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FAO PARAMETRIC VERSUS IFPRI NON-PARAMETRIC APPROACH TO ESTIMATING THE PREVALENCE OF UNDERNOURISHMENT:

Issues Relating to the Use of Household Level Data from National Household Surveys

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THE FAO PARAMETRIC VERSUS THE IFPRI NON-PARAMETRIC APPROACH TO ESTIMATING THE PREVALENCE OF UNDERNOURISHMENT: *Issues Relating to the Use of Household Level Data from National Household Surveys*

Sibrián, Ricardo[1]
Naiken, Loganaden[2]
Mernies, Jorge[3]

1/ Senior Statistician, Global Statistics Service (ESSG), Statistics Division, FAO
2/ Former Chief, ESSA, Statistics Division, FAO
3/ Former Chief, ESSA, Statistics Division, FAO

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SUMMARY

A non-parametric approach suggested by researchers from the International Food Policy Research Institute (IFPRI) for measuring food deprivation (undernourishment) is not an improvement to the current FAO parametric approach. This is mainly due to flaws arising from the use of an inappropriate methodological framework and the reliance on single household data from national household surveys (NHS) that are subject to undesirable sources of variation. FAO's parametric approach is still the only choice for estimating the prevalence of undernourishment for the purpose of monitoring hunger reduction at country, regional and global levels. The FAO approach estimates the average food consumption parameter from national food balances such as those from the FBS compiled and prepared by FAO on yearly basis. The FBS is the only data source for global monitoring. The parameter on inequality in food access is derived from NHS data, which are collected less frequently. For estimating the prevalence of undernourishment at sub-national levels and identifying population groups at high risk of food insecurity, countries are applying the FAO method to derive both the average and the inequality parameters from the NHS data.

I. INTRODUCTION

FAO has been traditionally estimating the prevalence of undernourishment in the total population using a parametric approach in the sense that it is based on the parameters of the distribution of dietary energy consumption (DEC) and a cut-off point reflecting an acceptable normative lower limit for dietary energy requirement (DER). This lower limit is referred to as the minimum dietary energy requirement (MDER). The part of the distribution of DEC below the MDER is taken as the estimate of the proportion of the population undernourished.

Recently, researchers from the International Food Policy and Research Institute (IFPRI) have proposed a non-parametric approach as an alternative to the FAO approach. The new approach is non-parametric in the sense that it is based on the direct comparison of the DEC of each sampled household in a NHS with the summation of the DER of all members in the corresponding household. The DER applied to each member is based on the median body-weight for the corresponding sex and age population group. Each household whose total DEC is below the respective total DER is classified as undernourished. The total number of individuals in the thus classified households is then divided by the total number of individuals in all the sampled households to estimate of the proportion of the population undernourished. This approach, which has been illustrated using NHS data for a number of countries in Sub-Saharan Africa, is being proposed by the IFPRI researchers as an improvement to the FAO approach (Smith, Alderman and Aduayom, 2006).

However the IFPRI researchers' proposal is misleading because of three main reasons. First, as the prevalence of undernourishment in the population is derived by comparing the DEC of each household in the sample with the DER obtained as an aggregation of the DER calculated for each of the individuals in the household, the resulting estimate is affected by the biases and errors inherent to the individual household level data from the NHS. A particular consequence of this approach is that it is implicitly based on biased estimates of the second moment of the distribution of DEC. This kind of bias is linked to the sampling designs used in NHSs (Scott, 1992; Arbia, 2002; Srivastava *et al*, 2002). Second, the calculation of the DER corresponding to each of the individuals in the household does not comply with the nutritional expert groups' recommendation that the energy requirements should be applied to groups and not single individuals of given sex and age (WHO, 1985; FAO, 2004). Third, the estimation of DER is incorrectly based on the 50^{th} percentile (median) of the distribution of acceptable body-weights for a given sex and age group. The use of the 50^{th} percentile leads to high probability of misclassifying normal individuals as undernourished.

The biases and errors that the household level data from the NHS are subject to leads to an overestimated inequality in DEC while the use of the 50^{th} percentile of the distribution of acceptable body-weights leads to overestimated DER values. As the effect of both is to raise the prevalence of undernourishment, it follows that the proposed non-parametric approach actually leads to overestimates. For this reason the estimates resulting from application of the approach gives the wrong impression that FAO's approach underestimates the prevalence of undernourishment.

