Measuring dietary energy deficiency and the impact of food price variations at the household level

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A Methodological Note on the Micro-Analysis of Undernourishment

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Abstract

FAO is the main provider of country-level estimates of undernourishment covering the whole world. Its methodology has the main advantage of facilitating comparisons across countries and over time, but also has a limited capacity to understand the causes of food insecurity within countries (FAO, 2003; Barret, 2010). The upward trends in global food prices, concerning many staple commodities between 2005 and 2008, stimulated us to extend the principles of the FAO methodology in order to assess the impact of rising food prices on household-level food security. The objective of this methodological note is to provide a detailed description of the methodology applied in Anriquez *et al*. (2010), providing guidelines for measuring undernourishment, and more specifically dietary energy deficiency at the household level; and suggestions for the implementation of micro-simulations of food price variations. Additionally this note provides guidelines to construct household specific dietary energy requirements, instead of using a single threshold (generally, 2100 kilocalories per person per day) for all households.

Key Words: Undernourishment, food prices, dietary energy deficiency, calories intake, dietary energy requirements, household surveys.

JEL: D12, I32, O12, Q18, I12.

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The following methodological note provides a detailed description of the methods applied in Anriquez et al. (2010) study of the household-level food security impacts of food price spikes. This note provides guidelines into two distinct empirical aspects covered in that paper: first measuring undernourishment, and more specifically dietary energy deficiency at the household level, and suggestions for the implementation of micro-simulations of food price variations.

The description of methods on using consumption household surveys to measure food-security should be viewed as an expansion of the excellent guide prepared by Smith and Subandaro (2007). The main contribution here is a guideline to construct household specific dietary energy requirements, in a way which is consistent both with the different needs of populations according to their physical constitution, age and gender; and consistent with the way FAO calculates energy requirements (FAO, 2008), which follows the best dietary energy requirements guidelines (FAO, 2004). In a sense, the methodology proposed below blends the focus on micro level measurement of undernourishment of Smith and Subandaro (2007), with FAO (2008) focus on the varying dietary energy requirements of different populations. As is usually done in poverty analysis, the methods presented below construct comparable household equivalence scale thresholds, where the equivalence is given by the different energy requirements of each household member.

Also, below we present a methodology for micro-simulating the impacts of food price changes on food and energy consumption. The suggested approach not only allows for the direct impact of food price changes on food and energy demand, but also accounts for substitution effects, which are likely an important buffer against food price spikes.

The next sections presents a brief description of how price changes transmit into changes in dietary energy consumption, followed by a description of the methodology used for measuring undernourishment at the household level, and a description of the food price changes micro-simulations .

I.- Theoretical Background: How Food Price Variations Impact Dietary Energy Intake

The total dietary energy consumed by individuals depends on the quantity of food consumed and its caloric content:

(1) $$TC = \sum_j c_j \cdot x_j(\mathbf{p}, y) .$$

Food consumption is usually measured at the household level, so we define x_j as the per-capita quantity of food *j*, c_j is the energy content of food *j*, and *TC* the total dietary energy intake, measured in kilocalories per capita. As the energy conversion factors are fixed, as they depend on their nutritional content, the changes in dietary energy consumption are given by the changes in food consumption.

(2) $$dTC = \sum_j c_j \cdot dx_j(\mathbf{p}, y)$$

Food consumption changes as a result of food price changes, both directly by changing real income, and indirectly by changing nominal household income if the household is a producer of food.

(3) $$dx_j = \frac{\partial x_j(\mathbf{p}, y)}{\partial p_i} \cdot dp_i + \frac{\partial x_j(\mathbf{p}, y)}{\partial y} \cdot \frac{\partial y}{\partial p_i} \cdot dp_i ,$$

In (3) income *y* is the sum of the different goods and services (including labour supplied) produced by the household, valued at their market prices, that is, $y = \sum_i p_i y_i$, and hence $\partial y / \partial p_i = y_i$. We can multiply and divide terms to re-write equation (3) as:

(3)' $$\frac{dx_j(\mathbf{p}, y)}{x_j} = \frac{dp_i}{p_i} \cdot \left[\varepsilon_{ji} + \alpha_i \cdot \eta_j \right],$$

which shows that as a result of a price change of food item *i*, the percentage change in each food item *j* consumed will vary by percentage change in food price *i* multiplied by the cross (or own) price demand elasticity (ε_{ji}) and the income demand elasticity η_j multiplied by the share in income of the value of the production of food item *i*, $\alpha_i = p_i y_i / y$.

