INCOME AND PRICE ELASTICITIES OF FOOD DEMAND AND NUTRIENT CONSUMPTION IN MALAWI

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Widespread malnutrition in developing countries calls for appropriate interventions, presupposing good knowledge about the nutritional impacts of policies. Little previous work has been carried out in this direction. We present a comprehensive analytical framework, which we apply for Malawi. Using household data and a demand systems approach, we estimate income and price elasticities of food, calorie, and micronutrient consumption. These estimates are used for policy simulations. Given multiple nutrient deficiencies, income-related policies are better suited than price policies to improve nutrition. While consumer subsidies for maize increase calorie and mineral consumption, they contribute to a higher prevalence of vitamin deficiencies.

Key words: quadratic almost ideal demand system, food security, micronutrient malnutrition, calorie elasticities, nutrient elasticities, Malawi

Introduction

Malnutrition has been identified as the largest risk factor for the global burden of disease (Murray and Lopez 1997). In developing countries, undernutrition in terms of insufficient calorie intakes is still prevalent. However, though less obvious, micronutrient deficiencies – mostly associated with insufficient mineral and vitamin intakes – are even more widespread, especially in Asia and sub-Saharan Africa (Mason, Rivers, and Helwig 2005). The resulting health problems call for appropriate public interventions, presupposing good knowledge about the economic determinants of malnutrition and the nutritional impacts of policies and other exogenous shocks on at-risk populations. Food demand analysis is an essential tool in this regard. Demand elasticities provide important information on people's consumption responses to income and price changes. And, traditional demand analysis, which primarily looks at food quantities consumed, can be extended to also yield calorie and nutrient elasticities, when reliable food composition tables are available. Understanding the patterns of nutrient consumption is a big advantage in designing effective food and nutrition policies, especially when people suffer from multiple nutritional deficiencies, as it is often the case in developing countries (Ramakrishnan 2002). Yet, relatively little research effort has been made by economists in this direction, especially with respect to micronutrients.

Several authors have estimated calorie elasticities. In general, two approaches can be distinguished. The first directly derives elasticities from reduced-form demand functions, with calorie consumption as dependent, and income, prices, and socio-demographic factors as independent variables (e.g., Bouis, Haddad, and Kennedy 1992; Sahn 1988; Subramanian and Deaton 1996). The second approach first estimates classical demand elasticities for several food groups, which are then used to calculate calorie elasticities based on technical coefficients for the calorie content of each food group (e.g., Pitt 1983; Strauss 1984). The advantage of this second approach is that demand elasticities can be derived from a complete demand system, thus better capturing cross-price effects and household income constraints. The disadvantage is that there might be inaccuracies due to food group aggregation. Apart from the fact that data on calorie contents are less precise for food groups than for individual items, use of broad food aggregates can also lead to overstated calorie elasticities (Behrman and Deolalikar 1987). The reason is that increases in the price per calorie as income rises are ignored. Such systematic changes in the unit costs of calories are consistent with consumers considering non-nutritive quality attributes such as taste and processing in their marginal food choices within food groups.

While the first approach of using reduced-form demand functions has also been employed in a micronutrient context (e.g., Abdulai and Aubert 2004; Bouis and Novernario-Reese 1997), hardly any previous work has used a theory-consistent demand systems approach to estimate micronutrient elasticities. One exception is Huang (1996), who provides expenditure and price elasticities for different nutrients in the US. These are based on food demand elasticities obtained from a differential-form demand system. We extend this line of research by estimating a more complex demand system in a developing country context and by embedding the analysis into the international food policy debate through a careful nutritional assessment at the household level.

In particular, we use representative household survey data from Malawi to analyze the prevalence of nutritional deficiencies and estimate expenditure (income) and price elasticities for calories and twelve essential macro- and micronutrients. A multistage budgeting framework is chosen, which allows for a high level of disaggregation in food groups at the lowest stage, but requires an appropriate technique to account for censored observations. To specify total food and food group demand, we apply the quadratic almost ideal demand system (QUAIDS). In order to address the problem of upwardly biased nutrient elasticity estimates, we use food prices adjusted for non-nutritive quality attributes and take the composition of the disaggregated food groups explicitly into account. The estimated elasticities are used for specific policy simulations concerning the nutritional outcomes of income and food price changes.

The rest of this article is structured as follows. The next section presents the methodology employed to specify the food demand system and to derive nutrient elasticities. Then, the data base and the nutritional assessment approach are discussed, before actual food and nutrient consumption patterns and adequacy levels are analyzed for households in Malawi. The subsequent sections present the estimation results, explain the policy simulations, and discuss conclusions.

Methodology

While poor consumers in developing countries may intentionally choose foods based on calorie contents, their awareness of specific nutrients – especially micronutrients – is generally low. Therefore, we consider the demand for food items as the actual reflection of consumer preferences, whereas the ‘demand’ for nutrients is latent. This assumption allows nutrient elasticities to be derived directly from food demand elasticities.

Budgeting

For the allocation of the household budget in our demand system, we adopt a three-stage decision process and assume weak separability of household preferences in the decision for food aggregates at each decision stage. We further assume that price changes between food groups are only channeled through the allocation of group expenditures. Thus, cross-price elasticities between aggregates of the same category can be positive or negative, whereas they can only be positive between aggregates of different categories.

Within the three-stage budgeting process, households first decide on the allocation of the total budget to food and non-food commodities. Since price information is not available for most non-food items, an extended Working-Leser model is applied at the first stage. At the second stage, the food budget is allocated to five basic food groups, namely starchy foods, pulses, vegetables and fruits, animal-source foods, and meal complements. Each group is further disaggregated into three to six subgroups. Eventually, based on the third stage parameter estimates, expenditure and price elasticities are calculated for 23 food aggregates. For the definition of food groups, we took typical Malawian food habits as well as nutritional aspects into account.[1] The QUAIDS is employed at the second and third budgeting stage. Six QUAIDS are estimated: one for the basic food groups applying the whole sample and one for each of the five basic food groups applying the respective subsamples.

Working-Leser Model

For modeling households' decision on allocating total expenditure, we follow Working's (1943) specification and extend the model by allowing for quadratic Engel curves in the logarithm. In addition, we control for price changes between food and non-food commodities by including food prices as aggregates. The expenditure share for food (w_F) is thus given by

(1) $$w_F = \alpha_F + \gamma_F \ln p_F + \beta_F \ln M + \lambda_F (\ln M)^2,$$

where p_F denotes the average food price and M the total per capita household expenditure. To control for effects of socio-demographic factors in budget allocation, we utilize a linear demographic translation through the intercept (cf. Pollak and Wales 1981). We account for household size, sex and age composition, education, and religious affiliation if practiced. Furthermore, we consider households' access to food by including the distance to the nearest market and by identifying whether the household is engaged in any agricultural activity, additionally controlling for marginal areas. Spatial differences are factored in by including a set of location variables. The computation of conditional expenditure and Marshallian price elasticities from equation (1) follows Leser's (1963) formulation.

