Undernutrition Overestimated*

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> It is not easy to think of any social problem in the contemporary world that deserves greater attention than the foggy adversity of chronic and widespread undernutrition.[1]

I. Introduction

Chronic undernutrition is widely considered one of the most deplorable tribulations of the poverty and misery in which large sections of the population in many parts of the world still live. Undernutrition is not only a consequence of poverty, however, but also a cause. Although seldom quantifiable with the desirable accuracy, undernutrition reduces the productivity of people directly, and also indirectly, by making them more susceptible to illness.[2] Undernutrition, especially among young children, also increases the risk of premature death.[3] Moreover, for those surviving, undernutrition in infancy and childhood is linked to chronic health problems in adulthood. Undernutrition may also affect cognitive development during childhood and, hence, impair the accumulation of the human capital that is crucial for economic growth and poverty alleviation.[4]

In late 1996, heads of states and representatives of governments from 186 nations gathered at the World Food Summit in Rome to address "the world hunger problem." The attendees unanimously agreed to reduce by half the absolute number of undernourished people in the world before the year 2015. To accomplish this worthy objective through new policy initiatives, a necessary, but far from sufficient, condition is the identification of those countries in which the "hunger problem" is most prevalent. Otherwise, it will be impossible to design and target the national and international policy interventions. Moreover, if undernourishment is to be halved before 2015, the initial number of undernourished must be known; to monitor progress, reliable time-series data are needed.

The Food and Agriculture Organisation (FAO) of the United Nations,

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which prepared the main policy documents for the World Food Summit and convened the event, claims to know the number of chronically undernourished. Based on estimates of national food "availability" and its distribution across households in most developing countries, the FAO purports that, altogether, 841 million people were chronically undernourished during 1990–92.[5] The FAO also claims to know the prevalence of undernutrition (POU) in 98 individual countries and that these estimates are "fully comparable across countries."[6] It ranges from close to nil in South Korea to well above 50% in Afghanistan and a half-dozen African countries. The FAO also claims to know how POU has changed in the 98 countries since 1969–71 and that it has appropriate data for monitoring progress toward the 2015 objective. Since the international community's efforts to attain this worthy objective—and also the monitoring—are to be based on the FAO analysis, its reliability is imperative.[7]

My previous work has demonstrated the fragility of the empirical basis for most of the parameter values inserted into the model used by the FAO in its pursuit to estimate POU in various parts of the world.[8] Keeping with the FAO model, I have also shown that POU estimates are highly sensitive to slight alterations in these already uncertain parameter values. The essence of this earlier work was to point out the large margins of uncertainty in the input data used by the FAO rather than to focus on systematic biases in the estimation model and in the data, which is the objective of this article.[9]

As others have demonstrated, the estimation model used by the FAO has a built-in flaw that leads to biased estimates of POU, irrespective of the accuracy of the data used for the calculation. An alternative, "unbiased" estimation model was first suggested by P. V. Sukhatme, a former chief statistician at the FAO; his model and the current one used by the FAO are briefly replicated in Section II below.[10] L. Naiken, the recently retired chief statistician at the FAO, conjectures that the alternative model was never used by Sukhatme in empirical work because all the data required were not available.[11] Naiken further cites the lack of data as the reason why the FAO has not made use of that estimation method.[12]

In this article, I will demonstrate that with the data the FAO actually claims to possess, the FAO could very well have used the "unbiased" method for the estimation of POU (Sec. III). I will also show that when applying the "unbiased" estimation model while using the FAO parameter values, the estimated POU becomes implausibly high (Sec. IV). I will argue further that this is a consequence of systematic biases in the parameter values inserted by the FAO in its calculations (Sec. V). Reestimation of POU, applying the "unbiased" model and alternative parameter values that are found to be more adequate, suggests that the FAO estimates of POU are biased upward on a net basis (Sec. VI). Hence, one can separate the downward bias induced in the FAO estimates of POU by the use of a faulty model and the upward bias induced by the use of inaccurate data for key parameters. The revised (net) lower estimates of POU square better with anthropometric observations, the

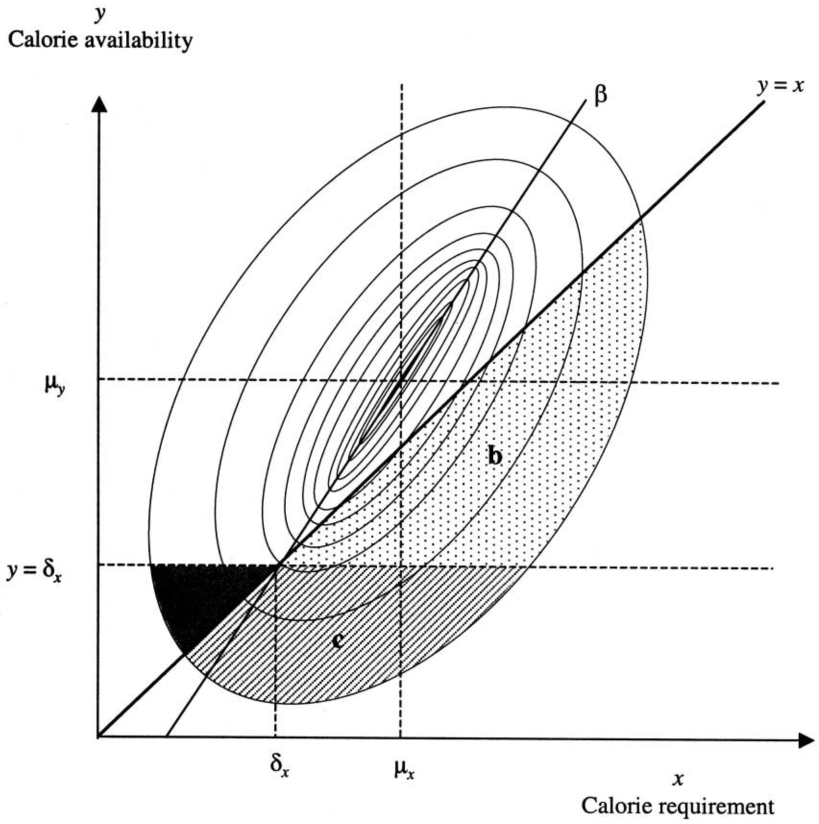

FIG. 1.—Joint distribution of per capita calorie intake and minimum calorie requirement in a population.

main alternative indicators of undernutrition (Sec. VII). On the basis of previous findings, suggestions for improvements in the FAO method for estimating POU are offered in Section VIII.

II. Estimation Models and Data Needs

The essential difference between the Sukhatme model and the one applied by the FAO can be described with the help of figure 1.[13] The common starting point is that there is a distribution of per capita calorie intakes and a distribution of minimum per capita calorie requirements (MPCCR) across households in all populations. The habitual per capita calorie intake (availability) of households is measured along the *Y* axis, with a mean at μ_y. The households' MPCCR are measured along the *X* axis, with a mean at μ_x. The MPCCR is what is needed, first, to maintain the lowest body weight for a given height consistent with health and, second, to fuel "necessary" physical activity (elaborated below). The households with the lowest MPCCR are the ones with members who have relatively small bodies (e.g., young children) and the ones where the adults are engaged in light physical work activities. The households at the highest end of the MPCCR distribution comprise mostly adults and adolescents, and most members are engaged in heavy manual work activities.

That the joint distribution—truncated at the edges and depicted as an ellipse—stretches out in the southwest-to-northeast direction reflects an assumption that there is a positive (but not perfect) correlation between per capita calorie intake and the minimum requirement across households in the population. The β-line gives the regression slope for (y, x). As we move toward the joint means of μ_x and μ_y, the increasingly closer oval isocontures indicate that the density of the joint function assumes its highest value here. Or, inversely, as we move away from the joint mean in different directions, we find increasingly smaller percentages of the population.

Prevalence of Undernutrition Estimates with the Joint-Distribution Model

The households in the joint distribution that are above the 45° line in figure 1 have a higher habitual per capita calorie intake (y) than they require to avoid undernutrition (x). That is, for all households (j) in this part of the joint distribution, $y_j > x_j$. These households are well nourished in the sense that the people have body weights and physical activity levels above the minima needed for health and functions. (Some of these households may be "overnourished," i.e., overweight or obese, but this subset is ignored in the following analysis.) The households (k) below the 45° line have intakes that fail to meet their specific MPCCR, signifying that $y_k < x_k$. These households are classified as undernourished. Quite obviously, the households on the 45° line have intakes that exactly match their minimum requirements ($y_i = x_i$). The households below the 45° line, namely, those in areas c and b (differentiated in fig. 1 with various shading), constitute, as a share of the total number of households, what I will call an "unbiased" estimate of POU.

To estimate the share of a population that is found in areas c and b (and, hence, obtain an unbiased POU estimate), data are required for all the parameters needed to solve the double integral:

$$\int_{-\infty}^{\infty}\int_{y}^{\infty}\frac{1}{2\pi\sigma'_x\sigma'_y\sqrt{1-\rho^2}}\exp\left[-\frac{q(x,y)}{2}\right]dxdy, \tag{1}$$

where

$$q(x,\,y)=\frac{1}{1-\rho^2}\left[\left(\frac{x-\mu'_x}{\sigma'_x}\right)^2-2\rho\left(\frac{x-\mu'_x}{\sigma'_x}\right)\left(\frac{y-\mu'_y}{\sigma'_y}\right)+\left(\frac{y-\mu'_y}{\sigma'_y}\right)^2\right], \tag{2}$$

and

$$\mu'_i = \log\mu_i-\frac{1}{2}\log(CV_i^2+1)\ \ i\in\{x,\,y\}, \tag{3}$$

$$\sigma_i' = \sqrt{\log(CV_i^2 + 1)}\ i \in \{x, y\}, \tag{4}$$

where ρ is the correlation coefficient between household per capita calorie intake and minimum requirement, and σ_y and σ_x are the standard deviations (SD) in the availability and requirement distributions, respectively. In the calculations to be carried out below on the basis of equations (1)–(4), it is assumed that the joint distribution is log-normal.[14] (For expository convenience, the distribution in fig. 1 was depicted as joint normal.)

Prevalence of Undernutrition Estimates with the FAO Model

The FAO starts out by estimating the per capita availability of calories (μ_y) in individual countries and the SD in the distribution of the available calories across households (σ_y) in the respective country. Subsequently, the FAO sets up a norm for what is the “lowest acceptable” MPCCR for all households in a respective population, called the calorie cutoff point (CCOP). In figure 1, this cutoff point is δ_x. All households with a per capita intake (availability) below this point ($y_k < \delta_x$) are classified as undernourished by the FAO. As a share of total population, these households, corresponding to areas *a* and *c*, constitute the estimated POU derived by the FAO. (Area *a* is bounded from above by the horizontal line $y = \delta_x$ and from below by the 45° line indicating $y = x$.)