This paper discusses the two approaches in the light of the above issues. Thus, the procedures involved in the two approaches are described in Sections II and III respectively. In Section IV, the inappropriateness of the non-parametric approach is discussed. Section V discusses the sources of the difference between the estimates of the prevalence of undernourishment resulting from the application of the two approaches for 12 countries in Sub-Saharan Africa and illustrates the flaw in the distribution underlying the estimates obtained using the non-parametric approach and the likely overestimation of the prevalence of undernourishment that this entails. Finally, Section VI emphasizes that there is still no alternative to the FAO approach for estimating the prevalence of undernourishment in a population and therefore efforts towards improvement should concentrate on improving the estimates of the parameters needed for applying this approach.

It is hoped that the views expressed in this paper will be helpful to the community of researchers and practitioners involved in food security assessments at the global as well as national level in clarifying the methodological issues addressed by the FAO approach and hence avoid the use of the non-parametric approach as proposed by the IFPRI researchers for the purpose of measuring undernourishment.

II. THE FAO PARAMETRIC APPROACH

According to the FAO approach, the estimate of the prevalence of undernourishment in the population is formulated as follows:

$$pU = \int_{x<r_L} f_X(x)\, dx \quad \ldots\ldots (1)$$

where X is a random variable representing dietary energy consumption (DEC), $f_X(x)$ is the density function of X, R represents DER and r_L is an acceptable lower limit of the distribution of R, i.e. MDER.

a. Derivation of the Formula for pU

The formula given by (1) was originally derived by considering the probability distributions of DEC and DER, i.e. X and R (Sukhatme, 1961). The formulation of the estimate of the prevalence of undernourishment within a distributional framework is based on two considerations: the first is that the food consumption data from household surveys refer to a probability sample rather the totality of households in the population and the second is that the DER of an individual is unknown but is normatively specified as the average for population groups of given age and sex.

The fact that the food consumption data from the NHS refers to probability sample of households from the population and DER is specified as an average implies that the inference regarding the prevalence of undernourishment has to be considered at the population level within a probability distribution framework. The unit of the distribution is the average individual implied by the expression of population data on per person basis. In other words the distribution refers to units that are free of the effect of differences due to sex and age.

There are in fact three probabilities regarding the status of an observed value of *X* vis-à-vis the individual's value of *R*: the probability of the observed value being below the individual's value of *R,* i.e. $P(x<r)$; the probability of the observed value being in balance with the individual's value of *R,* i.e. $P(x=r)$; and the probability of the observed value being above the individual's value of *R*, i.e. $P(x>r)$. At the population level these probabilities are conceived as an average or expected value over the distribution of *X* as follows:

$$P(X<R) = \int_{-\infty}^{\infty} P(x<r)\, f_X(x)\, dx \quad \text{(2)}$$

$$P(X=R) = \int_{-\infty}^{\infty} P(x=r)\, f_X(x)\, dx \quad \text{(3)}$$

$$P(X>R) = \int_{-\infty}^{\infty} P(x>r)\, f_X(x)\, dx \quad \text{(4)}$$

As explained in detail in a separate paper (Naiken, 2007), the above population level probabilities depends on whether the variation of *R* is random or systematic. If the variation is random, e.g. due to measurement or estimation error, the three probabilities reduce to the following:

$$P(X<R) = \int_{-\infty}^{\mu_R} f_X(x)\, dx \quad \text{(5)}$$

$$P(X=R) = 0 \quad \text{(6)}$$

$$P(X>R) = \int_{\mu_R}^{\infty} f_X(x)\, dx \quad \text{(7)}$$

where μ_R is the average or mean of *R*.

The above means that the use of the mean of *R* as cut-off point in estimating the prevalence of undernourishment (i.e. $P(X<R)$) implies that the variation of *R* is considered to be random.

However, since the variance of *R* considered here refers to the true variation arising from systematic sources, namely bodyweight and physical activity, the implied distribution of *R* in fact represents the distribution of *X* in a population where everyone is in the state of energy adequacy or balance. This means that the distribution of *R* reflects the realization of the joint distribution of *X* and *R*, i.e.

$$f_R(r)=f_{XR}(x,r)$$

where $f_R(r)$ represents the density function of *R* and $f_{XR}(x,r)$ the joint density function of *X* and *R*.