QUAIDS

The linear approximate form of the almost ideal demand system (LA/AIDS), which was popular for empirical studies in the 1980s and 90s, has been criticized more recently for yielding biased and inconsistent estimates in many cases (e.g., Asche and Wessels 1997). Banks, Blundell, and Lewbel (1997) demonstrated that the appropriate form for some consumer preferences is of quadratic nature, suggesting the generalization of the basic AIDS. In order to account for this, they introduced the quadratic version (QUAIDS), which nests the AIDS and allows for the flexibility of a rank three specification in the Engel curves. According to Banks, Blundell, and Lewbel (1997), the QUAIDS has indirect utility functions (V) of the form

$$(2) \qquad \ln V = \left\{ \left[\frac{\ln m - \ln a(p)}{b(p)} \right]^{-1} + \lambda(p) \right\}^{-1},$$

where m indicates total food or food group expenditure, and p is a vector of food prices. The term in squared brackets is the indirect utility function of a demand system of the price-independent generalized logarithmic (PIGLOG) preference class. The functions ln $a(p)$ and $b(p)$ are the translog and the Cobb-Douglas price aggregator functions defined by

$$(3) \qquad \ln a(p) = \alpha_0 + \sum_{i=1}^{n} \alpha_i \ln p_i + \frac{1}{2} \sum_{i=1}^{n} \sum_{j=1}^{n} \gamma_{ij} \ln p_i \ln p_j \quad \text{and}$$

(4) $$b(p) = \prod_{i=1}^{n} p_i^{\beta_i} \ .$$

The price aggregator function $\lambda(p)$ is given by

(5) $$\lambda(p) = \sum_{i=1}^{n} \lambda_i \ln p_i \ .$$

Applying Roy's identity to equation (2), food budget shares for each food group can be expressed as

(6) $$w_i = \alpha_i + \sum_{j=1}^{n} \gamma_{ij} \ln p_j + \beta_i \ln\left[\frac{m}{a(p)}\right] + \frac{\lambda_i}{b(p)} \left\{\ln\left[\frac{m}{a(p)}\right]\right\}^2, \quad \forall i = 1,\ldots,n \quad .$$

The theoretical restrictions of adding-up, homogeneity, and Slutsky symmetry are imposed in the basic QUAIDS by setting

(7) $$\sum_{i=1}^{n} \alpha_i = 1, \quad \sum_{i=1}^{n} \beta_i = 0, \quad \sum_{i=1}^{n} \lambda_i = 0, \quad \sum_{j=1}^{n} \gamma_{ij} = 0, \quad \forall i = 1,\ldots,n,$$

(8) $$\sum_{i=1}^{n} \gamma_{ij} = 0, \quad \forall j = 1,\ldots,n, \quad \text{and}$$

(9) $$\gamma_{ij} = \gamma_{ji}, \quad \forall i \neq j \ .$$

From equation (6), it can be seen that the QUAIDS collapses to the AIDS when all λ_i equal zero.[2] In conformity with the first budgeting stage, we allow for linear socio-demographic translation through the intercept in equation set (6).

Censoring

Using household budget survey data for demand system estimations often creates a major problem that is due to recording zero expenditure for food aggregates that are not consumed during the recall period. This causes censored dependent variables and leads to biased results when not accounted for. Heien and Wessells (1990) introduced a computationally simple, two-step estimation procedure based on Heckman's (1979) work. However, Shonkwiler and Yen (1999) demonstrated the inconsistency of Heien and Wessells' procedure and proposed an alternative and consistent two-step estimation procedure. We adopt this approach here to satisfy the consistency property of demand systems.

In both steps of the two-step procedure, all observations of the sample are applied. The first step obtains household-specific probit estimates $\hat{\omega}_h$ of ω_h that take the binary outcome of one, if household *h* consumes food items of the considered food aggregate, and zero otherwise. The univariate standard normal probability density $\phi(x_{hl_x}\hat{\omega}_h)$ and the cumulative distribution $\Phi(x_{hl_x}\hat{\omega}_h)$ are calculated for each household by regressing ω_h on a set of independent variables x_{hl_x}.[3] In the second step, the probability density and the cumulative distribution are incorporated in the budget share equations, and the system is finally estimated. Thus, equation set (6) is replaced by

$$(10) \qquad w_i^* = \Phi(x'_{hl_x}\hat{\omega}_h)w_i + \varphi_i\phi(x'_{hl_x}\hat{\omega}_h)\,.$$

Since the right-hand side of the system does not add up to one in the second step, the adding-up conditions specified in equation (7) cannot be imposed. Therefore, the system must be estimated based on the full *n*-vector (Yen, Kan, and Su 2002).

Food Demand Elasticities

To derive conditional expenditure and food price elasticities, equation (10) is differentiated with respect to $\ln m$ and $\ln p_j$, such that

$$(11) \qquad \mu_i \equiv \frac{\partial w_i^*}{\partial \ln m} = \Phi(x'_{hl_x}\hat{\omega}_h)\left(\beta_i + \frac{2\lambda_i}{b(p)}\left\{\ln\left[\frac{m}{a(p)}\right]\right\}\right) \quad \text{and}$$

$$(12) \qquad \mu_{ij} \equiv \frac{\partial w_i^*}{\partial \ln p_j} = \Phi(x'_{hl_x}\hat{\omega}_h)\left(\gamma_{ij} - \mu_i\left(\alpha_j + \sum_k \gamma_{jk} \ln P_k\right) - \frac{\lambda_i \beta_j}{b(p)}\left\{\ln\left[\frac{m}{a(p)}\right]\right\}^2\right),$$

where P_k is a price index calculated as the arithmetic mean of prices for all *k* food groups in the system. The conditional expenditure elasticities are then obtained by $E_i = \mu_i / w_i^* + 1$. These are greater than unity at low expenditure levels and eventually become less than unity when total expenditure increases, while the term λ_i becomes more important. The conditional, Marshallian (uncompensated) price elasticities are derived as $e_{ij}^u = \mu_{ij} / w_i^* - \delta_{ij}$, where δ_{ij} is the Kronecker delta equaling one when $i = j$, and zero otherwise. Using the Slutsky equation, the conditional, Hicksian (compensated) price elasticities are given as $e_{ij}^c = \mu_{ij} / w_i^* + E_i w_j^*$. All elasticities are computed at population means.

In deriving unconditional expenditure and price elasticities, we follow Edgerton (1997). The computation of the unconditional expenditure elasticities is straightforward by multiplying the conditional expenditure elasticities of each budgeting stage. The unconditional Marshallian price elasticities are derived as

$$(13) \qquad e_{ij}^u = \delta_{rs} e_{(r)ij}^c + E_{(r)i} w_{(s)j}^* (e_{rs}^c + E_r w_s^* e_F^u),$$

where the indices *i* and *j* represent the food subgroups at the third budgeting stage, *r* and *s* the basic food groups at the second budgeting stage, and *F* food as aggregate at the first budgeting stage. The Kronecker delta of the second stage is indicated by δ_{rs}.

Calorie and Nutrient Elasticities

Calorie elasticities with respect to expenditure and prices can be computed directly from the expenditure and Marshallian price elasticities of food demand. This has been done in previous studies (e.g., Pitt 1983; Sahn 1988). We extend this approach for various nutrients and calculate nutrient elasticities with respect to expenditure (E_N) and with respect to food prices (e_{iN}). Explicitly accounting for the composition of food aggregates, these are derived as follows:

(14) $$E_N = \frac{\sum_j \sum_f c_{jfN} s_{jf} q_j E_j}{\sum_f c_{jfN} s_{jf} q_j} \qquad \text{and}$$

(15) $$e_{iN} = \frac{\sum_j \sum_f c_{jfN} s_{jf} q_j e_{ij}}{\sum_f c_{jfN} s_{jf} q_j},$$

where c_{jfN} is a coefficient for the average content of a particular nutrient (*N*) in food item *f* belonging to food aggregate *j*. s_{jf} denotes the average share of food item *f* in the aggregate *j*, and q_j specifies the consumed quantity of food aggregate *j*.