The change in total dietary energy consumed will be given by:

(4) $$\frac{dTC}{TC} = \frac{dp_i}{p_i} \sum_j \beta_j \cdot \left[\varepsilon_{ji} + \alpha_i \cdot \eta_j \right],$$

where β_j is the share of good (j) in total dietary energy consumption. Equation (4) shows that the bulk of the change in dietary energy consumption will be given by the changes in the consumption of the staple foods, which account for a larger share of dietary energy intake.

Even if some food items suffer large proportional changes, their impact on dietary energy will be lower than smaller proportional changes in the consumption of the staple.

II.- Measuring Dietary Energy Intake Using Household Surveys

Household food consumption surveys usually contain information on food consumed that was: (i) purchased; (ii) obtained from own production; (iii) obtained as a gift or payment; (iv) was purchased and consumed away from home. The first issue is to convert quantities to standard units when these are reported in different and/or non-conventional units. We converted weights and volumes to the metric system, and did not drop quantities with missing unit codes, but imputed the unit in which it was most likely reported; i.e. for missing unit codes we used the unit code mode, by food item and secondary administrative unit (district or similar).

Once all quantities were reported in standard units we converted them to energy equivalent using country specific food composition tables, or in their absence a food composition table from a neighbouring country[1]. The food composition table will describe the edible portion of the different food items, and their average dietary energy content by weight.

We eliminate outliers, i.e. observation that are most likely misreported, by calculating at the household level daily calories per capita for each of the food groups present in the survey. Usually these groups are cereals, meats, fruits and vegetables, and other. We replace observations that lie outside the bounds of the median calories per capita by +/- 3 standard deviations, with the corresponding medians by food group and small administrative unit (usually districts or similar).

To add the energy content of food consumed away from home, we used two approaches. When the food is specified, for example “hot dog sandwich” we include the caloric content of that sandwich. However, in most cases only the amount of money spent in eating away from home is reported. In these cases we first calculate the average calories consumed at home per unit of local currency spent. This calculation involves several steps. First we calculate the value of the consumption of self-produced food, and food received as gifts or payment. We use small administrative area (district or similar level) consumption price medians to value own-consumption and food received. In some cases we could not find enough observations of purchased food to calculate prices, in those few cases we used the

[1] FAO site, http://www.fao.org/infoods/index_en.stm, provides information about food composition tables from around the world.

district level surveys that usually accompany all-purpose surveys (like the LSMSs and similar surveys that we used) to infer district or similar level prices. Thus, adding the value of purchased food, consumed from own-production, and food obtained as gifts or payments we obtain the total value of food for each group, which is used to divide the calories obtained from each food group to obtain a figure of calories per local currency, for each food group. Finally we obtain a household-level measure of calories per local currency, which is a weighted mean of the calculated calories per local currency of each food group, using the share of total energy derived from each food group as weights. We acknowledge the fact that diets vary by income group, by calculating a measure of calories per local currency by income quintiles (median). Finally, the amount of money spent on eating food away from home is converted into dietary energy using these quintile level estimates of calories per local currency.

Food Conversion Tables

In order to convert from food quantities to dietary energy intakes, we need a nutrient conversion table (NCT) data file containing nutrient conversion factors for the list of food items in the household survey expressed in standard metric equivalent quantities (i.e. grams or kilograms for solids and litres or millilitres for liquids). The NCT data file contains a detailed list of all food items identified in the survey together with the corresponding food codes, food group to which the food item belongs and units of quantity measurement. The nutrient values per 100 grams edible portion for each food item as well as their density coefficient and refuse factor are included. In Table 1 we report the countries for which we calculated the dietary energy intake and the relative source of NCT. The NCTs of four countries out of eight come from the database created by the Statistics division of FAO as discussed in Sibrián et al. (2008). Bangladesh and Malawi food composition values were obtained from the World Bank, and correspond to the data also used also for each country's Poverty Assessment. Nepal nutritive values are taken from Gopalan et al. (2004), Indian Council of Medical Research (ICMR). Finally, the Vietnam NCT comes from the Thai food composition tables constructed by Puwastien et al. (1999), the Institute of Nutrition at Mahidol University, Thailand.

