek; Hugo Sonnenschein
The Journal of Political Economy, Vol. 87, No. 6. (Dec., 1979), pp. 1368-1376.
Stable URL:
http://links.jstor.org/sici?sici=0022-3808%28197912%2987%3A6%3C1368%3AMCANDT%3E2.0.CO%3B2-C

Comparison of the Quadratic Expenditure System and Translog Demand Systems with Alternative Specifications of Demographic Effects
Robert A. Pollak; Terence J. Wales
Econometrica, Vol. 48, No. 3. (Apr., 1980), pp. 595-612.
Stable URL:
http://links.jstor.org/sici?sici=0012-9682%28198004%2948%3A3%3C595%3ACOTQES%3E2.0.CO%3B2-A

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http://links.jstor.org/sici?sici=0002-9092%28197912%2961%3A5%3C988%3ATGFPCE%3E2.0.CO%3B2-J

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Stable URL:
http://links.jstor.org/sici?sici=0002-9092%28197811%2960%3A4%3C674%3AECODEF%3E2.0.CO%3B2-C

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James Tobin
Econometrica, Vol. 26, No. 1. (Jan., 1958), pp. 24-36.
Stable URL:
http://links.jstor.org/sici?sici=0012-9682%28195801%2926%3A1%3C24%3AEORFLD%3E2.0.CO%3B2-R

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