Household Data and Nutritional Assessment Approach

The data for the empirical part of this study are taken from the second Malawi Integrated Household Survey (IHS-2), which was carried out over one year in 2004/05. The sample comprises 11,280 households and is representative nationwide at the district level. The food consumption module of the IHS-2 provides the main data used in our analysis. Table 1 presents summary statistics of the main variables in the food demand model.

Household food consumption was surveyed through a seven-day recall. It records food quantities for in-home and away-from-home consumption, as well as expenditures for foods (including beverages other than water) if purchased.[4] We assume that food within the household is distributed according to the relative energy requirements of household members. To assess consumed nutrient amounts from food quantities, we apply conversion factors of the World Food Dietary Assessment System (WFOOD2 1996), primarily for Kenya and Senegal, which are the only available data bases for sub-Saharan Africa in the WFOOD2. Apart from calories, the nutrients considered include protein, the minerals calcium, iron, and zinc, as well as vitamin A, several B vitamins, and vitamin C. All these nutrients are of relevance in terms of deficiencies among Malawian households. Although iodine deficiency is also widespread, we do not include iodine in the analysis, because the IHS-2 does not provide any information on whether the consumed salt is iodized or not. Globally, including in sub-Saharan Africa, the prevalence of iodine deficiency disorders has been reduced significantly through increased coverage with iodized salt (Sanghvi et al. 2007).

Table 1. Summary Statistics of the Main Variables in the Demand System

	Weighted mean / standard deviation					
Categories (Obs.)	***Budget shares (w)*** [a]		***Expenditures (m) per capita & day in US ¢***		***Prices (p) in US ¢/g***	
FOOD (11,280)	**0.728**	**0.152**	**33.78**	**208.17**	**0.019**	**0.005**
Starchy foods (11,272)	**0.459**	**0.162**	**14.67**	**204.98**	**0.012**	**0.004**
Maize	0.721	0.255			0.012	0.002
Rice	0.051	0.110			0.056	0.010
Other cereals	0.102	0.160			0.011	0.003
Cassava	0.069	0.141			0.006	0.001
Potatoes	0.057	0.092			0.008	0.002
Pulses (9,403)	**0.096**	**0.082**	**2.57**	**2.95**	**0.029**	**0.005**
Phaseolus beans	0.370	0.403			0.030	0.005
Peas & soybeans	0.203	0.337			0.027	0.006
Groundnuts	0.266	0.353			0.030	0.007
Vegetables & fruits (11,215)	**0.147**	**0.085**	**4.08**	**4.03**	**0.024**	**0.009**
Tomatoes	0.236	0.207			0.034	0.010
Pumpkins	0.083	0.175			0.024	0.010
Green leafy vegetables	0.394	0.256			0.025	0.008
Other vegetables	0.101	0.136			0.044	0.010
Bananas	0.067	0.118			0.011	0.002
Fruits	0.114	0.172			0.006	0.001
Animal-source foods (9,429)	**0.154**	**0.130**	**6.60**	**14.00**	**0.053**	**0.028**
Eggs	0.079	0.184			0.143	0.021
Fish	0.475	0.422			0.028	0.006
Red meat	0.113	0.241			0.084	0.013
White meat	0.132	0.272			0.088	0.017
Milk & dairy products	0.035	0.121			0.030	0.010
Meal complements (11,189)	**0.145**	**0.108**	**5.86**	**12.21**	**0.028**	**0.010**
Fat & oil	0.161	0.211			0.006	0.002
Sugar	0.319	0.283			0.044	0.005
Spices	0.300	0.346			0.017	0.003
Beverages	0.212	0.281			0.036	0.013

Note: All continuous variables enter the model in logarithmic terms.

[a] Budget shares of the food subgroups do not add up to one due to censoring.

Nutritional Assessment Approach

In order to assess the nutritional status of households in Malawi, we compare per capita calorie and nutrient consumption derived from the household data with appropriate reference values for adequacy from the literature. We use standard recommendations and requirements for individuals as suggested by the Food and Agriculture Organization of the United Nations (FAO) and the World Health Organization (WHO), based on which we calculate household-specific reference values by taking household size and age and sex composition into consideration. Values are reported on a per capita basis, on average equaling 0.785 adult (male) equivalences with respect to mean energy requirements. The average nutritional situation in the country is examined by comparing the aggregated mean consumption levels of different nutrients with the aggregated mean recommendations and requirements. The prevalence of particular deficiencies is calculated as the proportion of households with consumption levels below their calculated requirements.

To compute calorie recommendations and requirements we apply the recommended mean energy intakes (RMEI) published in FAO/WHO/UNU (2001). We define calorie recommendations for all individuals as average requirements necessary to maintain a normal lifestyle with moderate physical activity level (PAL) and a median body mass index (BMI) of 21.0 among adults. Calorie requirements are defined as minimum requirements needed for a light PAL and a low BMI of 18.5. The calculation of BMIs for adults employs average height values from the literature (NSO 2005; Pelletier, Low, and Msukwa 1991). For protein, recommendations and requirements are derived from the safe level of protein intakes (SLPI) presented in FAO/WHO/UNU (1985) and determined for average and low BMIs, respectively. For the micronutrients considered here, the two reference levels are recommended nutrient intakes (RNIs) and estimated average requirements (EARs). RNIs are available from WHO/FAO (2004); they also provide the basis for calculating EARs, applying conversion factors reported in WHO/FAO (2006). For iron and zinc, where issues of bioavailability are of particular concern, we assume low bioavailability, because staple food crops are the major source of these minerals in typical Malawian diets.

Data Limitations

Using food consumption recalls from household surveys for nutritional assessment has certain drawbacks in terms of accuracy. First, respondents might not remember the exact quantities consumed, especially when the recall period is long. Second, food consumption recalls capture the total food entering the household, not all of which is actually consumed by household members. Some amounts might be fed to pets, discarded, or given to guests or hired laborers. This can lead to an overestimation of actual food intakes, especially in richer households (Bouis 1994). Third, food records are usually not itemized for individual meals, so that adjustments for the bioavailability of micronutrients due to enhancing or inhibiting factors cannot be made. Thus, assumptions on bioavailability have to be based on general dietary patterns in the region. While these general drawbacks have to be kept in mind, the resulting inaccuracies might be fairly small in our case. The seven-day recall period used in the IHS-2 is relatively short, so that data recording should be fairly precise. To improve the data base, we also consulted additional health and anthropometric data available for Malawi. Issues of seasonality in food consumption, which are generally a problem in single-round surveys, are of lesser concern here, because the data were collected over the period of an entire year. In the econometric approach, we account for seasonal differences in food availability through a dummy variable that controls for observations from the hungry season.