The FAO estimation method hence reduces to solving the single integral:

$$\int_{-\infty}^{\delta_x} \frac{1}{\sigma_y'\sqrt{2\pi}} \exp\left(-\frac{(y - \mu_y')^2}{2\sigma_y'^2}\right) dy. \tag{5}$$

On the face of it, this estimation model may seem less demanding data wise than the joint-distribution method, but, as will be shown in the second part of Section IV, this turns out not to be the case.

From figure 1, one can immediately see that the FAO estimates contain two types of errors. The observations in area *a* are classified as undernourished while in fact they are well nourished; these are false positives. The observations in area *b* are classified as well nourished but are in fact undernourished; these are false negatives. If the number of false positives and false negatives differ, POU estimates are either downward or upward biased.[15] Quite obviously, the relative size of the false positive and negatives depends on where the cutoff point is established.

The official documents from the FAO make no mention of biases.[16] Here it is implicitly maintained that the cutoff points have been set at levels ensuring that the false positives and negatives are of equal size in all countries and, hence, offsetting. Before probing the empirical validity of this possibility, I shall describe—as a stepping-stone—how the FAO has derived its calorie cutoff points (δ_x in fig. 1).

III. The Calorie Cutoff Points

In deriving its calorie cutoff point for a country, the FAO begins by estimating the minimum per capita calorie requirement for the average household (μ_x) in the population. This estimate is derived from the following formula:

$$\mu_x = \Sigma\alpha_i \text{PAL}_i[\text{BMR}_i(W_i)], \text{ for } i = 1 \ldots n \text{ age and sex categories.} \quad (6)$$

The basal metabolic rate (BMR) is the energy requirement for internal body functions during complete rest (sleep), which is determined by body weight (*W*). Per kilogram of body weight, the BMR is assumed to be identical across populations for each age and sex category (*i*). For adolescents and adults, the "desirable" weight (*W*) is set at the median of the range of body weights (for height) that is consistent with good health and physical functioning. This height-adjusted weight is derived from a body mass index (BMI) equal to 22.0.[17] The acronym PAL stands for the daily average physical activity level for the average (adult) person in the population that is compatible with functions and "economically necessary work." The PAL is expressed as a multiple of BMR, which means that if a particular physical activity requires an energy expenditure twice that of sleep, the ensuing PAL is equal to 2.0.[18] Finally, the α_i are the weights (shares) of different age and sex categories in the population in the respective country. (Hence, the α vector is the only entity in eq. [6] that is allowed to vary across regions/countries.)

The first column of table 1 specifies what the FAO has estimated to be the MPCCR for the average household (μ_x) in the five major geographical regions in the developing world. Column 2 lists what the FAO calls the "lowest acceptable" per capita energy requirement, or the cutoff point it uses to delineate the undernourished households. The cutoff point (δ_x) is derived as 2 SDs (σ_x) below the estimated MPCCR for the average household (μ_x) in the respective region:

$$\delta_x = \mu_x - 2\sigma_x. \quad (7)$$

The coefficient of variation is defined as

$$CV_x = \sigma_x/\mu_x. \quad (8)$$

Substituting equation (7) into equation (8) and rearranging, we get

$$CV_x = (1 - \delta_x/\mu_x)/2. \quad (9)$$

With the help of equation (9), one can put numbers on the distribution of the MPCCR that the FAO has worked with, although not published.[19] It then turns out (table 1, col. 5) that the FAO has attached a specific value to the CV_x parameter (0.075), which is the same for each and every region (and country).

Some, but not all, of the details on how the FAO has arrived at the precise number attached to the CV_x parameter are traceable.[20] It is acknowledged that "there is a range of energy requirements for individuals" related to "a range of body weights that are consistent with healthy individuals" and "a range of

TABLE 1

DERIVATION OF THE IMPLICIT COEFFICIENT OF VARIATION IN INTERHOUSEHOLD PER CAPITA CALORIE REQUIREMENT DISTRIBUTION (CV_x) USED IN THE FAO ESTIMATES OF POU, BY MAJOR GEOGRAPHICAL REGIONS, 1990–92

Region	Average Calorie Requirement* (μ_x) (1)	Minimum Calorie Requirement* (δ_x) (2)	Two Standard Deviations ($2\ \sigma_x$) (3)	One Standard Deviation (σ_x) (4)	Coefficient of Variation (CV_x) (5)†
Sub-Saharan Africa	2,100	1,800	300	150	.075
Near East and North Africa	2,150	1,840	310	155	.075
East and Southeast Asia	2,220	1,880	340	170	.075
South Asia	2,110	1,790	320	160	.075
Latin America and Caribbean	2,200	1,870	330	165	.075

SOURCE.—The values in cols. 1–2 are from the FAO, *The Sixth World Food Survey* (Rome: FAO, 1996), table 16.

NOTE.—$2\sigma_x = \mu_x - \delta_x$. $CV_x = \sigma_x/\mu_x$. FAO = Food and Agriculture Organisation of the United Nations; POU = prevalence of undernutrition.

* Number of calories per capita per day for households.

† Dividing col. 4 with col. 1 gives CV_x values that differ on the third decimal points because the FAO has rounded off the values of μ_x and δ_x to even 10 numbers. A quick check reveals that "imagined" nonrounded numbers attached to these two entities are consistent with a uniform CV_x of 0.075 for all five regions.

physical activity levels that may be considered to be economically necessary."[21] The lower limit for adult body weight set by the FAO corresponds to a BMI of 18.5; health risks have been identified in medical studies for people below this weight. This number implies a coefficient of variation in health-consistent body weight of about 0.08 (table A1). Variations in requirements for other age cohorts, namely, children and the elderly, may have been considered, but no details have been published.

The energy requirements for physical activity in work have been derived from laboratory measures of the average physical activity levels (PAL) needed to pursue the kind of job activities in which most working-age people in the developing countries are engaged.[22] These estimated averages are subsequently scaled down somewhat, to what the FAO on normative grounds finds to be the minimum "desirable" work activity for adult individuals in all countries.[23] The implicit coefficients of variation in the distribution of work activities are 0.078 for men and 0.046 for women. On this basis, the FAO estimates that the minimum energy requirement during working hours corresponds to a PAL of 2.53 for men and 2.57 for women.[24] By weighting the PALs for the different daily activities, the FAO arrives at an average PAL over 24 hours of 1.55 for men and 1.56 for women (table A1). These numbers are applied worldwide, irrespective of intercountry differences in job activities and work productivity.

IV. "Unbiased" POU Estimates Possible?

The FAO has refrained from estimating POU with the joint-probability distribution model, citing the lack of data on certain parameters. This section demonstrates that with the data the FAO actually claims to possess, one can derive estimates of POU based on the joint-distribution formula. Comparing these "unbiased" estimates with the ones actually derived by the FAO provides an indication of the size of the bias induced by the FAO estimation methodology, based on calorie cutoff points (while ignoring, for the time being, biases in the data).

The Missing Parameters

The two parameter values that the FAO claims are missing and that prevent the use of the joint-distribution model are the SD in the interhousehold MPCCR distribution (σ_x) and the correlation between intake and minimum requirement across households (ρ). As shown in table 1, the first of these parameters (σ_x) has, in fact, been assigned a specific value by the FAO in its pursuit to establish the calorie cutoff points. There are no empirically based data on the second parameter (ρ).

Theoretically, ρ can assume values in the range $0 \leq \rho \leq 1$. The zero value is obtained when there is no correlation whatsoever between per capita calorie intakes and minimum requirements across households; the value unity is obtained when the correlation is perfect. Without presenting definitive numbers, the FAO maintains that "a high positive correlation between intake and requirement" should be expected.[25] This notion is based on the analysis provided by an expert committee involved in the preparations for *The Fifth World Food Survey*. The committee argues that the expected correlation should be high because "most people have the ability to select their food intake in accordance with their energy requirement over the long term, since it is believed that regulatory mechanisms operate to maintain a balance between energy intake and energy requirement over long periods of time."[26]

In the absence of empirically derived values of the correlation coefficient ρ, what I do in the following is to set up a range of "plausible" values. I assume, in accordance with the FAO expert committee, that the household per capita calorie intake (effective demand) is a function of the household minimum calorie requirement and other parameters, such as a preference for body weights and physical activity levels above the minimum health-consistent ones and, hence, the income needed to satiate these preferences. If the household-specific minimum requirements explain 25% of the total interhousehold variability in habitual intakes in a population, as conventionally measured by adjusted R^2, the ensuing ρ takes the value 0.50 ($R^2 = \rho^2$). If varying minimum requirements explain 81% of the variability in habitual intakes, ρ assumes the

TABLE 2

Robustness Test of Unbiased Estimates of POU to Variation in the Correlation Coefficient, by Major Geographical Regions, 1990–92 (%)

Region	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	Assumed Range of Correlation Coefficient (ρ)						
	.00	.40	.50	.60	.70	.80	.90
	Estimated POU (%)						
Sub-Saharan Africa	56	57	57	57	57	58	58
Near East and North Africa	27	25	24	24	23	22	21
East and Southeast Asia	36	35	34	33	33	32	31
South Asia	46	46	46	46	46	45	45
Latin America and Caribbean	34	32	32	31	31	30	29

Source.—Estimates based on the joint-distribution method and Food and Agriculture Organisation of the United Nations (FAO) data (see text).

Note.—POU = prevalence of undernutrition. It should be noted that when ρ assumes increasingly higher values, the estimated POU for the sub-Saharan African region increases marginally but declines in the other four regions. The reason for this is that, for sub-Saharan Africa, the FAO estimate of per capita availability of calories is below the estimated average per capita calorie requirement ($\mu_y < \mu_x$), while the opposite holds in the other regions (see table 5 below).

value 0.90. I hence interpret the FAO's, and the expert committee's, expectation that the correlation should be "high" to imply that it assumes a value in the range $0.50 \leq \rho \leq 0.90$.