Table 1. Nutrient conversion tables (NCT)

Country	Year	Acquisition / Purchases	Food Items	Sources of NCT
Bangladesh	2000	Consumption	135	World Bank
Cambodia	2004	Consumption	193	Sibrián et al. (2008)
Guatemala	2000	Acquisition	99	Sibrián et al. (2008)
Kenya	2005	Consumption	157	Sibrián et al. (2008)
Malawi	2004	Consumption	112	World Bank
Nepal	2003	Consumption	65	Gopalan et al. (2004)
Tajikistan	2003	Consumption	32	Sibrián et al. (2008)
Vietnam	2002	Acquisition	57	Puwastien et al. (1999)

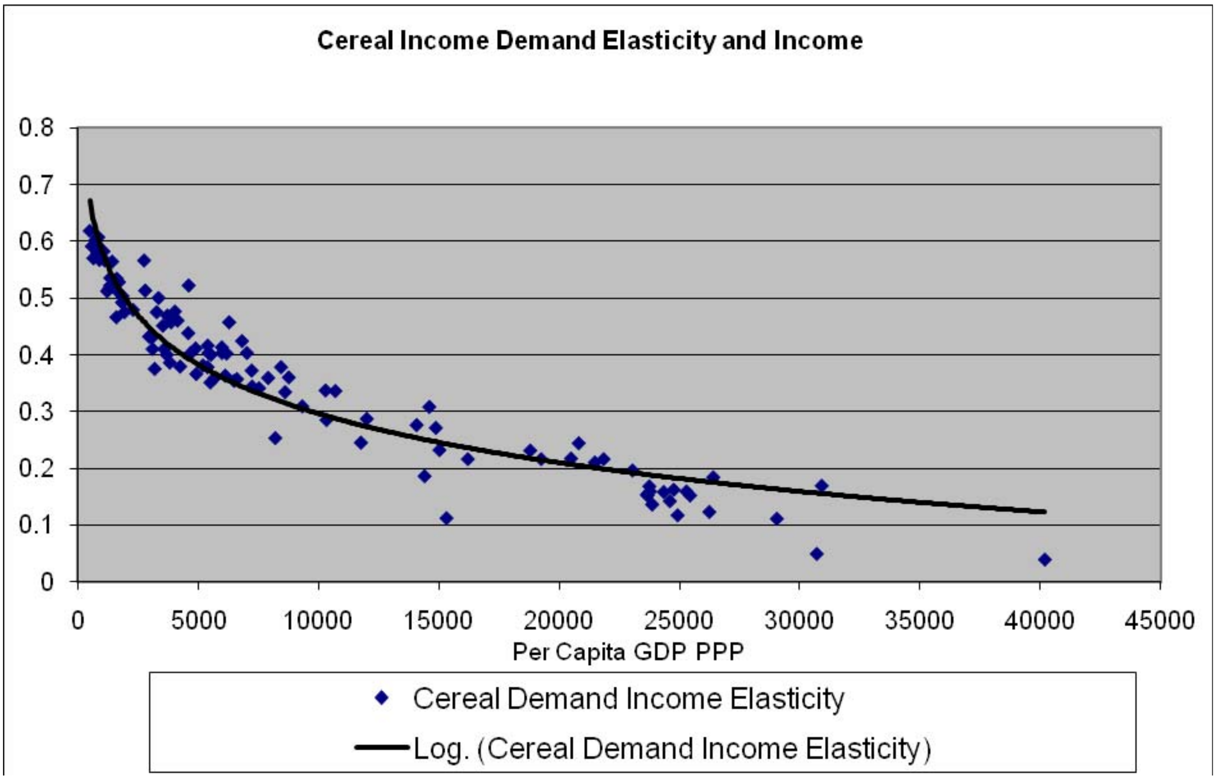
III.- Simulating Price Shocks

The change in food consumption caused by food price increases is calculated at the household level using equation (3)'. This equation shows that for an assumed price (percentage) change, the change in food demand depends on food demand price and income elasticities, and the share of the relevant food item in household income. The latter share we obtain directly by calculating it at the household level using information from the household survey. The food demand elasticities we obtain from the literature. We used two approaches for the necessary food demand elasticities. When available we used estimated food demand systems, which allows us to calculate both the direct effect on the staple whose price is being shocked, as well as the effects on the demand of the other food items (or food groups), for which cross-price elasticities are needed.

However, to achieve the maximum comparability across countries examined, we also computed the effects on dietary energy intake and the prevalence of undernourishment using the own-price cereal demand elasticities from a comparable cross-country study, Seale et al. (2003). We enriched the calculations by also calculating the implicit cross-price elasticities to allow for food substitution effects. In the case of income demand elasticities we observed that cereal demand elasticities were highly correlated with income, as figure 1 shows. Note that this is actually an expected result, which is related, but not equivalent to Engel's law. Engel's law observes that the share spent on food falls with income, however, this study and others have shown that the food demand income elasticity also falls with income. Thus, instead of using national level demand elasticities we use the cereal demand income elasticity that is predicted for each income decile, using per capita expenditure, annualized and converted into

PPP dollars as the predictor (the predicted value is the line in Figure 1). In the case of the own-price elasticity, we used the national level estimate for each household.