Some authors have also voiced more specific criticism with respect to using household survey data for nutritional assessment, especially in terms of determining the prevalence of nutritional deficiencies based on cut-off levels (e.g., Gibson 2005). Nutrient requirements and recommendations are defined for a particular group of individuals of the same sex, age, and physiological status. They refer to intake levels required to maintain health and development in healthy and well-nourished individuals (FAO/WHO/UNU 2001; WHO/FAO 2004). Household level surveys ignore the intra-household distribution of food and commonly do not record the health status of household members. Furthermore, nutrient reference intakes are defined for the average daily need over a reasonable – but usually unspecified – period of time that might not be properly reflected in a single-round food recall. We are aware of these issues and therefore stress that the exact results of our study should be interpreted with some caution. Nevertheless, since individual level food intake and clinical assessment data are hardly ever available for developing countries on a representative basis, we feel that our analysis can provide important and – in certain ranges – reasonable information on the nutritional status of the population. It should be mentioned that use of representative household survey data is already a notable improvement over much cruder methods that are often used for assessing the prevalence of undernutrition in developing countries (Smith, Alderman, and Aduayom 2006).

Food and Nutrient Consumption and Deficiencies

Food consumption in Malawi is generally characterized by a high risk of chronic food insecurity and driven by extreme poverty, especially in rural areas (Benson, Chamberlin, and Rhinehart 2005). Accordingly, dietary choice in many households is primarily focused on avoiding shortages in calorie supply, so to avoid a feeling of hunger. A high level of subsistence food production dominated by resource-scarce smallholders and inefficient and volatile food markets still persists (Harrigan 2007). Three-quarters of the Malawian population draw their main livelihood from farming; 52% live below the local poverty line, and 22% are considered as ultra poor with a strong concentration in rural areas (NSO 2005). The IHS-2 data further show that the average household per capita expenditure – including the opportunity value for all own-produced foods – amounts to US$ 0.54 per day, of which 73% is spent on food. Own-produced food adds up to 58% of the total food quantity consumed and corresponds to half of the food expenditure.

Table 2 shows average food and nutrient consumption patterns and also states nutrient intake recommendations and requirements as reference values. Mean nutrient amounts available are adequate to meet intake recommendations for most nutrients except for iron,

Table 2. Food and Nutrient Consumption and Estimated Prevalence Rates of Nutritional Deficiencies

	Quantity *(g)*	**Calories** *(kcal)*	**Protein** *(g)*	**Calcium[a]** *(mg)*	**Iron** *(mg)*	**Zinc** *(mg)*	**Vit. A[b]** *(µg RE)*
Starchy foods	**624.6**	**1957**	**42.91**	**61.0**	**17.17**	**9.10**	**49.8**
Maize	459.7	1622	36.75	27.0	15.46	8.05	0.0
Rice	18.6	68	1.25	1.5	0.11	0.20	0.0
Other cereals	29.6	96	2.78	11.9	0.54	0.34	0.8
Cassava	62.8	112	0.94	16.2	0.68	0.25	5.0
Potatoes	53.9	60	1.19	4.3	0.38	0.24	44.0
Pulses	**80.6**	**290**	**17.65**	**77.0**	**4.52**	**2.29**	**3.2**
Phaseolus beans	28.7	94	6.48	20.8	2.17	0.81	0.0
Peas & soybean	23.9	80	5.81	35.7	1.29	0.76	3.0
Groundnuts	28.0	115	5.37	20.5	1.06	0.72	0.2
Vegetables & fruits	**196.9**	**79**	**1.98**	**79.5**	**1.01**	**0.32**	**408.8**
Tomato	24.8	5	0.22	1.2	0.12	0.02	21.6
Pumpkin	38.9	8	0.19	2.7	0.08	0.08	78.3
Green leafy vegetables	57.8	12	0.74	60.4	0.42	0.07	247.2
Other vegetables	15.4	5	0.25	5.6	0.16	0.05	7.9
Bananas	16.8	18	0.15	0.6	0.08	0.02	9.0
Fruits	43.1	32	0.43	8.9	0.15	0.07	44.7
Animal-source foods	**66.4**	**97**	**14.24**	**25.9**	**0.45**	**0.74**	**15.5**
Eggs	4.1	6	0.52	2.0	0.05	0.05	7.8
Fish	38.9	53	10.49	6.4	0.22	0.30	3.6
Red meat	8.0	17	1.46	0.5	0.09	0.23	0.0
White meat	7.0	13	1.33	0.8	0.08	0.11	1.4
Milk & dairy products	8.4	6	0.45	16.2	0.01	0.06	2.8
Meal complements	**130.1**	**283**	**0.19**	**16.8**	**0.09**	**0.01**	**0.5**
Fat & oil	16.9	149	0.00	0.0	0.00	0.00	0.0
Sugar	29.3	94	0.00	0.6	0.03	0.00	0.0
Spices	13.3	5	0.02	5.4	0.05	0.00	0.2
Beverages	70.6	36	0.18	10.8	0.01	0.00	0.3
TOTAL	**1098.5**	**2706**	**76.97**	**260.3**	**23.23**	**12.46**	**477.8**
Standard deviations	732.4	1712	55.16	294.2	15.06	8.00	730.0
Recommendations		*2079*	*34.12*	*958.4*	*30.82*	*11.82*	*530.1*
Requirements		*1714*	*32.16*	*798.5*	*17.78*	*9.87*	*378.8*
Prevalence of deficiency (%)		***34.1***	***13.0***	***97.4***	***46.0***	***53.2***	***64.8***

Note: All values are based on edible portions.

[a] Calcium consumption is underestimated (consumption from drinking water is not considered).

[b] RE = retinol equivalences.

Table 2 continued.

	Thiamin *(mg)*	Riboflavin *(mg)*	Niacin[c] *(mg NE)*	Vit. B6 *(mg)*	Folate[d] *(µg DFE)*	Vit. B12 *(µg)*	Vit. C *(mg)*
Starchy foods	**2.033**	**0.968**	**18.03**	**1.762**	**161.9**	**0.002**	**35.35**
Maize	1.802	0.900	16.41	1.330	132.4	0.000	3.32
Rice	0.011	0.011	0.20	0.026	1.1	0.000	0.00
Other cereals	0.052	0.024	0.39	0.025	7.3	0.002	0.01
Cassava	0.111	0.018	0.51	0.248	12.8	0.000	25.50
Potatoes	0.058	0.015	0.51	0.133	8.3	0.000	6.53
Pulses	**0.275**	**0.135**	**3.58**	**0.198**	**219.2**	**0.000**	**2.92**
Phaseolus beans	0.118	0.044	0.44	0.090	96.6	0.000	0.86
Peas & soybean	0.101	0.066	0.52	0.050	86.5	0.000	1.97
Groundnuts	0.055	0.025	2.62	0.057	36.1	0.000	0.09
Vegetables & fruits	**0.107**	**0.104**	**1.09**	**0.252**	**80.7**	**0.000**	**53.31**
Tomato	0.015	0.012	0.15	0.020	3.7	0.000	4.72
Pumpkin	0.019	0.004	0.16	0.016	5.5	0.000	1.95
Green leafy vegetables	0.029	0.039	0.22	0.090	50.1	0.000	15.19
Other vegetables	0.009	0.012	0.08	0.009	4.2	0.000	1.30
Bananas	0.008	0.012	0.11	0.066	3.8	0.000	1.70
Fruits	0.027	0.025	0.37	0.051	13.4	0.000	28.45
Animal-source foods	**0.088**	**0.091**	**1.73**	**0.147**	**8.8**	**1.185**	**0.45**
Eggs	0.003	0.021	0.00	0.005	1.8	0.045	0.00
Fish	0.063	0.028	1.23	0.102	5.6	0.968	0.30
Red meat	0.012	0.011	0.20	0.020	0.3	0.097	0.00
White meat	0.006	0.011	0.27	0.015	0.3	0.024	0.01
Milk & dairy products	0.005	0.020	0.01	0.006	0.8	0.051	0.15
Meal complements	**0.007**	**0.022**	**0.29**	**0.030**	**3.8**	**0.010**	**0.84**
Fat & oil	0.000	0.000	0.00	0.000	0.0	0.000	0.00
Sugar	0.000	0.005	0.00	0.000	0.0	0.000	0.00
Spices	0.000	0.000	0.00	0.001	0.3	0.000	0.17
Beverages	0.007	0.016	0.28	0.029	3.5	0.010	0.67
TOTAL	**2.510**	**1.319**	**24.72**	**2.388**	**474.4**	**1.197**	**92.87**
Standard deviations	1.558	0.830	16.01	1.545	434.0	2.841	125.01
Recommendations	*0.992*	*1.022*	*13.10*	*1.136*	*341.3*	*1.944*	*40.11*
Requirements	*0.815*	*0.852*	*10.02*	*0.953*	*273.1*	*1.614*	*32.91*
Prev. of deficiency (%)	***5.2***	***32.1***	***10.4***	***7.6***	***36.5***	***83.5***	***33.3***