The "Unbiased" POU Estimates

With the range of plausible values of ρ, we have data for all the parameters needed to derive "unbiased" estimates of POU with the aid of the joint-distribution formula (eq. [1]). Table 2 shows that whatever the number assigned to ρ in the "high" range ($0.50 < \rho < 0.90$), the estimated POU for all the major geographical regions does not change by more than a few percentage points. It also turns out that this robustness carries over to a wider range of ρ values ($\rho < 0.50$). Even under the extreme assumption that there is no correlation whatsoever between per capita intakes and minimum requirements ($\rho = 0$), the "unbiased" estimates of POU remain largely unaltered.[27]

Comparing FAO with "Unbiased" POU Estimates

The "unbiased" POU estimates are compared with the estimates derived by the FAO (col. 1), using CCOP's, in table 3. The numbers in table 3, column 2 were obtained by reestimating POU with the FAO method. The reason for the discrepancy between columns 1 and 2 in table 3 is that the FAO's regional estimates have been derived as weighted averages of estimates for individual countries (with the notable exception of sub-Saharan Africa, which is presumably treated as one country by the FAO). The recalculated POU estimates

TABLE 3

COMPARISON BETWEEN FAO AND "UNBIASED" ESTIMATES OF POU, BY MAJOR GEOGRAPHICAL REGIONS, 1990–92 (%)

Region	Estimates Based on FAO Calorie Norms ($a + c$ in fig. 1)		Unbiased Estimates	Percentage Point Bias	
	FAO (1)	Reestimated (2)	($b + c$) (3)	FAO (4)	Reestimated (5)
Sub-Saharan Africa	43	43	57	−14	−14
Near East and North Africa	12	17	23	−11	−6
East and Southeast Asia	16	22	33	−17	−11
South Asia	22	32	46	−24	−14
Latin America and Caribbean	15	21	31	−16	−10

SOURCE.—The numbers in col. 1 are from FAO, *The Sixth World Food Survey* (Rome: FAO, 1996), table 14. The numbers in col. 2 were obtained when POU was reestimated with the FAO method (see text). The numbers in col. 3 are from table 2 above (for $\rho = 0.70$). The numbers in col. 4 are derived by subtracting values in col. 3 from values in col. 1. The numbers in col. 5 are derived by subtracting values in col. 3 from values in col. 2.

NOTE.—FAO = Food and Agriculture Organisation of the United Nations; POU = prevalence of undernutrition.

here are derived on the basis of (aggregate) data for regional averages. The FAO's estimates of POU could not be replicated for the simple reason that the country-specific "input" data on CCOPs and CV_y used by the FAO have not been published. Table 3, column 3, gives the "unbiased" estimates (for $\rho = 0.70$), as reported in table 2.

The difference between the numbers in columns 2 and 3 in table 3 suggests, first, that the FAO's method—relying on CCOP's—leads to an underestimation of POU in all major geographical regions for given (FAO) input data. In terms of figure 1, this means that the observations in area *a* (the false positives) are much fewer than those in area *b* (the false negatives). The FAO's implicit claim that its POU estimates are unbiased is hence rejected.[28] Moreover, that the underestimation is larger for some regions than others implies that the cross-regional comparability is compromised.[29]

V. Are the FAO Data to Be Trusted?

The implausibly high POU estimates obtained when applying the "unbiased" method raises concern as to whether there is something wrong with FAO input data. (The incompatibility of these estimates with the anthropometric indicators of undernutrition also suggest this—cf. Sec. VII.) In what follows, I shall briefly discuss some doubts about the accuracy of the FAO's main parameter values.

The Minimum Per Capita Calorie Requirement for an Average Household

Two of the core assumptions behind the establishment of the MPCCR for the average household, as derived by the FAO, are that the median of the range of health-consistent body weights corresponds to a BMI of 22.0 and that, on average, people should be able to work with an intensity given by a PAL multiple of 3.0 during work hours (table A1). The first of these assumptions seems to square with empirical evidence and is accepted by most physiologists and nutritionists. If one accepts the normative justification for establishing standards for physical activity, the second assumption seems noncontroversial as well.

Two other core assumptions behind the MPCCR for the average household (as well as the lower-bound household) as estimated by the FAO are questionable, however. These are the assumptions that the BMR per kilogram of body weight is (1) a constant and (2) is of equal size for people of a given age and sex in all populations. There has been a long and heated debate on the "constancy" issue. The FAO has sided with those who claim that the human body's ability to lower metabolism in the wake of low energy intake is too small to be considered. Since no widely accepted conclusion has emerged, the FAO position is ambiguous but cannot be disproved.[30]

When it comes to the further assumption that BMR per kilogram is identical across populations, however, there is reason to object. Several studies during the 1990s have shown that people in the "tropics" have, on average, about 10% lower BMR per kilogram than people in the "north."[31] In establishing its calorie norms, the FAO has used data regarding BMR per kilogram for northern populations and has applied them worldwide. A 10% lower BMR per kilogram, and hence lower MPCCR for the average household, would mean (ceteris paribus) cutoff points that are equally much lower (cf. eq. [6]).

The Calorie Requirement Distribution Estimates

The lower bound of the range of health-consistent body weights for adolescents and adults used by the FAO to derive its cutoff points ($\mathrm{BMI} = 18.5$) is widely accepted. The minimum allowance of energy for work (PAL) in the cutoff points (see table A1) is established on normative grounds that can only be challenged by invoking other subjective arguments.

There is one outright omission in the FAO calculations of the distribution of MPCCRs across households, however. As emphasized by Naiken, the "FAO has adopted an approach that considers the *household* rather than the *individual* as the unit of assessment."[32] Hence, it is of consequence that one factor with notable influence on the variance in the minimum per capita calorie requirement across households is entirely left out in the FAO estimates: the fact that different households have different sizes and compositions in terms of age and sex (although Naiken admits that it should not have been left out, had data been available).

There are, unfortunately, no ready-to-use estimates of the composition

TABLE 4

EXAMPLES OF ESTIMATED PER CAPITA CALORIE REQUIREMENT FOR BMR AND MPCCR FOR HOUSEHOLDS OF DIFFERENT SIZE AND AGE COMPOSITION

	BMR OF INDIVIDUALS*							
	Number of Adults†		Number of Children‡					
COMPOSITION OF HOUSEHOLD	(1)	(2)	(1)	(2)	(3)	(4)	BMR PER CAPITA (FAO) *Alternate*§	MPCCR[‖](FAO) *Alternate*§
A. One adult and two children aged 1 and 4	1,330	…	430	850	…	…	870 *785*	1,350 *1,215*
B. Two adults and two children aged 1 and 4	1,330	1,330	430	850	…	…	985 *885*	1,535 *1,380*
C. One adult and four children aged 1, 4, 7, 10	1,330	…	430	850	980	1,170	950 *855*	1,485 *1,335*
D. Two adults and four children aged 1, 4, 7, 10	1,330	1,330	430	850	980	1,170	1,015 *915*	1,585 *1,425*
M. Two adults and four children-adolescents ages 10, 13, 16, and 19	1,330	1,330	1,170	1,350	1,420	1,460	1,345 *1,210*	2,095 *1,885*

SOURCE.—All base data on BMR per kilogram of body weight are from Food and Agriculture Organisation/World Health Organization/United Nations University, *Energy and Protein Requirements* (Geneva: WHO, 1985), as replicated in table A3.

NOTE.—BMR = basal metabolic rate; MPCCR = minimum per-capita calorie requirements; FAO = Food and Agriculture Organisation of the United Nations; BMI = body mass index.

* Average for males and females.

† The BMR for adults has been calculated from a BMI = 18.5 for a given height of 168/157 cm for males/females.

‡ The BMR for children below the age of 10 has been derived from normal body weights in the reference population, and the BMR for adolescents has been derived from a BMI = 18.5 and heights equal to normal height for age in the reference population.

§ Italicized numbers in these columns are 90% of the values derived on the basis of data from Food and Agriculture Organisation/World Health Organization/United Nations University, *Energy and Protein Requirements*.

[‖] MPCCR = 1.56 times BMR per capita.

of households according to age, sex, and size in the various countries of the world. What I do here is to estimate the per capita BMR and MPCCR for a few “typical” household categories with different size and age structures. For each household category, two sets of per capita BMR and MPCCR estimates are derived (table 4). One set is derived on the basis of BMR data used by the FAO itself.[33] The other set is estimated as 90% of these data so as to account for the observation that people in the “tropics” have lower BMR per kilogram of body weight than northerners (the latter estimates are in italics).

The household categories with the lowest per capita BMR, and hence the lowest MPCCR, are those with a young profile (categories A–D, table 4), comprising one or two adults and a few young children (with small bodies). The MPCCR estimates for these households are well below the FAO cutoff points at around 1,800. In the other tail of the requirement distribution are households with an "old" composition, mainly adults and adolescents (category M, table 4), with an MPCCR well above the FAO norm.

What the examples in table 4 reveal are that differences in household composition and size induce significant differences in per capita calorie requirement for BMR (and, hence, MPCCR). It should further be noted that "young" households (categories A–D, table 4), with household heads (parents) in their 20s and children predominantly below the age of 10, constitute between 35% and 45% of all households in the typical South Asian and African country.[34]

The Calorie Availability Distribution Estimates

The FAO has estimated the distribution of "available" calories across households with methods that differ from country to country depending on the kind of data obtainable: household expenditure surveys, estimates of household income distribution, and, as the crudest method when all data are lacking, extrapolations from "neighboring countries."[35] The country-specific CV_y estimates are not published, but the regional-average estimates are almost identical and hover around 0.30.[36]

The lack of alternative data prevents reestimation of the regional CV_y parameters. What we can do is "test" the plausibility of the availability distributions as estimated by the FAO. The lower "tails" of the FAO household per capita calorie availability distributions, about 5%, are shown in panel A of table 5 by major geographic regions. What the numbers in column 2 tell us is that in sub-Saharan Africa and in South Asia (with $CV_y \approx 0.30$, as suggested by the FAO), the households in the lower tail of the distribution have a calorie availability (intake) of 820– 920 per capita per day on a habitual basis (the availability estimates are derived by the FAO as 3-year averages).

It is doubtful whether a habitual per capita intake of 820–920 calories is feasible in a living household. These intakes are roughly half of the number of calories (about 1,800) that the FAO considers to be the minimum required to maintain the lowest body weight that is consistent with health (BMI $=$ 18.5) and relatively light daily physical activity (PAL $\approx$ 1.56). More important, acknowledging that minimum requirements vary with household size and composition, an intake of 820 calories is only about two-thirds of the MPCCR estimated for the household category with the lowest requirement (category A in table 4), at 1,215 calories. An amount that is two-thirds of this MPCCR is sufficient only to maintain a BMI of about 12.4 ($12.4 = 0.67 \times 18.5$) and a PAL of 1.38 ($1.38 = 1 + 0.67 \times 0.56$) for adolescents and adults. It also implies that the body weights for young children would be about two-thirds of what is regarded as "normal."