Figure 1. Cereal Demand Elasticities and Income Across 114 Countries



Source: Authors' calculations using data from Seale et al. (2003)

Cross-Price Elasticities

We calculate cross-price elasticities following the technique suggested by Beghin et al. (2003). The proposed methodology imposes diagonal dominance to calculate the off-diagonal elements of the Slutsky substitution matrix. The assumption of quasi-concavity of preferences translates into a positive semi-definite and symmetric Slutsky matrix. The diagonal dominance means that the absolute value of each diagonal term must be at least as large as the absolute value of the sum of all off diagonal elements of the row/column (which are the same given symmetry). Beghin et al. (2003) further assume that preferences can be expressed with a LINQUAD incomplete (in that it only describes food and not total consumption) expenditure system. The conditions imposed by diagonal dominance exactly identify the set of unknown parameters of a LINQUAD expenditure system, provided that the diagonal elements are known[2]. Thus, what the proposed approach does is to jointly scale the absolute value of all cross-price effects until the sufficient condition for concavity (of the expenditure function) is met. Table 2 shows the numbers used to calculate cross-price elasticities in Malawi as an example. Elasticities need to be converted into marginal effects with information about prices and quantities. We use an updated version of the same data that Seale et al. (2003) used in their cross-country study: the 2005 round of the International Comparison Programme (World Bank, 2008), whose disaggregated data was generously made available to this study by the World Bank. In the first three columns we show yearly expenditures per capita in international dollars for the food groups used in the Seale et al. (2003) and this study; the corresponding total budget shares (out of total household expenditure), and the implicit prices (see Appendix I for details on calculating aggregate food prices). The diagonal elements of the Slutsky matrix can be constructed with the own-price and income elasticities, shown in the next two columns, borrowed from the above mentioned study. With the information shown in the first five columns we proceed to calculate the full substitution matrix, and Marshallian cross-price elasticity matrix following the Beghin et al. (2003) diagonal dominance methodology (using the DNLP solver of the GAMS software). The last two columns of Table 2 show the column out of the substitution matrices which is important for this study, the cross price elasticities with respect to cereals[3]. The table shows that all Hicksian cross-price effects are positive as theory imposes, but all Marshallian elasticities are negative. This means that negative income effects dominate, and reverse the pure substitution effects, given the large share of cereals in total consumption. The fact that cross-price Marshallian elasticities are negative is also consistent with what has been found in the literature[4], and actually should be expected for poor countries where cereal demand amounts to a large share of total household consumption. For our analysis, this means that facing price increases households actually cut the consumption of other foods in order to dampen the fall in their consumption of the staple, which is usually the (revealed) cheaper source of dietary energy.

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[2] Another way to impose concavity of the expenditure function is to use the Cholesky decomposition as suggested by Lau (1978).
[3] Complete substitution matrices for all countries included in this study are available upon request from the authors.
[4] Cf. Zanias and Gunjal (2008) who estimated a food demand system also for Malawi, or Talukder (1990) for Bangladesh among others.

Table 2. Food Expenditure and Demand elasticities in Malawi.

Food Group	Household Expenditure†1	Total Budget Shares[1] (%)	Prices[1]	Elasticities[2]		Elasticities With Respect to Cereals[3]	
				Own-price	Income	Hicksian	Marshallian
Cereals/ Bread	75.12	10.39	0.606	-0.479	0.592	-0.418	-0.479
Meat	1.82	0.25	1.607	-0.670	0.828	0.042	-0.046
Fish	0.49	0.07	0.978	-0.801	0.991	0.050	-0.055
Dairy	4.17	0.58	0.930	-0.748	0.925	0.047	-0.052
Oils/Fats	0.97	0.13	0.868	-0.490	0.606	0.031	-0.034
Fruits/Vegetables	8.83	1.22	2.883	-0.551	0.681	0.035	-0.038
Other Food	72.07	9.97	1.031	-0.667	0.825	0.042	-0.046
Beverages/Tobacco	16.44	2.27	1.859	-1.243	1.538	0.078	-0.086

Sources: 1. Authors' calculations using basic heading PPP data from the 2005 round of the World Bank ICP project. 2. Seale et al. 3. Authors' calculations.
Notes: † In per-capita international dollars of 2005 per annum.