Note:
[c] NE = Niacin equivalences.
[d] DFE = Dietary folate equivalences.

calcium, vitamin A, and vitamin B12; zinc consumption exceeds zinc recommendations by only 5%. The consumption of vitamin B12 and calcium even falls short of the EAR.[5] However, these mean values mask considerable variation across households. Standard deviations also shown in table 2 indicate that there is a relatively high degree of inequality in consumption for many of the nutrients. This suggests that a large proportion of the Malawian population is at risk of multiple nutrient deficiencies. Indeed, several studies demonstrate that the prevalence of undernutrition and micronutrient malnutrition in Malawi exceeds average values for sub-Saharan Africa (e.g., FAO 2006; Mason, Rivers, and Helwig 2005).

Available previous data on the nutritional situation in Malawi are actually quite similar to our own findings, a fact which increases the confidence in our approach. Table 2 shows that 34% of the Malawian population suffer from calorie deficiency which exactly equals the proportion of undernourished estimated by the FAO (2006). Also a prevalence of 46% for iron deficiency is reasonable across the entire population. Mason, Rivers, and Helwig (2005) found that anemia affects 76% of preschool children and around 55% of women, but the prevalence among men is usually much lower. For zinc deficiency, our estimate of 53% is higher than the 34% reported by the International Zinc Nutrition Consultative Group (IZiNCG 2004). But the IZiNCG figure is derived from the FAO Food Balance Sheets, which are less reliable than household survey data, so that our estimate is probably more precise. Only for vitamin A, the prevalence might be somewhat overrated. Mason, Rivers, and Helwig (2005) estimated that 51% of children in Malawi suffer from vitamin A deficiency. For the other nutrients, there are no comparable data available from the literature.

Table 2 also shows that food consumption is poorly diversified in Malawi, a fact which substantially contributes to micronutrient malnutrition. More than 60% of the total food quantity consists of starchy foods, primarily maize, which accounts for 45% of total food quantity and for 60% and 48% of energy and protein consumption, respectively.[6] Maize is also the source for 67% of the iron, 65% of the zinc, and 56-72% of the less ramified B vitamins. Particularly when animal-source foods are scarce in the diet, low consumption of vegetables and fruits is often the main cause of clinical micronutrient deficiencies (Ruel, Minot, and Smith 2005). Animal-source foods only account for 6% of the total food quantity, and the average quantity of vegetables and fruits consumed hardly reaches half of the minimum recommended intake (cf. WHO/FAO 2003). Nonetheless, vegetables and fruits account for 86% of vitamin A consumption, of which 60% is provided by green leafy vegetables. Vegetables and fruits also contribute significantly to vitamin C and calcium availability. The low vitamin B12 availability is due to the low consumption of animal-source foods. Due to the country's location bordering Lake Malawi, fish is the lowest-priced and most consumed animal-source food. It amounts to 82% and 14% of the vitamin B12 and protein consumption, respectively.

Estimation Results

Table 3 shows expenditure and Marshallian price elasticities of food demand evaluated at population means.[7] For food as a whole, the expenditure elasticity is 0.87, which is quite high in an international context. This reflects the situation of widespread food insecurity in Malawi: increases in household budgets are mainly spent on additional food. Yet, large differences can be observed between the food groups. Strikingly, the income responsiveness is high for starchy foods, while it is relatively low for vegetables and fruits. This indicates that local consumers do not consider vegetables and fruits as high-value products. The highest expenditure elasticities are observed for animal-source foods and for meal complements such as cooking oil, sugar, and beverages. Yet there are also notable differences within the food aggregates. For instance, root and tuber crops are less preferred than cereals, and green leafy vegetables are less preferred than other vegetables and fruits.

Table 4 shows the implied calorie and nutrient elasticities evaluated at population means. For most nutrients, expenditure elasticities are relatively high – similar to those for food demand. Unsurprisingly, the high expenditure elasticity for starchy foods entails a high calorie elasticity. Moreover, due to the high share of maize in total food consumption, calorie intake is also closely associated with the availability of protein, iron, zinc, and the less ramified B-vitamins thiamin, riboflavin, niacin, and vitamin B6. With rising income, the consumption of protein and vitamin B12 increases overproportionally relative to calorie intakes, while especially the consumption of