Clinical examinations have found that the critical low weight-for-height at which death occurs in adolescents and adults corresponds to a BMI of about 11 for males and 13 for females.[37] The lowest daily physical activity level consistent with life at complete rest, called the "short-term survival

TABLE 5

Estimated Lower-Bound Per Capita Calorie Availability and MPCCR for Different Combinations of Parameter Values, by Major Geographical Regions, 1990–92

A. Per Capita Calorie Availability in Low Tail

		CV_y		
Region	μ_y	.30 (1)*	.25 (2)*	.20 (3)*
Sub-Saharan Africa	2,040	820	1,020	1,225
Near East and North Africa	2,960	1,185	1,480	1,775
East and Southeast Asia	2,680	1,070	1,340	1,610
South Asia	2,290	920	1,145	1,375
Latin America and Caribbean	2,740	1,150	1,370	1,645

B. MPCCR in Low Tail

		CV_x		
	μ_x	.075 (1)†	.125 (2)‡	.15 (3)‡
Sub-Saharan Africa	2,100	1,800	1,420	1,325
Near East and North Africa	2,150	1,840	1,450	1,355
East and Southeast Asia	2,220	1,880	1,500	1,400
South Asia	2,110	1,790	1,425	1,330
Latin America and Caribbean	2,220	1,870	1,485	1,385

Source.—Data for μ_y and μ_x are from FAO, *The Sixth World Food Survey* (Rome: FAO, 1996), tables 1, 16.

Note.—MPCCR = minimum per capita calorie requirements.

* The estimates in this column are derived as $\mu_y(1 - 2CV_y)$.

† The estimates in this column are from the FAO (cf. table 1) and are derived as $\mu_x(1 - 2CV_x)$.

‡ The estimates in this column are derived as $0.90\ \mu_x(1 - 2CV_x)$.

requirement," is a PAL of about 1.27.[38] Young children with only about 60%–70% of the normal weight have been estimated to face a mortality risk that is five to six times the average in African and South Asian child populations, which means that the risk approaches unity.[39]

If it were the case that the households in the lowest tail of the intake distribution (5%) only have a habitual intake of 820–920 calories per capita per day over a 3-year period, we would witness permanent famine in sub-Saharan Africa and South Asia. That is, unrelated to war and natural catastrophes, tens of millions of people would die from outright starvation each year. Since there is no empirical evidence to support such a gruesome corollary, I tentatively conclude that the FAO has overestimated the interhousehold variance in household intakes, at least in these two regions.[40]

The National Per Capita Calorie Availability Estimates

An alternative or supplementary explanation for the implausible low-calorie intakes in the lower tail of the intake distribution, especially in sub-Saharan Africa and South Asia, is that the per capita availability of calories in these two regions (and possibly elsewhere) has been underestimated by the FAO. For the African countries it has been demonstrated that this is most likely the case.[41] The main reason is that very primitive methods for the enumeration of crop acreage are used throughout the region. This explanation does not carry over to South Asia, however. In fact, it was the examination of the introduction of modern crop estimation methods in this region that revealed that the primitive methods used there earlier (and still applied throughout Africa) led to the underestimation of cereal production by 20%–25% on average.[42]

There is reason to expect that food "availability" is underestimated in most parts of the developing world, although less so elsewhere than in Africa. A substantial share of the food produced in almost all developing countries is for subsistence, which tends to be underestimated in official statistics worldwide.[43] A related problem is that minor food items in all countries, such as fruits, vegetables, and poultry, are incompletely or not at all covered in the FAO statistics, as acknowledged in the *Food Production Yearbooks* in small print.[44] There are, however, no quantitative data available that can help us put numbers on these biases and no reliable method for checking their consistency.[45] I therefore choose the most cautious option possible and accept the FAO food availability estimates at face value in the reestimations of POU in Section VI. It should be noted, though, that underestimation of food (calorie) supplies, even if it defies quantification, in terms of direction, unambiguously leads to overestimation of POU (ceteris paribus).

VI. Reestimates of POU with Alternative Parameter Values

This section focuses on reestimating POU with both the FAO and the joint-distribution methods, but with alternative values for the main parameters. Acknowledging that people in the "tropics" have repeatedly been estimated to have a 10% lower BMR per kilogram of body weight than people from "northern" climates, I presume that the minimum per capita calorie requirement for the average household (μ_x) is 10% lower than that asserted by the FAO. Furthermore, the revised estimates will be based on the hypothesis that the FAO has overestimated the interhousehold variability in per capita calorie availability (CV_y) and underestimated the variability in per capita calorie requirement (CV_x). This means that only one of the four main parameters in the FAO estimations, national per capita calorie availability (μ_y), is left unaltered.

The Alternative Distribution Parameter Values

The CV_y parameter is assumed to take two alternative values, 0.25 and 0.20, respectively. These are below the value assigned to this parameter by the FAO

(≈ 0.30), which was found to produce habitual intakes in the lower tail of the distribution that seem impossible for living households, at least in Africa and South Asia. The alternative numbers are not very solid but have some empirical support. International Food Policy Research Institute researchers have derived CV_y estimates with relatively reliable methods in samples from five countries. For four of the samples, the estimated CV_y values are in the 0.17 to 0.27 range, and the five-sample average is 0.256, which is approximately equal to the higher of the two alternative values suggested here. The FAO itself has estimated CV_y for other countries with much cruder methods (see above) but did not publish the results. Some of these estimates evidently turned out to be implausibly large or small, which the FAO has "rectified" by truncating them to the 0.20 to 0.35 range.[46] It is notable that the two alternative CV_y values are within this range.

The CV_x parameter is also assigned two alternative values, 0.125 and 0.15. That these values are higher than the uniform value of CV_x (0.075) from the FAO accounts for the fact that the FAO has ignored the interhousehold variation in MPCCR resulting from differences in household size and age or sex composition. The highest alternative value of CV_x (0.15), together with a 90% of the μ_x value, produces calorie cutoff points (panel B of table 5) that are some 10%–20% higher than the estimated MPCCR for the households with the lowest requirements (table 4, category A).[47] These cutoff points square with the FAO principle that these should be set somewhat above the lower tail of the MPCCR distribution.[48]

Reestimation of POU with Alternative Parameter Values

Prevalence of undernutrition is first reestimated with the FAO method by relying on cutoff points but applying the alternative values of the key parameters (table 6, panel A). The first set of revised estimates (col. 2) suggests that POU is practically nonexistent in three of the five major regions, and 14% and 8% in sub-Saharan Africa and South Asia, respectively. The second set of revised estimates, based on parameter values somewhat further from those of the FAO (col. 3), shows POU ranging from 1% to 9% in the five regions.

Prevalence of undernutrition estimates based on the joint-distribution method and the alternative parameter values are reported in panel B of table 6 (cols. 2–3). These estimates are also considerably lower than the ones derived with this method and based on the FAO input data (col. 1).[49] This applies to sub-Saharan Africa as well, although the estimated POU here is less sensitive to alternative parameter values than for other regions.[50] The overall conclusion is that when empirically more reasonable values are attached to the key parameters, the estimated worldwide POU becomes considerably lower than what is purported by the FAO. This is the case with both estimation methods. These results are also robust to the application of alternative values of ρ.

TABLE 6

ESTIMATED POU WITH ALTERNATIVE METHODS AND COMBINATIONS OF PARAMETER VALUES, BY MAJOR GEOGRAPHICAL REGIONS, 1990–92

REGION	PARAMETERS	COMBINATION OF PARAMETER VALUES: FAO (1)	Alternative (2)	Alternative (3)
	CV_y	≈.30	.25	.20
	CV_x	.075	.125	.15
	μ_x*	1.00	.90	.90
		A. Estimated POU with FAO Method (%)†		
Sub-Saharan Africa		43	14	9
Near East and North Africa		17	2	1
East and Southeast Asia		22	5	2
South Asia		32	8	4
Latin America and Caribbean		21	4	1
		B. Estimated POU with Joint-Probability Method (%)†		
Sub-Saharan Africa		57	42	38
Near East and North Africa		23	7	3
East and Southeast Asia		33	16	9
South Asia		46	28	20
Latin America and Caribbean		31	14	7

SOURCE.—Author's calculations as explained in the text and in the notes below.

NOTE.—FAO = Food and Agriculture Organisation of the United Nations; POU = prevalence of undernutrition.

* The number .90 on this row means that this parameter has been assigned a value 90% of the FAO value.

† All estimates in this panel are derived on data for regional averages, as reported in table 3, col. 2, above.

VII. Comparison with Anthropometric Indicators

Anthropometric Measurements and Norms

The shares of people who have weights and heights below established anthropometric norms are the main alternative indicators of the nutritional (and health) status of a population that can be used to check the trustworthiness of the FAO estimates of POU. The most commonly applied anthropometric indicators for preschool children are the percentages below 2 SDs of the median height-for-age (*H/A*), weight-for-height (*W/H*), and weight-for-age (*W/A*) in a reference (norm) population. For adult women (ages 20–49 years), the most frequently used anthropometric indicators are the shares that have a BMI less than 18.5 and a height shorter than 1.45 meters. (For adult men, no widely accepted norms exist.) Since growth in stature ceases around the age of 20 independent of nutrition, however, height reveals practically nothing about an adult person's nutritional status (neither acute nor chronic), which is the concern here. The heights of adult persons indicate only their historical nutritional and health status (i.e., during childhood and adolescence).

Expected Correspondence between POU and Anthropometric Status

In the absence of measurement biases, one would expect the share of young children in a country who are stunted (below the height-for-age norm) to be consistently higher than a POU estimate derived from national per capita calorie availability. This expectation stems from the fact that inadequate access to calories is only one of many reasons why a child's growth falters. Other main reasons are frequent, prolonged, and untreated illness that reduce the appetite and the absorption of energy in the body. Energy may also be diverted by intestinal parasites. Malnutrition, understood as lack of crucial micronutrients in the form of minerals, vitamins, and proteins, as well as physically and mentally depriving environments, also prevent children from fully utilizing the energy in the food that they ingest and thwart growth in stature.[51]

The correspondence between estimates of POU in a country or region and the share of its population that is wasted (low weight for height) by anthropometric standards is of special concern. As shown in Section III, the lowest body weights that are health consistent constitute the core determinants of the calorie cutoff points set up by the FAO. What the FAO's estimates of POU basically measure, then, is the share of the households in a particular country or region that has a habitual per capita calorie intake that is insufficient to cover the energy expenditures (BMR) needed to maintain above-norm body weights for the household members. One thus expects that direct anthropometric assessment of body weight in representative sample populations in a country or region should find—on average—roughly the same percentages to be wasted as predicted by POU estimates.