IV.- Calculating Dietary Energy Requirements at the Household Level

In order to characterize a household (or individual) as food insecure and quantify the level of the food energy gap, actual household (individual) calorie intake should be compared with a relevant energy requirement threshold. This threshold quantifies the necessary (minimum) or the recommended (average) energy requirement, to balance the energy expenditures needed to maintain body size and composition, and a level of necessary (minimum) or desirable (average) physical activity that is consistent with good health in the long run. This threshold needs to take into account the different energy requirements of different age groups and gender as well as the weight gain requirements of infants, children and teenagers. Furthermore, it needs to correspond as much as possible to the characteristics of a country that shape livelihoods, health and physical characteristics of its inhabitants.

Two such thresholds are considered, the Minimum Dietary Energy Requirements (MDER) consistent with sedentary lifestyle and the requirements of the lower tail of the physical constitution distributions; and the average dietary energy requirements (ADER) necessary for moderate activity level for an individual of average physical stature in a country. ADERs would probably be more adequate to assess food security in its more accepted definition[5], however we take the more conservative approach of using MDERs both

[5] "Food security, at the individual, household, national, regional and global levels [is achieved] when all people, at all times, have physical and economic access to sufficient, safe and nutritious food to

to be comparable with official FAO global undernourishment monitoring methodology, and also because a more cautious measure of dietary energy requirements is probably desirable to deal with the under-reporting of consumption from which household surveys usually suffer.

The methodology used to measure dietary energy requirements relies on data and analytical tools agreed by the experts consultation on human energy requirements convened by FAO, WHO and UNU (FAO, 2004). Equations utilized to compute MDER by age and gender, are included in Table 3. An example is included to compute MDER for Tajikistan (2003) for females (Table 4) and for males (Table 5).

Specific data on heights by country and by age and gender are utilized. The Body Mass Index[6] (BMI) recommended (for children up to 10 years old), and necessary (for children and adults above 10 years old) is employed. From the BMI[7] and the height, the associated body weight by age and gender is computed. With the use of equations from the nutrition literature that relate body weight with energy intake, the energy requirements are computed. No differentiation is considered between rural and urban populations. Energy requirements are adjusted for children and teenagers up to 18 years old, to consider energy needs for body growth. In particular energy needs for these age groups need to take into account energy needed to synthesize tissues as well as energy deposited in the tissues. For children up to 2 years old and if Under 5 Mortality Rate (U5MR)[8] is above 10 ‰, energy needs for body growth are doubled.

Other adjustments are also applied. In particular for children from 1 and up to 2 years old, energy requirements (excluding growth), are obtained by multiplying total energy expenditures (TEE) by 0.93 since the equation used to predict them produces values that were deemed about 7 percent higher than actual measurements (FAO, 204: p.21). The other adjustment refers to children from 10 up to 18 years old, their energy requirements are obtained by multiplying TEE by 0.85, in order to account for a lower physical activity level consistent with minimum requirements.

More specific details are given below:

- **Children up to 10 years old.** The Body Mass Index (BMI) consistent with the median (50th) percentile is employed. Energy requirements for babies up to 1 year old have been estimated to be very similar for boys and girls and relate linearly with body

meet their dietary needs and food preferences for an active and healthy life." *Declaration of the World Food Summit*, 1996.

6 Body Mass Index (BMI) equals weight over the square of height.

7 The sources for the BMI are the following: 1) WHO, BMI-for-age tables for children up to 5; 2) WHO, Growth reference data for 5-19 years; 3) FAO, SOFI 2006 for adults 18 years and above.

8 Source: Unicef

weight. For children from 1 and up to 10 years old the equation is quadratic in body weight and different for boys and girls.

- **Children from 10 up to 18 years old.** The Body Mass Index (BMI) consistent with the 5th percentile is employed. Energy requirements are quadratic in body weight and different for boys and girls.
- **Adults from 18 years old and above.** The Body Mass Index (BMI) consistent with the 5th percentile is employed. Energy requirements are linearly related to body weight but different for males and females and by different age sub-groups (18 up to 30 years old, 30 up to 60 years old and above 60 years old). The equation that estimates the Basal Metabolic Rate[9] (BMR) is multiplied with the Physical Level of Activity[10] (PAL), consistent with sedentary lifestyle. The PAL is the same for male and female across the three age groups (equal to 1.55) and indicates that energy requirements per day per person are 1.55 times the BMR.
- **Pregnancy allowance.** The energy allowance adopted for pregnancy and lactation is a fixed value of 210 kcal during 9 months per child born. The official FAO global undernourishment methodology accounts for it by considering the birth-rates at national or sub-national level. In this framework, our goal is to measure energy requirements for each household thus, we account for pregnancy allowance, the additional energy required by the lactating mother, by adding 210 kcal to all children less then one year.