Table 3. Expenditure and Marshallian Price Elasticities of Food Demand

	Expenditure elasiticities		Marshallian own- and cross-price elasticities							
FOOD	**0.870**		*11*	*12*	*13*	*14*	*15*	*21*	*22*	*23*
Starchy foods	**0.907**									
Maize	0.856	*11*	**-0.487**	0.152	0.074	-0.264	-0.083	0.053	0.029	0.038
Rice	1.419	*12*	0.981	**-1.449**	0.094	0.779	0.080	0.087	0.048	0.063
Other cereals	1.552	*13*	0.528	-0.014	**-1.193**	0.224	-0.220	0.095	0.052	0.069
Cassava	0.655	*14*	0.067	-0.047	-1.258	**0.180**	-0.257	0.040	0.022	0.029
Potatoes	0.738	*15*	0.110	-0.044	-1.252	0.184	**-0.253**	0.045	0.025	0.033
Pulses	**0.870**									
Phaseolus beans	1.026	*21*	0.497	0.035	0.070	0.048	0.039	**-1.198**	-0.056	-0.255
Peas & soybeans	0.568	*22*	0.275	0.020	0.039	0.026	0.022	-0.017	**-0.987**	0.802
Groundnuts	1.412	*23*	0.683	0.049	0.097	0.066	0.054	-0.368	0.765	**-1.940**
Vegetables & fruits	**0.350**									
Tomatoes	0.424	*31*	0.515	0.037	0.073	0.049	0.040	0.023	0.013	0.017
Pumpkins	0.373	*32*	0.452	0.032	0.064	0.043	0.035	0.020	0.011	0.015
Green leafy vegetables	0.211	*33*	0.256	0.018	0.036	0.025	0.020	0.011	0.006	0.008
Other vegetables	0.432	*34*	0.524	0.037	0.074	0.050	0.041	0.024	0.013	0.017
Bananas	0.400	*35*	0.486	0.035	0.069	0.047	0.038	0.022	0.012	0.016
Fruits	0.424	*36*	0.515	0.037	0.073	0.049	0.040	0.023	0.013	0.017
Animal-source foods	**1.138**									
Eggs	1.211	*41*	0.314	0.022	0.044	0.030	0.025	0.084	0.046	0.061
Fish	1.040	*42*	0.270	0.019	0.038	0.026	0.021	0.072	0.040	0.052
Red meat	1.344	*43*	0.349	0.025	0.049	0.033	0.027	0.093	0.051	0.067
White meat	1.123	*44*	0.292	0.021	0.041	0.028	0.023	0.078	0.043	0.056
Milk & dairy products	0.814	*45*	0.211	0.015	0.030	0.020	0.017	0.057	0.031	0.041
Meal complements	**0.959**									
Fat & oil	1.001	*51*	-0.006	0.000	-0.001	-0.001	0.000	0.051	0.028	0.037
Sugar & sweets	1.175	*52*	-0.007	-0.001	-0.001	-0.001	-0.001	0.060	0.033	0.043
Spices	0.195	*53*	-0.001	0.000	0.000	0.000	0.000	0.010	0.005	0.007
Beverages	1.197	*54*	-0.007	-0.001	-0.001	-0.001	-0.001	0.061	0.034	0.044

Table 3 continued.

	Marshallian own- and cross-price elasticities														
	31	*32*	*33*	*34*	*35*	*36*	*41*	*42*	*43*	*44*	*45*	*51*	*52*	*53*	*54*
11	0.048	0.017	0.080	0.020	0.014	0.023	0.011	0.069	0.016	0.019	0.005	-0.002	-0.003	-0.003	-0.002
12	0.079	0.028	0.132	0.034	0.023	0.038	0.019	0.115	0.027	0.032	0.009	-0.003	-0.006	-0.005	-0.004
13	0.086	0.030	0.144	0.037	0.025	0.042	0.021	0.126	0.030	0.035	0.009	-0.003	-0.006	-0.006	-0.004
14	0.036	0.013	0.061	0.016	0.010	0.018	0.009	0.053	0.013	0.015	0.004	-0.001	-0.003	-0.002	-0.002
15	0.041	0.014	0.069	0.018	0.012	0.020	0.010	0.060	0.014	0.017	0.004	-0.001	-0.003	-0.003	-0.002
21	0.029	0.010	0.048	0.012	0.008	0.014	0.030	0.181	0.043	0.050	0.013	0.031	0.062	0.058	0.041
22	0.016	0.006	0.027	0.007	0.005	0.008	0.017	0.100	0.024	0.028	0.007	0.017	0.034	0.032	0.023
23	0.040	0.014	0.067	0.017	0.011	0.019	0.041	0.249	0.059	0.069	0.019	0.043	0.085	0.080	0.056
31	**-0.691**	-0.194	0.091	-0.095	0.042	-0.271	0.018	0.109	0.026	0.031	0.008	0.043	0.086	0.081	0.057
32	-0.169	**-0.855**	0.132	-0.061	0.034	-0.077	0.016	0.096	0.023	0.027	0.007	0.038	0.075	0.071	0.050
33	0.184	0.111	**-0.891**	0.084	0.043	-0.060	0.009	0.054	0.013	0.015	0.004	0.022	0.043	0.040	0.028
34	-0.181	-0.118	0.129	**-0.881**	-0.099	0.254	0.018	0.111	0.026	0.031	0.008	0.044	0.087	0.082	0.058
35	0.022	0.065	0.226	-0.130	**-1.435**	-0.052	0.017	0.103	0.024	0.029	0.008	0.041	0.081	0.076	0.054
36	-0.370	-0.116	-0.168	0.191	-0.020	**-0.631**	0.018	0.109	0.026	0.031	0.008	0.043	0.086	0.081	0.057
41	0.060	0.021	0.101	0.026	0.017	0.029	**-1.213**	-0.040	-0.546	0.249	0.459	0.038	0.074	0.070	0.049
42	0.052	0.018	0.086	0.022	0.015	0.025	-0.023	**-0.771**	-0.035	-0.017	0.041	0.032	0.064	0.060	0.042
43	0.067	0.023	0.112	0.029	0.019	0.032	-0.414	-0.031	**-1.246**	0.097	0.507	0.042	0.083	0.078	0.055
44	0.056	0.020	0.093	0.024	0.016	0.027	0.139	0.045	0.058	**-0.978**	-0.152	0.035	0.069	0.065	0.046
45	0.040	0.014	0.068	0.017	0.012	0.020	0.661	0.162	0.848	-0.353	**-1.266**	0.025	0.050	0.047	0.033
51	0.044	0.015	0.073	0.019	0.012	0.021	0.026	0.156	0.037	0.044	0.012	**-0.764**	0.179	0.039	0.042
52	0.051	0.018	0.086	0.022	0.015	0.025	0.030	0.183	0.043	0.051	0.014	0.084	**-1.002**	0.099	0.287
53	0.008	0.003	0.014	0.004	0.002	0.004	0.005	0.030	0.007	0.008	0.002	0.005	0.137	**-0.014**	0.013
54	0.052	0.018	0.087	0.022	0.015	0.025	0.031	0.187	0.044	0.052	0.014	0.072	0.540	0.146	**-1.042**

Table 4. Calorie and Nutrient Elasticities with Respect to Household Expenditure and Food Prices