The Empirical Picture

Estimates of the anthropometric status of young children and adult women in the major geographical regions for the early 1990s are reported in table 7. The hypothesis that the share of children who are stunted (table 7, col. 2) is higher than POU estimates from the FAO (col. 1) is corroborated by the data for most of the regions. The only exception is sub-Saharan Africa, the region for which the POU estimate is by far the highest. This abnormality strengthens the earlier suspicion that the FAO's estimate of POU for Africa is especially questionable (too high), mainly because its per capita calorie-supply estimate for this particular region is more downward biased than for elsewhere (cf. the fourth part of Sec. V).

The estimated shares of young children and adult women who are wasted, as reported in table 7, are averages for a large number of representative sample populations in the respective region (only a few, to which I will return below, are not representative; see table 7, nn. *, †). Most of these estimated averages

TABLE 7

Contrasting POU Estimates with Shares of the Population below Anthropometric Norms (%), by Major Geographical Regions, Early 1990s

Region	POU Estimates (FAO Method and Parameters) (1)	Anthropometric Status		
		Preschool Children		Adult Women
		$H/A < -2$SD* (2)	$W/H < -2$SD* (3)	BMI < 18.5† (4)
Sub-Saharan Africa	43	38	7	11
Near East and North Africa	17	32	9	2
East and Southeast Asia	22	33	5	16
South Asia	32	60	17	52
Latin America and Caribbean	21	23	3	6

Source.—POU estimates in col. 1 are taken from table 6 above and derived on data for regional averages. The estimates for preschool children in cols. 2–3 are from the WHO, *Global Data Base on Child Growth* (Geneva: WHO, 2000), as replicated by the FAO, *The Sixth World Food Survey* (Rome: FAO, 1996), table 21. The estimates for adult women in col. 4 are mainly from United Nations Administrative Committee on Coordination, Subcommittee on Nutrition Policy, *Fourth Report on the World Nutrition Situation* (Geneva: United Nations Administrative Committee on Coordination, Subcommittee on Nutrition Policy, 2000), table 1.8; also Marteen Nubé, “Confronting Dietary Energy Supply with Anthropometry in the Assessment of Undernutrition Prevalence at the Level of Countries,” *World Development* 29 (2001): app. A, table 1. Both are based on data from Macro International, *Demographic and Health Surveys* (Washington D.C.: Macro International, 1999), available at http://www.measuredhs.com/.

Note.—POU = prevalence of nutrition; FAO = Food and Agriculture Organisation of the United Nations; BMI = body mass index.

* Nationally representative estimates of the share of children with weight-for-height and height-for-age below the norms are available for most countries in all the regions.

† Estimates of adult women with a BMI < 18.5 are available for one country only in the Near East and North Africa (Egypt) and two countries in East and Southeast Asia (China and Indonesia), which is not adequate to ensure acceptable representativity. The estimates for sub-Saharan Africa, South Asia, and Latin America and Caribbean cover most countries in the respective regions.

are completely at odds with POU estimates from the FAO. The estimated shares of children below the weight-for-height norm are 3%–17% in the five regions (table 7, col. 3), all notably lower than the estimates of POU. The shares of adult women with a BMI < 18.5 are also considerably lower than POU estimates for most of the regions. Only for South Asia, where more than half the women are below the BMI norm, does the opposite hold true. The exceptionally poor anthropometric status of women in South Asia as compared with the status of women of the other regions has yet to be convincingly explained.[52]

What Explains the Incongruity?

The observation that POU estimates are considerably higher than the estimated shares of wasted children and adult women in almost all the regions has two possible explanations. The first is that at least one set of estimates is biased. The other is that the two measurement approaches are noncomparable in some way.

I have previously argued that POU estimates from the FAO are generally upward biased. The anthropometric estimates are reliable in the sense that they are obtained with small measurement errors and biases.[53] Moreover, the estimates for young children are based on sufficiently large and numerous samples to ensure that they are representative for their respective region. The latter holds for the estimates of adult women in some regions, but not for East and Southeast Asia and the Middle East and North Africa (see table 7, n. †). Thus, there is little reason to think that the anthropometric indicators are generally biased or nonrepresentative.

There are problems with comparability, however. First, the comparison between POU estimates and the shares of wasted children is distorted by the fact that different weight norms for young children have been used. In deriving its calorie cutoff points, the FAO uses the median value of weight-for-age range in a U.S. reference population as the norm for children. The weight-for-age norms used in the anthropometric assessments are 2 SDs below the median values, or about 15%–20% lower. Had the FAO used the anthropometric weight norms for children, their calorie cutoff points (ceteris paribus) would have been somewhat smaller and the estimated POU would have been 2%–10% lower in the various regions.[54] It would still be difficult to reconcile the revised POU estimates of these orders with the incidence of child wasting, especially in sub-Saharan Africa and Latin America.

The discrepancy between POU estimates from the FAO and the estimated shares of wasted adult women is unrelated to body-weight norms. Prevalence of undernutrition estimates—as shown in Section III—and the direct anthropometric estimates are derived from exactly the same weight norm for adults ($\mathrm{BMI} = 18.5$). Hence, it is notable that the “indirect” FAO estimates of the share of the population with weight failure are almost four times higher than the direct anthropometric estimates of the share of wasted adult women in sub-Saharan Africa and Latin America and the Caribbean.[55]

There are, however, two other complications that have to be addressed. One is that there are no anthropometric estimates for adult men. The conventional view is that women are the chief victims of undernutrition. Hence, the anthropometric indicators for the two sexes combined ought to be lower than for women alone. If so, the gap between POU estimates and incidence of adult wasting would be even larger when men are included.[56]

The other complication is that anthropometric assessments of body weight reveal nothing about the physical activity that people exert. The calorie cutoff points behind POU estimates, as demonstrated, allow for the energy expenditure of light physical activity. It may be that the great majority of adult women in sub-Saharan Africa and Latin America have a calorie intake sufficient to have body weights above the anthropometric norm but not to expend enough energy in work and other physical activities and still stay healthy.

Considering that the estimated workforce participation rates for women (mainly in agriculture) in these two regions are comparatively high, the probability that physical inactivity is a main explanation for the discrepancy between the indirect (POU) and direct estimates of women's weight failure seems low.[57]

All in all, the observation that the anthropometric indicators of the prevalence of wasting among young children and adult women are generally much lower than POU estimates from the FAO is not the definitive proof that the latter are upward biased. There are, as discussed above, unresolved issues concerning comparability. What can be ascertained for certain, however, is that the direction in the discrepancies does not contradict the earlier conclusion that the FAO has generally overestimated POU. The anthropometric estimates are also, in general, more in line with the alternative POU estimates derived here (table 6, panel B).

VIII. Summary and Conclusions

The FAO's estimates of POU in the world form the empirical basis for the recent initiative to reduce the number of undernourished people by half before the year 2015. These estimates derive from a model that has a built-in bias, which has long since been pointed out, and the FAO justifies its use by the lack of crucial data.[58] The first contribution of this article is to demonstrate that the FAO has, de facto, assigned a number to the critical "missing" parameter when constructing its cutoff points. It has been further shown that with a number on this parameter, the FAO could have used the alternative, joint-distribution estimation method, which produces "unbiased" estimates of POU (since the second missing parameter turns out to be of minuscule quantitative importance). The application of this alternative model—while still keeping with the FAO food-supply-based approach and basic data—suggests a notably higher incidence of undernutrition than that reported by the FAO. Thus, I was able to put numbers on the (downward) bias in the estimated POU in the world, induced by the estimation method used by the FAO (see table 3).

There is also reason to doubt most of the key parameter values that the FAO inserted in its estimations, however. First, the FAO has failed to recognize that, since the early 1990s, physiologists have revised their estimates of BMR per kilogram of body weight for people in the "tropics" downward by about 10%. Second, the FAO has ignored the fact that the household per capita calorie requirement for BMR (and, hence, MPCCR) varies across households because of differences in size and age composition. Third, the FAO must have overestimated the variance in the calorie-availability distribution across households because the ensuing habitual intakes in the lower tail are impossibly low for living households. Prevalence of undernutrition was therefore reestimated with both the FAO and the alternative model, using other parameter values that are more plausible or square better with empirical observations. The estimated POU then fell drastically in most regions (see table 6).

Comparing the original POU estimates from the FAO with estimates based on the alternative model and data gives an indication of the net effect of the two biases in POU estimates, that is, the underestimation that is induced by the use of the cutoff-point method and the overestimation resulting from inadequate data. This comparison indicates a relatively small net overestimation by the FAO in sub-Saharan Africa, but substantial overestimation in the other regions (panel B of table 6). The overall conclusion is that, on a net basis, the FAO has overestimated POU in the world, although unevenly so, signifying that the comparability across regions (and presumably individual countries) has been compromised. The revised POU estimates are also more compatible with anthropometric indicators for most regions, which further strengthens the notion that the FAO estimates are generally too high.

The revised POU estimates must be interpreted cautiously nevertheless. One reason is that the (uniform) alternative values attached to the two distribution parameters (CV_y and CV_x) are not sufficiently well founded empirically. Moreover, given the lack of alternative data, I have used the FAO national per capita calorie availability estimates (μ_y). These estimates, it is widely agreed, contain large margins of error. However, if the FAO calorie-supply estimates are systematically biased, it is on the downward side, especially in sub-Saharan Africa.[59] In that case, the revised POU estimates reported in table 6 are on the high side as well.

What the above exercises demonstrate is, above all, that POU estimates provided by FAO are much too unreliable for directing policy in any meaningful way, or for simply providing an acceptably accurate “map” of POU in various parts of the world. The main contribution of this article is hence not the particular revised estimates of POU that have been derived. The main contributions are the demonstrations of (1) how sensitive POU estimates are to the choice of (a biased) estimation model, (2) how brittle or unsubstantiated the empirical bases are for key parameter values, and (3) how fragile the estimated POU is for slight variations in these uncertain parameter values (irrespective of estimation method).

The process of undertaking the numerical exercises also sheds light on what has to be done to improve the estimation method and data collection. First, the FAO has to replace the present calorie cutoff-point model, which is inherently biased, with the joint-distribution model. Second, the FAO has to start collecting more complete and reliable data on the key parameters in that model. The least costly and time-consuming improvements would be to lower the BMR estimates in accordance with recent findings and to undertake estimates of interhousehold variance in MPCCR caused by differences in age structure and size. To improve the estimates of national food (calorie) supplies and their distribution over households would be more costly and take more time.