Measuring Undernourishment and Food Gaps

Using the methodology described above we calculate the MDERs for each household, using the age and gender composition of the household, and assuming that the physical constitution is, as explained above, average for children, and only that equivalent to the 5th percentile of the national distribution for adults. All the individuals in the household are counted as undernourished if the household dietary energy intake is lower than the household's MDER. This calculation is then repeated using the energy intake level after the food price increase simulation.

Dividing the household energy requirements by the energy requirements of a male 30-34 years old, we get the number of adult equivalents of each household. This number is then used to calculate calories per adult equivalent which provides a comparable individual level of

[9] Energy consumed at inertia and compatible with life.
[10] Energy requirements as multiple of BMR shows the energy necessary to conduct basic activities (sleeping, personal care, eating, cooking, driving, sitting, housework, light walking and light leisure activities).

food calories intake. Additionally we calculated the dietary gap, which measures as a percentage of the MDER the amounts of calories necessary to overcome undernourishment:

(5) $$GAP_i = \sum_{i \in U} \frac{MDER_i - x_i}{MDER_i};$$

where the index i refers to households, and the summation is over those who are undernourished, i.e. $x_i < MDER_i$, and x_i refers to the household daily caloric intake.

Differences with the Official FAO Global Undernourishment Methodology

Estimated MDER and undernourishment rates, while sometimes maybe similar, are not necessarily comparable with the official FAO global estimates. MDER is measured in both cases using the same equations recommended by the experts consultation on human energy requirements but, small differences may occur from the different procedures adopted. Using the methodology described above we measure MDER for each household while the official FAO methodology measures it at national or sub-national aggregation level.

The major difference between the two methodologies regards the approach adopted for the measurement of undernourishment rates. The official FAO methodology utilizes a parametric approach where the lognormal distribution is assumed for the distribution of dietary energy consumption and the two parameters that fully describe the distribution (mean and coefficient of variability) are estimated[11]. Then, the rate of undernourishment is defined according the following probabilistic framework:

(6) $$P_U = P(x < MDER) = \int_{x<MDER} f(x)dx = F_x(MDER)$$

As it was shown in the previous section, our methodology is based on a nonparametric approach where the household is classified as undernourished if its dietary energy consumption is lower then its MDER. The main advantage of our methodology is that classifying each household allows the use of econometric models for analysing the impacts of different factors (type of employment, education, livelihoods etc...), shocks (food prices, job loss etc...) and other socio-economic variables on undernourishment in order to inform adequately the policy-making process. Also, non-parametric methods allow for more flexibility in the types of policy interventions analyzed and the causes of food insecurity, albeit at the cost of greater computation and data requirements.

[11] The mean is estimated mostly using country food balance sheets and the coefficient of variation is measured through household surveys using an *ad-hoc* methodology (See Sibrian *et al*. 2008).

Table 3. Minimum energy requirements (MDER) by age group and gender.

Females		
Age class	**Equation for Lower Limit of Energy Requirement**	**Notes**
0+	(-99.4 + 88.6* Body Weight) + Weight gain per age* Energy per kilo of weight gain + Lactation Requirement	
0+	(-99.4 + 88.6* Body Weight) + 2 * Weight gain per age* Energy per kilo of weight gain + Lactation Requirement	if under 5 mortality is greater than 10‰
1+	0.93 * (263.4 + 65.3 * Body Weight - 0.154 * Body Weight^2) + Weight gain per age * Energy per kilo of weight gain	
1+	0.93 * (263.4 + 65.3 * Body Weight - 0.154 * Body Weight^2) + 2 * Weight gain per age * Energy per kilo of weight gain	if under 5 mortality is greater than 10‰
2+ to 9+	(263.4 + 65.3 * Body Weight - 0.154 * Body Weight^2) + Weight gain per age * Energy per kilo of weight gain	
10+ to 17+	0.85 * (263.4 + 65.3 * Body Weight - 0.154 * Body Weight^2) + Weight gain per age * Energy per kilo of weight gain	
18+ to 29+	PAL * (486.6 + 14.818 * Body Weight)	
30+ to 59+	PAL * (845.6 + 8.126 * Body Weight)	
60+	PAL * (658.5 + 9.082 * Body Weight)	
Males		
Age class	**Equation for Lower Limit of Energy Requirement**	**Notes**
0+	(-99.4 + 88.6 * Body Weight) + Weight gain per age * Energy per kilo of weight gain + Lactation Requirement	
0+	(-99.4 + 88.6 * Body Weight) + 2 * Weight gain per age* Energy per kilo of weight gain + Lactation Requirement	if under 5 mortality is greater than 10‰
1+	0.93 * (310.2 + 63.3 * Body Weight - 0.263 * Body Weight^2) + Weight gain per age * Energy per kilo of weight gain	
1+	0.93 * (310.2 + 63.3 * Body Weight - 0.263 * Body Weight^2) + 2 * Weight gain per age * Energy per kilo of weight gain	if under 5 mortality is greater than 10‰
2+ to 9+	(310.2 + 63.3 * Body Weight - 0.263 * Body Weight^2) + Weight gain per age * Energy per kilo of weight gain	
10+ to 17+	0.85 * (310.2 + 63.3 * Body Weight - 0.263 * Body Weight^2) + Weight gain per age * Energy per kilo of weight gain	
18+ to 29+	PAL * (692.2 + 15.057 * Body Weight)	
30+ to 59+	PAL * (873.1 + 11.472 * Body Weight)	
60+	PAL * (587.7 + 11.711 * Body Weight)	