	Calories	Protein	Calcium	Iron	Zinc	Vit. A	Thiamin	Riboflavin	Niacin	Vit. B6	Folate	Vit. B12	Vit. C
Expenditure elasticity	0.922	0.946	0.720	0.874	0.907	0.362	0.857	0.851	0.919	0.819	0.795	1.065	0.506
Marshallian price elasticities													
Maize	-0.166	-0.023	0.236	-0.188	-0.164	0.319	-0.251	-0.218	-0.177	-0.141	0.146	0.274	0.272
Rice	0.057	0.059	0.021	0.100	0.080	0.017	0.104	0.097	0.096	0.068	0.056	0.019	0.008
Other cereals	-0.064	-0.017	-0.110	-0.019	-0.017	-0.087	-0.044	0.012	-0.003	-0.157	-0.016	0.037	-0.394
Cassava	-0.112	-0.084	0.026	-0.147	-0.133	0.049	-0.162	-0.156	-0.146	-0.097	-0.035	0.027	0.078
Potatoes	-0.066	-0.040	-0.019	-0.062	-0.059	-0.002	-0.075	-0.059	-0.058	-0.080	-0.017	0.021	-0.071
Phaseolus beans	-0.009	-0.082	-0.100	-0.088	-0.055	0.020	-0.019	-0.001	-0.015	-0.009	-0.253	0.074	0.016
Peas & soybeans	0.028	0.000	-0.064	-0.002	0.005	0.006	0.000	-0.011	0.085	0.020	-0.120	0.041	-0.005
Groundnuts	-0.033	-0.064	-0.044	-0.038	-0.047	0.019	0.011	0.029	-0.161	-0.007	-0.038	0.053	0.033
Tomatoes	0.041	0.041	0.048	0.038	0.040	0.005	0.036	0.033	0.035	0.033	0.030	0.053	-0.108
Pumpkins	0.013	0.013	0.019	0.012	0.009	-0.101	0.007	0.011	0.008	0.010	0.007	0.019	-0.040
Green leafy vegetables	0.073	0.067	-0.162	0.056	0.071	-0.433	0.064	0.047	0.067	0.039	-0.044	0.088	-0.157
Other vegetables	0.020	0.017	0.017	0.014	0.016	0.032	0.017	0.014	0.018	0.016	0.017	0.023	0.058
Bananas	0.004	0.010	0.012	0.008	0.010	0.001	0.008	-0.001	0.006	-0.027	0.001	0.015	-0.020
Fruits	0.014	0.017	-0.019	0.015	0.018	-0.109	0.012	0.006	0.010	0.001	-0.011	0.026	-0.208
Eggs	0.012	0.001	0.046	0.011	0.006	-0.004	0.011	0.001	0.012	0.008	0.014	-0.067	0.014
Fish	0.078	-0.020	0.086	0.083	0.069	0.065	0.060	0.063	0.051	0.044	0.103	-0.618	0.078
Red meat	0.014	-0.006	0.068	0.016	0.000	0.013	0.013	0.012	0.010	0.008	0.025	-0.112	0.020
White meat	0.021	0.006	0.003	0.022	0.016	0.019	0.019	0.012	0.014	0.015	0.031	-0.031	0.022
Milk & dairy products	0.008	0.014	-0.067	0.009	0.011	0.005	0.007	-0.002	0.010	0.008	0.009	0.035	0.004
Fat & oil	-0.034	0.013	0.022	0.007	0.007	0.026	0.005	0.008	0.009	0.008	0.018	0.033	0.022
Sugar & sweets	-0.010	0.027	0.060	0.012	0.015	0.052	0.010	0.016	0.022	0.021	0.039	0.069	0.047
Spices	0.016	0.024	0.041	0.013	0.014	0.049	0.009	0.014	0.017	0.015	0.034	0.062	0.041
Beverages	0.006	0.015	-0.018	0.009	0.010	0.034	0.003	-0.003	-0.001	-0.003	0.016	0.034	0.021

vitamins A and C increases underproportionally. Obviously, these patterns are due to the high expenditure elasticities for animal-source foods and the relatively low expenditure elasticities for vegetables and fruits. Overall, the nutrient elasticity estimates suggest that income increases will lead to substantial improvements in household nutritional status, except for those nutrients that are primarily provided by vegetables and fruits.

With few exceptions for individual food items, the estimated Marshallian own- and cross-price elasticities presented in table 3 indicate a strong price responsiveness of food demand in Malawi. Apart from cassava, all own-price elasticities are negative, as expected. They are even above unity for some luxury foods for which cheaper substitutes are available, such as rice, groundnuts, and red meat, and for lower-value foods which can easily be substituted, such as banana. Household demand responses to prices are mainly driven by substitution effects, as becomes evident when comparing Marshallian and Hicksian price elasticities.[8] For most foods, households are able to adjust their consumption patterns, so that the impacts of moderate short-term food price variations on nutritional status are relatively small. Exceptions include the demand for maize and fish, for which income effects are stronger than substitution effects.

These findings are confirmed by the implied nutrient price elasticities (table 4). Overall, nutrient consumption is highly price-inelastic, but there are remarkable differences between individual nutrients and food items. For instance, the consumption of vitamins A, B12, and C is more price-responsive than that of other nutrients; since these micronutrients are provided by relatively few food items, it is more difficult for households to substitute. In terms of food items, the biggest nutritional effects occur for maize price changes. Declining maize prices are associated with increases in the consumption of calories, protein, iron, zinc, and the low ramified B vitamins. However, at the same time they lead to significantly lower calcium, vitamin A, C, B12, and folate consumption. This is an important finding, given that maize consumer subsidies are a popular policy tool in Malawi aimed at improving food and nutrition security (Harrigan 2008). Our results suggest that such a policy can reduce protein-energy malnutrition, while aggravating the vitamin status of households. Further details are analyzed below.

Policy Simulations

Calorie and nutrient elasticities can be used to simulate the nutritional outcomes of policies or other external shocks. As examples, we analyze the effects of household income and maize price changes within four scenarios. We simulate the effects for every single household in the data set, in order to derive new mean consumption levels of calories and nutrients and new prevalence rates of associated deficiencies. The results are shown in table 5. Scenario 1a considers a per capita income (expenditure) increase of 10%, for instance, as the result of economic growth or direct cash transfers. As expected, this would notably increase the nutrition status. In particular, mean calorie, protein, iron, and zinc consumption would increase by around 9%. The prevalence of calorie deficiency would drop from 34.1% to 27.6%. Iron and zinc deficiency would fall by 6.4 and 7.4 percentage points, respectively. The impact on vitamin A and C deficiency is

Table 5. Simulation Results

	Calories *(kcal)*	Protein *(g)*	Calcium[a] *(mg)*	Iron *(mg)*	Zinc *(mg)*	Vit. A[b] *(μg RE)*	Thiamin *(mg)*	Riboflavin *(mg)*	Niacin[c] *(mg NE)*	Vit. B6 *(mg)*	Folate[d] *(μg DFE)*	Vit. B12 *(μg)*	Vit. C *(mg)*
Status quo													
Mean consumption	2706	76.97	260.3	23.23	12.46	477.8	2.510	1.319	24.72	2.388	474.4	1.197	92.87
Prevalence of deficiency (%) [e]	*34.1*	*13.0*	*97.4*	*46.0*	*53.2*	*64.8*	*5.2*	*32.1*	*10.4*	*7.6*	*36.5*	*83.5*	*33.3*
Scenario 1a: Per capita income increase of 10%													
Mean consumption	2955	84.25	279.0	25.26	13.59	495.1	2.726	1.432	26.99	2.584	512.1	1.324	97.57
Prevalence of deficiency (%) [e]	*27.6*	*9.9*	*97.0*	*39.6*	*45.8*	*63.5*	*4.1*	*26.1*	*8.2*	*6.1*	*31.6*	*81.7*	*31.5*
Scenario 1b: Per capita income decrease of 10%													
Mean consumption	2456	69.69	241.5	21.20	11.33	460.5	2.295	1.207	22.45	2.193	436.7	1.069	88.16
Prevalence of deficiency (%) [e]	*41.8*	*17.4*	*97.8*	*53.9*	*60.9*	*66.3*	*6.4*	*39.7*	*13.3*	*10.0*	*41.7*	*85.0*	*35.5*
Scenario 2a: Maize price increase by 50%													
Mean consumption	2481	76.09	291.0	21.04	11.44	554.0	2.195	1.176	22.53	2.221	508.9	1.361	105.51
Prevalence of deficiency (%) [e]	*40.9*	*13.4*	*96.7*	*54.5*	*60.2*	*59.0*	*7.2*	*42.0*	*13.2*	*9.5*	*32.0*	*81.3*	*29.0*
Scenario 2b: Maize price decrease by 50%													
Mean consumption	2931	77.85	229.5	25.41	13.48	401.6	2.826	1.463	26.91	2.556	439.8	1.033	80.22
Prevalence of deficiency (%) [e]	*28.1*	*12.7*	*98.1*	*39.1*	*46.7*	*71.7*	*3.8*	*24.8*	*8.3*	*6.3*	*41.1*	*85.5*	*39.1*

Note: All values are based on edible portions.