If the objective to reduce by half the absolute number of undernourished people in the world before the year 2015 is taken seriously, and new policies are to be initiated, the international community simply must have more detailed and reliable information on where the undernourished are, who they are, and how many there are.[60] Reliable indicators of undernutrition are needed not only for directing and designing interventions, however. Equally important, we need accurate measurements if we are to find out to what extent undernutrition at the level of countries affects economic growth and poverty reduction negatively. If it can be convincingly demonstrated that undernutrition—like poor health and low educational attainment—is a significant and independent barrier to growth in poor countries, it may become easier to mobilize political (financial) support to alleviate such conditions than if the motivation for such support rests solely on humanitarian grounds.

Appendix

TABLE A1

DERIVATION OF THE MINIMUM BODY WEIGHT AND PHYSICAL ACTIVITY LEVEL ALLOWED FOR BY THE FAO IN ESTIMATING CALORIE CUTOFF POINTS WORLDWIDE

	MALES			FEMALES		
VALUES UNDERLYING THE CCOP	Average (1)	Minimum (2)	*CV* (3)	Average (4)	Minimum (5)	*CV* (6)
A. BMI	22.0	18.5	.080	22.0	18.5	.080
B. PAL:						
1. Sleep 8 hours	1.00	1.00	0	1.00	1.00	0
2. Low-active 8 hours*	1.40	1.40	0	1.40	1.40	0
3. Work activity 8 hours*	3.00	2.53	.078	2.83	2.57	.046
4. Average activity 24 hours	1.78	1.55	.065	1.64	1.56	.024

SOURCE.—FAO, *The Sixth World Food Survey* (Rome: FAO, 1996), p. 131, table 1; and author's calculations (*CV*s and rows 2 and 3 in sec. B of this table).

NOTE.—FAO = Food and Agriculture Organisation of the United Nations; BMI = body mass index; BMR = basal metabolic rate; PAL = daily activities. By multiplying the BMR for each age and sex category by the PAL multiple and aggregating, the FAO derives the estimated minimum calorie requirement (CCOP).

* Details on rows 2–3 may differ slightly from the numbers actually used (but not published) by the FAO in deriving the numbers on row 4.

TABLE A2

Robustness Test of Estimated POU with the Joint-Distribution Method and Alternative Combinations of Parameter Values

Region	Parameter	(1)	(2)	(3)	(4)	(5)
		Combination of Parameter Values				
	CV_y	.30	.25	.25	.20	.20
	CV_x	.075	.125	.15	.125	.15
	μ_x*	1.00	.90	.90	.90	.90
		Estimated POU (%)				
A. $\rho = .50$:						
Sub-Saharan Africa		57	43	43	40	40
Near East and North Africa		24	11	11	6	6
East and Southeast Asia		34	20	20	14	15
South Asia		46	31	30	25	26
Latin America and Caribbean		32	18	17	12	12
B. $\rho = .70$:						
Sub-Saharan Africa		57	42	42	38	38
Near East and North Africa		23	7	7	3	3
East and Southeast Asia		33	16	15	10	9
South Asia		46	28	27	21	20
Latin America and Caribbean		31	14	13	7	7
C. $\rho = .90$:						
Sub-Saharan Africa		58	40	38	34	31
Near East and North Africa		21	3	2	0	0
East and Southeast Asia		31	11	8	3	2
South Asia		45	23	20	13	10
Latin America and Caribbean		29	8	6	2	1

Source.—Estimates in col. 1 are from the FAO, *The Sixth World Food Survey* (Rome: FAO, 1996); estimates in the other columns are derived as explained in text on the basis of eq. (1) and data for regional averages (see table 3 above).

Note.—POU = prevalence of undernutrition.

* The number 0.90 on this row means that this parameter has been assigned a value which is 90% of FAO value.

TABLE A3

Estimated BMR in Individuals, by Sex and Age

	Males				Females			
Age Range (Years) (1)	Height (Centimeter) (2)	Norm Weight (Kilogram) (3)	BMR/ Kilogram/ Day (4)	Total BMR/ Day (5)	Height (Centimeter) (6)	Norm Weight (Kilogram) (7)	BMR Kilogram/ Day (8)	Total BMR/ Day (9)
0–1	67	8	57	460	65	7	57	400
1–2	82	12	57	680	81	11	56	620
2–3	94	14	57	800	91	13	57	740
3–4	99	16	54	860	98	15	56	840
4–5	106	18	50	900	106	17	52	880
Average male/female for 0–5-year-olds								720
5–6	113	20	48	960	112	19	49	930
6–7	119	22	45	990	118	21	46	970
7–8	124	24	43	1,030	124	23	44	1,010
8–9	129	27	41	1,110	129	27	41	1,110
9–10	135	30	39	1,170	135	30	39	1,170
Average male/female for 5–10-year-olds								1,045
10–11	140	36	38	1,370	142	37	34	1,260
11–12	147	40	35	1,400	148	41	32	1,310
12–13	153	43	33	1,420	155	44	29	1,280
13–14	160	47	31	1,460	159	47	28	1,320
14–15	166	51	30	1,530	161	48	27	1,300
Average male/female for 10–15-year-olds								1,365
15–16	171	54	29	1,570	162	49	26	1,270
16–17	175	57	28	1,600	163	49	26	1,270
17–19	177	58	28	1,620	164	50	26	1,300
Average male/female for 15–19-year-olds								1,450
20–60	168	52	28	1,460	157	46	26	1,200
Average male/female for 20–60-year-olds								1,330
Over 60	166	51	23	1,170	155	45	24	1,080
Average male/female for over 60 year olds								1,125

Source.—Data on the basal metabolic rate (BMR) per kilogram are from FAO/WHO/UNU, *Energy and Protein Requirements*, Technical Report Series no. 724 (Geneva: WHO, 1985); height-for-age and weight data are from Lani S. Stephenson, Michael C. Latham, and Ad Jansen, *A Comparison of Growth Standards* (Ithaca, N.Y.: Cornell University Press, 1983); and Hans W. Jürgens, Ivar A. Aune, and Ursula Pieper, *International Data on Anthropometry*, Occupational Safety and Health Series no. 65 (Geneva: International Labour Organisation, 1990).

Notes

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1. A. K. Sen, “Foreword,” in *Poverty and Undernutrition: Theory, Measurement, and Policy,* by Peter Svedberg (Oxford: Oxford University Press, 2000).

2. See, e.g., Jere R. Behrman, “The Economic Rationale for Investing in Nutrition in Developing Countries,” *World Development* 21 (1993): 1749–71; John Strauss and Duncan Thomas, “Human Resources: Empirical Modelling of Household and Family Decisions,” chap. 34 in *Handbook of Development Economics*, vol. 3A, ed. Jere R. Behrman and T. N. Srinivasan (Amsterdam: North Holland, 1996).

3. For empirical evidence, see David L. Pelletier, “The Relationship between Child Anthropometry and Mortality in Developing Countries: Implications for Policy, Programs and Future Research,” *Journal of Nutrition* 124, suppl. (1994): S2045–S2081; Svedberg, *Poverty and Undernutrition*.

4. For assessments of current knowledge about these consequences of chronic undernutrition in humans, see Siddiq R. Osmani, “Poverty and Nutrition in South Asia,” in *Nutrition and Poverty,* United Nations Administrative Committee on Coordination, Subcommittee on Nutrition Policy Paper no. 16 (Geneva: United Nations Administrative Committee on Coordination, Subcommittee on Nutrition Policy, 1997), pp. 23–51; Nevil S. Scrimshaw, “Nutrition and Health from Womb to Tomb,” *Nutrition Today* 31 (1996): 55–67. There are, by now, a large number of empirical growth studies that have found various proxy variables for initial “human capital,” mainly in terms of education, but also health, to be significantly and robustly correlated to economic growth in subsequent periods. See Jonathan Temple, “The New Growth Evidence,” *Journal of Economic Literature* 37 (1999): 112–56; Alok Bhargava, Dean T. Jamison, Lawrence J. Lau, and Christopher J. L. Murray, “Modelling the Effects of Health on Economic Growth,” *Journal of Health Economics* 20 (2001): 423–40. For empirical results based on cross-country investigation showing that economic growth leads to poverty alleviation (i.e., generally benefits also the poorest population strata), see David Dollar and Art Kraay, “Growth Is Good for the Poor” (World Bank, Development Research Group, Washington, D.C., 2000, mimeographed), available at http://www.worldbank.org/research.

5. FAO, *The Sixth World Food Survey* (Rome: FAO, 1996), and *The State of Food Insecurity in the World, 1999* (Rome: FAO, 1999). The terminology used by the FAO is confusing. In the introductory chapter of *The Sixth World Food Survey,* the FAO maintains that its concern is “food inadequacy.” Then the FAO states that “the terms ‘inadequate food intake’ and ‘inadequate access to food’ cannot be equated with undernutrition as tends to be done in popular discussions” (p. 44). However, on the next page, in table 14, the proportion “undernourished” is estimated. In subsequent tables and figures, the terms “undernourishment” and “food inadequacy” are used interchangeably with no explanations attached. The follow-up report, *The State of Food Insecurity in the World, 1999,* adds to the confusion by making a distinction between undernutrition and undernourishment and by claiming that the latter is the concern of the FAO. The definitions of the two concepts are not well defined, however. It could be noted further that Naiken uses the term “undernutrition” in the title of his article, “On Certain Statistical Issues Arising from the Use of Energy Requirements in Estimating the Prevalence of Energy Inadequacy (Undernutrition),” *Journal of Indian Social and Agricultural Statistics* 51 (1998): 113–28. A draft of *The Sixth World Food Survey* carried the title “World Food Supplies and Prevalence of Chronic Undernutrition in Developing Regions as Assessed in 1992” (FAO, Rome, 1992, mimeograph).

6. See FAO, *Poster with Data on “Percentage of Population Chronically Undernourished in 98 Developing Countries (1990–92)”* (Rome: FAO, 1997), and *The State of Food Insecurity*.

7. The first attempt by the FAO to monitor progress toward the 2015 objective was published in 1999 (FAO, *The State of Food Insecurity*). According to the FAO, the absolute number of “hungry people” declined to 790 million by 1995–97, or by

some 50 million since the early 1990s. Prevalence of undernutrition estimates for 1990–92 (and earlier) have at the same time been revised by a few percentage points. In this article, I have taken the estimates from FAO (*The Sixth World Food Survey*) as the benchmark, since an insufficient number of details on the base data from which the 1999 revised estimates were derived have been published.