Notes and data sources:

1) The first part of the equation, for example; (-99.4 + 88.6* Body Weight) for childs 0+, is the age-specific model to predict the total energy expenditure (TEE). See FAO (2004) for more details.
2) Body weight = BMI*(height/100)^2, where: BMI is the WHO reference BMI, which is constant for all countries, while heights are specific to each country and are generally available from DHS databases (http://www.measuredhs.com) or UNICEF - Multiple Indicator Cluster Surveys. Body weights, BMI and heights are specified by age and gender.
3) Weight gain per age are constant for all countries and are available from WHO: Measuring change in nutritional status. The energy per kilo of weight gain is also constant for all countries. (Available from FAO, 2004)
4) Under 5 mortality rates (U5MR) are specific to each country and are made available from UNICEF.
5) Physical activity level (PAL) for a light (sedentary) activity level is fixed at 1.55 for all countries and has been established during a Technical meeting held in Rome in January 2005.

Table 4. Example for Tajikistan 2003-Females

AGE	Attained HEIGHT (cm)	BMI (Body Mass Index)	Body Weight (kg) (3)*((2)/100)^2))	Weight gain per age (gr per day)	Energy per kilo of weight gain (kcal)	PAL (Physical Activity Level)	Lower Limit of Energy Requirement MDER (kcal/caput/day)
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
FEMALES							
0+	67	16.9	7.6	15.1	4.4		705.4
1+	79	15.7	9.8	6.6	2		825.8
2+	88	15.5	12.0	6.3	2		994.4
3+	96	15.3	14.1	5.2	2		1104.3
4+	102	15.3	15.9	4.7	2		1197.1
5+	108	15.246	17.8	4.9	2		1290.9
6+	115	15.32	20.3	6.3	2		1412.7
7+	121	15.524	22.7	8.2	2		1529.5
8+	124	15.874	24.4	10.1	2		1607.0
9+	130	16.343	27.6	11.0	2		1742.6
10+	135.7	14.128	26.0	7.9	2		1422.6
11+	141.4	14.623	29.2	8.8	2		1534.4
12+	147.5	15.193	33.1	9.9	2		1656.7
13+	152.7	15.768	36.8	9.9	2		1762.7
14+	157.3	16.278	40.3	8.8	2		1851.0
15+	159.9	16.674	42.6	6.6	2		1902.0
16+	161.2	16.941	44.0	3.8	2		1927.2
17+	162.2	17.098	45.0	1.6	2		1943.1
18+	160.2	17.188	44.1			1.55	1767.4
19+	160.2	16.87	43.3			1.55	1748.6
20-24+	160.2	17.38	44.6			1.55	1778.7
25-29+	160.2	17.38	44.6			1.55	1778.7
30-34+	160.2	17.38	44.6			1.55	1872.5
35-39+	160.2	17.38	44.6			1.55	1872.5
40-44+	160.2	17.38	44.6			1.55	1872.5
45-49+	160.2	17.38	44.6			1.55	1872.5
50-54+	160.2	17.38	44.6			1.55	1872.5
55-59+	160.2	17.38	44.6			1.55	1872.5
60-64+	160.2	17.38	44.6			1.55	1648.6
65-69+	160.2	17.38	44.6			1.55	1648.6
70+	160.2	17.38	44.6			1.55	1648.6
	Specific to country height by age and gender	50th for 0+ to 9+ and 5th for 10+ to 70+	(3)*((2)/100)^2))	WHO: Measuring change in nutritional status		Energy requirement per 24 hours for light activity	Equation from Table 3