[a] Calcium consumption is underestimated (consumption from drinking water is not considered).

[b] RE = retinol equivalences.

[c] NE = Niacin equivalences.

[d] DFE = Dietary folate equivalences.

much smaller, as these micronutrients are mainly derived from vegetables and fruits, the consumption of which only increases moderately with rising household incomes. Scenario 1b considers a 10% decrease in per capita incomes with opposite effects, that is, an increase in nutritional deficiencies. For zinc, mean consumption levels would even drop below the average recommendation.

The other two scenarios shown in table 5 consider maize price changes, namely a price increase (scenario 2a) and a price decrease (scenario 2b) by 50%. This is not only important because maize is the main staple food in Malawi, but also because the Malawian government has a tendency to intervene in maize markets through subsidies, price controls, or other instruments (Harrigan 2008). Moreover, world market prices for major cereals have been increasing dramatically in 2007/08, and policy and climatic factors are expected to increase international food price volatility in the future. The scenario results show that nutritional effects of maize price changes are ambiguous. A 50% price decrease leads to 8-9% increases in average consumption of calories, iron, and zinc, but, at the same time, mean consumption levels of vitamins A and B12 fall by 16% and 14%, respectively. Accordingly, the prevalence of calorie, iron, and zinc deficiency would decline by 6-7 percentage points, whereas the prevalence of vitamin A deficiency would rise by seven percentage points. Likewise, the prevalence of deficiencies in folate and vitamin B12 and C deficiencies would rise. By contrast, with a 50% maize price increase, mean zinc availability would even fall below the recommended level, while mean vitamin A consumption would suddenly satisfy nutritional recommendations.

It becomes evident that the instrument of consumer price subsidies should be administered only with great care. Beyond the usual losses in economic efficiency, subsidies are also associated with undesirable nutritional side effects, as a result of household dietary adjustments. These effects are especially pronounced for maize, but they also occur for other food items. Income-related policies are not only less market distorting, but they are also more effective in reducing dietary deficiencies across the range of nutrients. Apart from policies that directly promote economic growth, targeted cash transfers and employment generating programs could be interesting strategies to consider. For some micronutrients – especially for vitamin A – more direct nutrition interventions will also be required. Apart from food supplementation and industrial fortification, biofortification might be an interesting option (cf. Qaim, Stein, and Meenakshi 2007). For Malawi, biofortified maize in particular could be a promising technology. Moreover, given the low consumption of vegetables and fruits, home-garden programs would deserve greater attention.

Conclusion

In this article, we have presented a comprehensive analysis of food demand and nutrient consumption using recent, representative household survey data from Malawi. Expenditure and price elasticities have been estimated for 23 food groups using a quadratic almost ideal demand system. These elasticities have subsequently been used to derive elasticities for the consumption of calories and 12 macro- and micronutrients. Finally, we have used these calorie and nutrient elasticities to simulate the nutritional effects of certain income and food price changes.

Due to data limitations, some caution is warranted when interpreting the exact numerical results. Nonetheless, the household data suggest that food insecurity remains a major problem in Malawi. Diets are dominated by starchy staple foods, primarily maize. About one-third of the population is not able to meet its calorie requirements. In addition, poorly diversified consumption patterns increase the risk of micronutrient deficiencies. Especially the consumption of vegetables and fruits, but also of animal-source foods, falls short of recommended levels. Accordingly, micronutrient malnutrition is widespread. From a public health perspective, the prevalence of deficiencies in Malawi is particularly serious for iron, zinc, vitamin A, folate, and vitamin B12.

The elasticity estimates demonstrate that the demand for starchy foods is highly income responsive. Furthermore, increases in income lead to remarkable growth in the demand for animal-source foods, but only to relatively low increases in the demand for vegetables and fruits. As a result, in the context of Malawi, income growth is associated with a significant improvement of the nutrition situation, except for vitamin A for which consumption increases would be relatively small. Price elasticities are high for food demand, while they are generally low for nutrient consumption. This is due to important substitution effects, which help to reduce the nutritional impacts of moderate price changes. An exception is maize, where income effects are more important. Our simulations show that declining maize prices would result in increases in the consumption of calories, iron, and zinc, but in significant decreases in the consumption of vitamins A, B12, C, and folate. For instance, a consumer maize subsidy of 50% would increase the prevalence of vitamin A deficiency by seven percentage points.

Many developing country governments use price subsidies on staple foods, in order to promote food and nutrition security. Our results demonstrate that such policies can have undesirable side effects, especially when people suffer from multiple nutrient deficiencies, as is often the case. In general, income-related policies seem to be better suited than price policies to improve overall nutritional status. Moreover, especially for certain micronutrients, more direct nutrition interventions will be required.

Given that malnutrition remains a huge problem in the developing world, it is surprising that economists have made relatively little recent effort to understand and predict the nutritional impacts of policies and other exogenous shocks on at-risk populations. While calorie effects are relatively well documented, aspects of micronutrient consumption have been analyzed much less. We have presented a comprehensive and theory-consistent analytical framework, but certainly much more work is required in this direction.

[1] Typical Malawian basic meals consist of a thick porridge from staple foods, mostly from maize flour, enriched with a relish of either beans, vegetables, fish, or meat.

[2] The index *i* refers to the considered food group, and *j,* to any food group in the system; *n* denotes the total number of food groups in the system.

[3] The vector x_{hl_x} gives the determinants for consumption and non-consumption of the food aggregate under consideration. It includes own- and cross-prices, linear household food expenditure, a vector of household characteristics, and a vector identifying access to and the seasonal availability of foods. All continuous variables enter in logarithmic form.

[4] The absence of consistent information on food market prices requires the use of unit values calculated from reported food quantities and expenditures. Missing unit values such as due to own-production are predicted item-specifically following the concept of opportunity values. We assume that products of equal quality have the same value at the same place and at an equal point in time, independent of their sources. To avoid inconsistencies in price elasticity estimates due to consumer quality choice, measurement errors in food quantities and expenditures (Deaton 1988), and economies of scale in purchase, we employ a price approximation procedure similar to that presented by Alfonzo and Peterson (2006). To do so, we adjust unit values for the systematic changes in unit costs and account for the composition of food aggregates. We explicitly allow for spatial and temporal variation in food prices.

[5] Calcium consumption is underestimated in this study since the consumption from drinking water is not taken into account due to the absence of information in the IHS-2.

[6] All figures of total food quantity given in the text exclude beverages.

[7] Most parameters estimated from our food demand system show high statistical significance, but they have no direct economic interpretation and are therefore not presented here. More information on the model's significance can be obtained from the authors upon request.

[8] Hicksian price elasticities of food demand and nutrient consumption are not presented in this study but can be obtained from the authors upon request.

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