8. Using a slightly modified version of the FAO model and alternative values of key parameters, the World Bank (*Poverty and Hunger* [Washington D.C.: World Bank, 1986]) derived POU estimates for the years 1970 and 1980. The Bank's estimates of POU turned out to be considerably higher than the FAO estimates for the same years. In order to identify the reasons for this discrepancy, George H. Beaton ("Energy in Human Nutrition: Perspectives and Problems," *Nutrition Reviews* 41 [1983]: 325–40) made detailed recalculations for four countries. He found that the main reason was the use of considerably higher calorie norms by the Bank, while the different assumptions regarding calorie distribution mattered less. For a response to these findings, see Loganaden Naiken "Comparison of the FAO and the World Bank Methodology for Estimating the Incidence of Undernutrition," *FAO Quarterly Bulletin of Statistics* 1 (1988): iii–v; Shlomo Reutlinger and Harold Alderman, "The Prevalence of Calorie-Deficient Diets in Developing Countries," *World Development* 8 (1980): 399–411. Reutlinger and Alderman, the chief architects behind the IBRD study, also estimated the proportion of people with a "calorie-deficient" diet, based on an index "which measures the share of the population whose *average* calorie intake is below *average* requirements" (p. 400; my emphasis). The use of a very high calorie norm (compared with that of the FAO) was probably the main reason why 65% of the population (weighted average) in the 41 sample countries were found to be calorie deficient in the mid-1960s.

9. See P. Svedberg, "841 Million Undernourished?" *World Development* 27 (1999): 2081–98, and *Poverty and Undernutrition*.

10. P. V. Sukhatme, "The World's Hunger and Future Needs in Food Supplies," *Journal of the Royal Society A* 124 (1961): 463–585. The term "unbiased" has been put in quotes to underscore the limited and partial meaning of the term in this context, where the concern is the bias induced by the choice of estimation model (Sec. IV). There are also biases in the data used by the FAO to estimate POU, which are discussed in Sec. V. Later contributions include T. N. Srinivasan, "Malnutrition: Measurement and Policy Issues," *Journal of Development Economics* 8 (1981): 3–20; see also T. N. Srinivasan, "Undernutrition: Concepts, Measurements, and Policy Implications," pp. 97–120; Sudhir Anand and Christopher J. Harris, "Issues in the Measurement of Undernutrition," pp. 187–218; and Nanak C. Kakwani, "Measuring Undernutrition with Variable Requirements," pp. 165–86, all in *Nutrition and Poverty*, ed. Siddiq R. Osmani (Oxford: Clarendon, 1992).

11. Naiken, "On Certain Statistical Issues," pp. 113–14, and "Comparison of the FAO and the World Bank Methodology." Also see FAO, *The Sixth World Food Survey*, p. 117.

12. The only study that has used the joint-distribution type of model for the estimation of the proportion undernourished is the one by Kakwani ("Measuring Undernutrition"). He applied this model to household survey data for rural and urban India from 1970 to 1971. Over the course of the present article, I will point out some interesting similarities and differences in methods, in derivation of key parameters, and in results to compare Kakwani's work with my own. Both Kakwani and Reutlinger and Alderman further derived estimates of the depth of the calorie deficiency ("calorie gaps") in respective populations, making use of Sukhatme-type models. In this article, I do not deal with the "gap" issue for the sake of space.

13. This graphic representation of the Sukhatme model is adapted from Anand and Harris.

14. There is not much empirical evidence to lean on when assigning the property

of the joint distribution (normal, log-normal, or other). The FAO estimations are based on a log-normal distribution of calorie availability since “the log-normal distribution was found to outperform the other two distributions [the normal and the beta] in terms of the standard tests for goodness of fit” (FAO, *The Sixth World Food Survey*, p. 132). I will follow the FAO procedure in order to accomplish comparability, although the empirical basis for the FAO results has not been published and, hence, examined.

15. This result has been shown previously by, e.g., Srinivasan (“Undernutrition”); Anand and Harris; and Kakwani (“Measuring Undernutrition”).

16. FAO, *The Sixth World Food Survey* (n. 5 above), and *The State of Food Insecurity* (n. 5 above).

17. The BMI is defined as weight (in kilograms) divided by height squared (in meters). For example, if a person’s weight is 73 kilograms and his height is 1.82 meters, his BMI is $73/(1.82)^2 = 22.0$.

18. The calorie requirement for children below the age of 10 is derived in a different way. In terms of body weight, it is set at the median value of the weight for height range found in a U.S. reference population. The calorie requirement for physical activity it is set equal to “usual activity of children in affluent societies . . . plus 5% allowance for desired activity” (FAO, *The Sixth World Food Survey*, p. 131).

19. That the cutoff points are derived this way is not explicitly reported in the official FAO documents but acknowledged by the former chief statistician at the FAO (Naiken, “On Certain Statistical Issues” [n. 5 above]). This kind of procedure for estimating the calorie requirements for individuals was originally proposed by Sukhatme (n. 10 above) and is also suggested in a report from a nutritionist expert consultation group (Food and Agriculture Organisation/World Health Organization/United Nations University (FAO/WHO/UNU), *Energy and Protein Requirements*, Technical Report Series no. 724 [Geneva: WHO, 1985], pp. 14–19) set up as part of the preparations for *The Fifth World Food Survey* (Rome: FAO, 1987). The same statistical procedure is commonly used in related areas. For instance, most of the anthropometric norms used to assess the nutritional or health status of young children are derived in this manner, which is to say, the norms are set as 2 or 3 SDs from the median height or weight in a reference population.

20. Some of these details are found in the appendix on “methodology for assessing food inadequacy” in FAO, *The Sixth World Food Survey*. Most of the database used by the FAO is contained in WIlliam P. T. James and E. C. Schofield, *Human Energy Requirements: A Manual for Planners and Nutritionists* (Oxford: Oxford University Press, 1990), which was commissioned by the FAO. However, the details on how the cutoff points have been derived are not spelled out.

21. FAO, *The Sixth World Food Survey*, p. 117.

22. See FAO/WHO/UNU, annex 5; James and Schofield.

23. Naiken, “On Certain Statistical Issues.”

24. “Economically necessary” work is, hence, equated with 8 hours per day of “moderately heavy” manual work. This definition of “economically necessary” has little to do with economics, since it does not allow for the fact that workers within and across countries have different productivity and, hence, differing incomes. The FAO definition is normative: people should be able to work in moderately heavy activities for normal hours.

25. FAO, *The Sixth World Food Survey* (n. 5 above), pp. 117–18.

26. FAO/WHO/UNU, pp. 16, 19.

27. In the previous applications of joint-distribution approaches for estimating POU and “calorie gaps,” similar results are reported (Reutlinger and Alderman [n. 8 above]; Kakwani, “Measuring Undernutrition” [n. 10 above]). Hence, it is puzzling that the FAO has chosen to use the biased cutoff-point model, citing lack of data as the justification, when it in fact has assigned a value to one of the two “missing” parameters ($CV_x = 0.075$), and that it has long since been known that the value of the

other parameter (ρ) matters only marginally for the size of POU estimates. The latter result further implies that the data requirements are basically the same (μ_y, μ_x, CV_y, and CV_x) with the two estimation methods.

28. Naiken notes, however, that "among other analysts . . . of particular concern was the fact that the [FAO] approach appeared to ignore the risk of inadequacy among individuals whose intakes are within the range of variation in requirement" ("On Certain Statistical Issues," p. 114). This concern is thus supported by the above findings.

29. Since the FAO does not publish the detailed data that it used for deriving POU estimates for individual countries, there is no way to reestimate these results with the "unbiased" method.

30. For a succinct attempt to bring some clarity into this sometimes confusing controversy, see Siddiq R. Osmani, "On Some Controversies in the Measurement of Undernutrition," in Osmani, ed. (n. 10 above), pp. 121–64. Also see Srinivasan, "Undernutrition" (n. 10 above), for a defense of the intraindividual adaptation theory.

31. See, e.g., J. E. Hayter and C. J. K. Henry, "A Reexamination of Basal Metabolic Rate Predictive Equations: The Importance of Geographical Origin of Subjects in Sample Selection," *European Journal of Clinical Nutrition* 48 (1994): 702–7; P. S. Shetty, C. J. K. Henry, A. E. Black, and A. M. Prentice, "Energy Requirements of Adults: An Update on Basal Metabolic Rates (BMR) and Physical Activity Levels (PALs)," *European Journal of Clinical Nutrition* 23, suppl. (1996): S11–S23.

32. Naiken, "Comparison of the FAO" (n. 8 above), p. iii; emphasis added. The use of the household as the unit of observation means that the study of intrahousehold allocation of nutrients, and along gender lines, is beyond the reach of the FAO method. The significance of considering intrahousehold allocation has been highlighted in several studies. See, e.g., Jere R. Behrman, "Nutrition, Health, Birth Order, and Seasonality: Intrahousehold Allocation in Rural India," *Journal of Development Economics* 28 (1988): 43–62, and "Intrahousehold Allocation of Nutrients in Rural India: Are Boys Favored? Do Parents Exhibit Inequality Aversion?" *Oxford Economic Papers* 40 (1988): 32–54; Jere R. Behrman and Anil B. Deolalikar, "The Intrahousehold Demand for Nutrients in Rural South India: Individual Estimates, Fixed Effects and Permanent Income," *Journal of Human Resources* 25 (1990): 665–96; Mark M. Pitt, Mark R. Rosenzweig, and Nazmul Hassan, "Productivity, Health and Inequality in the Intrahousehold Distribution of Food in Low Income Countries," *American Economic Review* 80 (1990): 1139–56; Lawrence J. Haddad, Ravi S. M. Kanbur, and Howarth Bouis, "How Serious Is the Neglect of Intrahousehold Inequality?" *Economic Journal* 100 (1990): 866–81, and "Intrahousehold Inequalities and Different Welfare Levels: Energy Intake and Energy Expenditure Data from the Philippines," *Oxford Bulletin of Economics and Statistics* 57 (1995): 389–410; Ravi S. M. Kanbur, "Children and Intrahousehold Inequality: A Theoretical Analysis," in *Choice, Welfare and Development: A Festschrift in Honour of Amartya Sen,* ed. Kaushik Basu, Prasanta K. Pattanaik, and Kotaro Suzumura (Oxford: Clarendon, 1995), pp. 242–52; and Amy Farmer and Jill Tiefenthaler, "Fairness Concepts and the Intrahousehold Allocation of Resources," *Journal of Development Economics* 47 (1995): 179–89. Gender issues are discussed in Peter Svedberg, "Undernutrition in Sub-Saharan Africa: Is There a Gender Bias?" *Journal of Development Studies* 26 (1990): 469–86, and "Gender Bias in Sub-Saharan Africa: Reply and Further Evidence," *Journal of Development Studies* 32 (1996): 933–43.