Table 5. Example for Tajikistan 2003-Males

AGE	Attained HEIGHT (cm)	BMI (Body Mass Index)	Body Weight (kg) (3)*((2)/100)^2))	Weight gain per age (gr per day)	Energy per kilo of weight gain (kcal)	PAL (Physical Activity Level)	Lower Limit of Energy Requirement MDER (kcal/caput/day)
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
MALES							
0+	68	**17.3**	8.0	16.2	4.1		741.9
1+	80	**16.1**	10.3	6.6	2		895.4
2+	89	**15.8**	12.5	6.3	2		1073.8
3+	97	**15.4**	14.5	5.8	2		1183.7
4+	104	**15.3**	16.5	5.5	2		1296.7
5+	111	**15.264**	18.8	5.5	2		1418.6
6+	116	**15.382**	20.7	6.0	2		1519.8
7+	122	**15.602**	23.2	6.6	2		1651.5
8+	127	**15.886**	25.6	7.7	2		1774.8
9+	132	**16.233**	28.3	9.0	2		1908.3
10+	136.6	**14.287**	26.7	6.3	2		1551.8
11+	141.4	**14.669**	29.3	8.2	2		1665.9
12+	146.2	**15.136**	32.4	10.4	2		1791.2
13+	151.4	**15.685**	36.0	13.2	2		1935.5
14+	157.3	**16.265**	40.2	14.2	2		2095.5
15+	163.9	**16.819**	45.2	13.4	2		2265.2
16+	168.9	**17.319**	49.4	10.7	2		2397.7
17+	172.2	**17.747**	52.6	6.6	2		2489.2
18+	172.6	**18.096**	53.9			1.55	2331.1
19+	172.6	**17.80**	53.0			1.55	2310.5
20-24+	172.6	**18.66**	55.6			1.55	2370.3
25-29+	172.6	**18.66**	55.6			1.55	2370.3
30-34+	172.6	**18.66**	55.6			1.55	2341.8
35-39+	172.6	**18.66**	55.6			1.55	2341.8
40-44+	172.6	**18.66**	55.6			1.55	2341.8
45-49+	172.6	**18.66**	55.6			1.55	2341.8
50-54+	172.6	**18.66**	55.6			1.55	2341.8
55-59+	172.6	**18.66**	55.6			1.55	2341.8
60-64+	172.6	**18.66**	55.6			1.55	1920.0
65-69+	172.6	**18.66**	55.6			1.55	1920.0
70+	172.6	**18.66**	55.6			1.55	1920.0
	Specific to country height by age and gender	50th for 0+ to 9+ and 5th for 10+ to 70+	(3)*((2)/100)^2))	WHO: Measuring change in nutritional status		Energy requirement per 24 hours for light activity	Equation from Table 3

APPENDIX I: Aggregation of Prices for the Food Groups

The disaggregated data obtained through the World Bank's International Comparison Program (ICP 2005) include: Basic Headings Purchasing Power Parities (PPPs), Basic Headings Nominal Expenditures, Official Exchange Rates and Population. Therefore, deciding how to incorporate the price data into the demand system is not trivial for a series of reasons. First, prices denominated in national currencies cannot be used in a cross-country assessment since they represent different units of measurement, i.e. one Euro is different from one USD. Second, the use of the official exchange rates to convert the data into a single currency would not be a good solution since we need to account for the fact that goods and services are cheaper in the less developed countries. Finally, in order to estimate elasticities in the demand system the data need to be aggregated at the level of each food expenditure group. This aggregation can be done only if the additivity condition in the data holds. This means that the total group expenditure equals the sum of the individual food items composing that group. The use of the purchasing power parity data solves the first two problems regarding the units of measure but it may not maintain the additivity condition during the aggregation.

In this study, we use the Geary-Khamis procedure, which is the same used in the Seale et al. (2003) paper. Based on this method, we calculated the price of the food group *j* in country *c* using the following equation:

$$P_{cj} = \frac{\sum_i E_{cji} / \pi_{cji}}{\sum_i V_{cji}},$$

where: E_{cji} represents the per capita expenditure in national currency of country *c* for the food item *i* which is part of the food group *j*; V_{cji} is the per capita expenditure in USD; and, π_{cji} is the purchasing power parity.

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