33. These data are from FAO/WHO/UNU (n. 19 above).

34. United Nations, *Demographic Yearbook 1997* (New York: United Nations, 1997).

35. See FAO, *The Sixth World Food Report* (n. 5 above), pp. 131–42. In Reutlinger and Alderman, calorie distribution across broad income groups (not households, as in both the FAO study and this study) was derived from estimates of the distribution of incomes. The authors themselves discussed the hazards involved in using this approach.

Further assessments are found in Howarth E. Bouis and Lawrence J. Haddad, "Are Estimates of Calorie-Income Elasticities Too High? A Recalibration of the Plausible Range," *Journal of Development Economics* 39 (1992): 333–64; Howarth E. Bouis, "The Effects of Income on the Demand for Food in Poor Countries: Are Our Food Data Bases Giving Us Reliable Estimates?" *Journal of Development Economics* 44 (1994): 199–220; Kakwani (n. 10 above); and Svedberg, *Poverty and Undernutrition,* chap. 4.

36. FAO, "World Food Supplies and Prevalence of Chronic Undernutrition in Developing Regions as Assessed in 1992" (n. 5 above).

37. See William P. T. James, Anna Ferro-Luzzi, and John C. Waterlow, "Definition of Chronic Energy Deficiency in Adults," *European Journal of Clinical Nutrition* 42 (1988): 969–81.

38. FAO/WHO/UNU, p. 73.

39. See Pelletier (n. 3 above); Svedberg, *Poverty and Undernutrition* (n. 1 above).

40. In their joint assessment of the causes of mortality, the WHO and the IBRD find that 0.8% and 0.6% of all deaths in sub-Saharan Africa and India are directly attributable to "protein-energy malnutrition" (WHO, *World Health Report, 1999* [Geneva: World Health Organisation, 1999], app. table 2). In absolute numbers, these percentages translate into 77,000 and 56,000 deaths, respectively. Under- and malnutrition are, of course, contributing factors in many deaths caused by disease, but they are not the direct cause of death.

41. Svedberg, *Poverty and Undernutrition,* chaps. 6–7.

42. Robert E. Evenson and Carl E. Prey, "Measuring Food Production (with Reference to South Asia)," *Journal of Development Economics* 44 (1994): 173–98.

43. Alan Heston, "A Brief Review of Some Problems in Using National Account Data in Level of Output and Growth Studies," *Journal of Development Economics* 44 (1994): 29–52.

44. See, e.g., FAO, *Food Production Yearbook* (Rome: FAO, 1954–).

45. Estimates of calorie consumption from food consumption surveys have been contrasted with the calorie supply data from the FAO. Estimates from a large number of countries often show marked differences between the two sets of estimates for given years. See Elizabeth A. Dowler and Young O. Seo, "Assessment of Energy Intake: Estimates of Food Supply vs. Measurement of Consumption," *Food Policy* 10 (1985): 278–88; FAO, "A Comparative Study of Food Consumption Data from Food Balance Sheets and Household Surveys," Economic and Social Development Paper no. 34 (FAO, Rome, 1983). There is no systematic sign pattern in the differences, however, and hence it is not possible to conclude from consumption surveys that the FAO has systematically over- or underestimated calorie availability. Moreover, consumption surveys are generally not more reliable than the FAO food balance sheets.

46. FAO, *The Sixth World Food Survey* (n. 5 above), pp. 141–42.

47. The regression slope for intake as a function of minimum requirement can be expressed as: $\beta = \rho(CV_y/CV_x)(\mu_y/\mu_x)$. See also fig. 1. The high value of the ratio (CV_y/CV_x), derived from the FAO base data (about 4.0), means that β becomes very high (between 2.0 and 4.9). Such high β's imply that undernutrition is heavily concentrated within the households with the lowest MPCCR. Why this should be the case is not evident and remains for the FAO to explain.

48. See Naiken, "On Certain Statistical Issues" (n. 5 above).

49. All the estimates in panel B of table 6 have been derived with the assumption that the correlation coefficient ρ is 0.70, but estimates were also derived with the alternative assumptions that ρ is 0.50 and 0.90, respectively (table A2). This robustness test shows that POU estimates are not sensitive to the values of ρ in this range, which confirms our earlier findings (table 2).

50. That the estimate for sub-Saharan Africa is not as sensitive to altered parameter values depends mainly on the fact that the estimated (by FAO) national per capita

availability of calories is close to average per capita requirement in this region, while not in the others. Kakwani (n. 10 above) estimated POU in India on the basis of household survey data from 1970–71 with both an average-requirement norm method and the joint-distribution method, assuming different distribution functions and alternative values of the parameters CV_x and ρ (but not CV_y). He found practically no difference in the ensuing POU estimates for the rural population, presumably also because his average-calorie requirement norm was very close to the average rural intake in the data set. His estimates for the urban population, for which there was a significant difference between average intake and requirement, were much more sensitive to the value attached to the ρ parameter.

51. The intricate reinforcing interactions between illness and poor nutrition have long been known. See, e.g., Nevin S. Scrimshaw, C. E. Taylor, and J. E. Gordon, *American Journal of Medical Science* 237, no. 3 (1959): 367–403; Jere R. Behrman, "The Action of Human Resources and Poverty on One Other," LSMS Working Paper no. 74 (World Bank, Washington D.C., 1990); Philip Payne, "Assessing Undernutrition: The Need for a Reconceptualization," in Osmani, ed. (n. 10 above), pp. 49–96; and United Nations Administrative Committee on Coordination, Subcommittee on Nutrition Policy, *Fourth Report on the World Nutrition Situation* (Geneva: United Nations Administrative Committee on Coordination, Subcommittee on Nutrition Policy, 2000). For further analyses of the multifaceted web of reasons behind child growth failure, see various contributions to John C. Waterlow, ed., *Linear Growth Retardation in Less Developed Countries,* Nestlé Nutrition Workshop Series no. 14 (New York: Raven, 1988); Phyllis B. Eveleth and James M. Tanner, *Worldwide Variations in Human Growth* (Cambridge: Cambridge University Press, 1990); and David Maxwell, Carol Levin, Margaret Armar-Klemesu, Marie Ruel, Saul Morris, and Clement Ahiadeke, "Urban Livelihoods and Food and Nutrition Security in Great Accra, Ghana," International Food Policy Research Institute Research Report no. 112 (International Food Policy Research Institute, Washington D.C., 2000).

52. The main reason offered in the literature for the exceptionally poor anthropometric status of women in South Asia, especially in the form of stunting and wasting, is their discriminated social position, which is passed on from generation to generation. See V. Ramalingaswami, U. Jonsson, and J. Rohde, "The Asian Enigma," in *The Progress of Nations* (New York: United Nations Children's Fund, 1996); Osmani, "Poverty and Nutrition in South Asia" (n. 4 above); U. Ramakrishnan, R. Martorell, D. G. Schroeder, and R. Flores, "Role of Intergenerational Effects on Linear Growth," *Journal of Nutrition* 129 (1999): 10–17. There is also the possibility that the genetic potential for final growth in stature is lower in Asian populations than in other populations, but so far this is only a hypothesis.

53. For a detailed assessment of measurement errors and biases in anthropometric indicators, see R. Bairagi, "Effects of Bias and Random Error in Anthropometry and in Age on Estimation of Malnutrition," *American Journal of Epidemiology* 123 (1986): 185–91; G. C. Marks, J. P. Habicht, and W. H. Mueller, "Reliability, Dependability, and Precision of Anthropometric Measurements," *American Journal of Epidemiology* 130 (1989): 578–87. On the representativity of anthropometric measures and their comparability with POU estimates, see Svedberg, *Poverty and Undernutrition* (n. 1 above), chaps. 11–13; Marteen Nubé, "Confronting Dietary Energy Supply with Anthropometry in the Assessment of Undernutrition Prevalence at the Level of Countries," *World Development* 29 (2001): 1275–89.

54. It has not been possible to undertake more exact recalculations for the simple reason that the FAO has not published its data on the age composition of the population and the share of the per capita calorie requirements in the cutoff points that account for the children.

55. Severe to moderate underweight among adult women (ages 20–49) is practically nonexistent in Latin America. Observations from 11 countries, with about two-

thirds of the population in the region, show, on average, 2% to have a BMI below 17.0. In Latin America, the most serious nutrition problems by far are being overweight and obesity. In 10 of the 11 countries (Haiti being the exception), the share of overweight women ($BMI > 25.0$) is in the 32%–48% range, and the share of obese women ($BMI > 30.0$) is in the 8%–13% range. See United Nations Administrative Committee on Coordination, Subcommittee on Nutrition Policy, table 1.8.

56. While there are hardly any observations of the anthropometric status of male adults and the elderly of either sex, adolescents have been assessed in more than a dozen countries, mainly in Latin America. See FAO, *The Sixth World Food Survey* (n. 5 above), table 24; and United Nations Administrative Committee on Coordination, Subcommittee on Nutrition Policy, fig. 1.5. With one exception (stunting in India), these studies show adolescent males more frequently to be below the anthropometric norms in all the countries. This finding tentatively indicates that the conventional belief that women are the main victims of undernutrition (and poor health) may not stand up to closer scrutiny.

57. According to ILO estimates, the labor-market participation rates for women in sub-Saharan African and Latin American countries are in the 50%–70% range, while typically less than 20% in most of South Asia and in the Middle East and North Africa.

58. For references, see n. 10 above.

59. The most striking discrepancy (in the unexpected direction) between the revised POU estimates and the anthropometric indicators is that found for sub-Saharan Africa (table 7). This is a further indication that the national per capita calorie availability estimates—the parameter that was unaltered—for this particular region have been underestimated by the FAO, as discussed in the fourth part of Sec. V above.

60. It should be recalled that even if the aggregate food-supply based approach for the estimation of undernutrition is improved, it cannot be of help for all the policy purposes for which nutritional indicators are needed. As underscored by the FAO itself (*The Sixth World Food Survey,* pp. 120–27), the method can only be used to estimate the proportion of calorie-deficient households (see also *The Sixth World Food Survey,* fig. 1), not for identifying specific undernourished households, indicating that the FAO approach is of no use for targeting interventions at the microlevel. Moreover, since the household is the unit of assessment, the study of intrahousehold allocation of nutrients must rely on other methods (e.g., anthropometrics or household surveys).