The above implies that $P(x=r)=1$ for all *x* overlapping the range of *R*. Thus, since by definition $P(x<r)=1$ for all *x* below the the lower limit of the range of *R* and $P(x>r)=1$ for all *x* above the upper limit, the three population level probabilities are given as follows:

$$P(X<R) = \int_{-\infty}^{r_L} f_X(x)\, dx \quad (8)$$

$$P(X=R) = \int_{r_L}^{r_U} f_X(x)\, dx \quad (9)$$

$$P(X>R) = \int_{r_U}^{\infty} f_X(x)\, dx \quad (10)$$

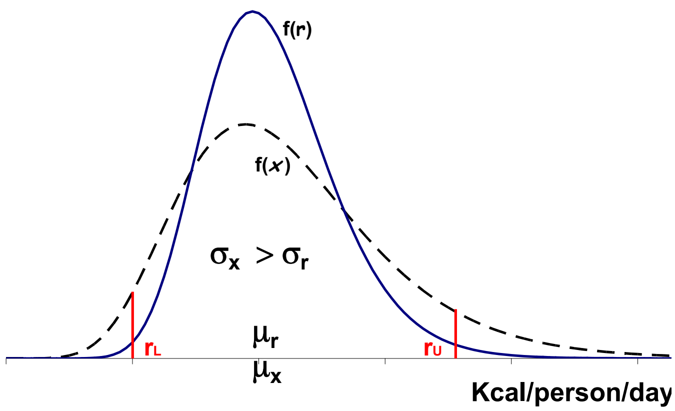
where r_L and r_U represent the lower and upper limits of the range of *R*.

Note that the right hand side (RHS) of (8) is equivalent to the RHS of (1). Thus the formula for *pU* given by (1) results from the consideration that the variation of *R* due to body-weight and physical activity is not random but systematic and consequently the implied distribution of *R* reflects the realisation of the joint distribution of *X* and *R*.

The probability framework illustrating the probabilities given by (8), (9) and (10) is shown in Figure 1.

In the figure, the distribution of *X* is shown to be wider than that of *R* since the distribution of requirement is located within the range of variation of *X* and the variance of *X* is expected to be larger than that of *R*. The larger variance of *X* is due the fact that it includes, in addition to the variance of *R* due to body-weight and physical activity, the variance due to income and residual factors. The area corresponding to $P(X=R)$, is represented by part of the distribution of *X* ranging from r_L to r_U while $P(X<R)$ is represented by the part below r_L and $P(X>R)$ by the part above r_U.

Figure 1: Distribution of R and X, $f_R(r)$ and $f_X(x)$, respectively



The means of *X* and *R* are shown to be equal in the figure solely for simplicity and the purpose of illustrating the extension of the distribution of *X* beyond the limits of the distribution of *R*. This implies a higher variance or standard deviation of *X*. It is obvious that in most cases, the two means are not equal.

As the extension of the two tails of the distribution of *X* beyond the limits of the distribution of *R* mainly reflects the effect of the income factor, the distribution of *X* is shown to be skewed to the right just as the income distribution.

The distribution of *R* also is likely to be skewed as it is induced by a slightly skewed distribution of weight for height in the reference population and the skewed distribution of physical activity levels which concentrates more population on the side of sedentary lifestyles than vigorous lifestyles. Moreover, as the true lower and upper limits of the range of *R*, i.e. r_L and r_U, are actually not known, the positions that they are shown in the figure reflect the fact that they have been taken to correspond to the 5^{th} and 95^{th} percentiles respectively of the distribution of *R*. In other words the 5^{th} and 95^{th} percentiles have been considered as acceptable limits of the range of *R* due to differences in body-weight and physical activity.

b. Evaluation of the Formula for pU

For the purpose of evaluating the formula for $P(X<R)$ it is necessary to specify the distribution of *X*, i.e. $f_X(x)$, and the lower limit of the distribution of *R*, i.e. r_L. In this context the distribution of *X*, is assumed to be lognormal with parameters μ and σ. Thus, given the parameters of the distribution of *X* and r_L, the proportion of the population undernourished is evaluated using the cumulative standard normal distribution as follows:

$$pU = \Phi \{(\log_e r_L - \mu) / \sigma \}$$

The assumption of a lognormal distribution for *X*, implies that μ and σ can be determined on the basis of the mean and coefficient of variation of *X* as follows:

$$\mu = \log_e \mu_X - [\log_e \{CV^2_X + 1\}]/2$$

$$\sigma = [\log_e \{CV^2_X + 1\}]^{0.5}$$

where μ_X and CV_X refer to the mean and coefficient of variation of *X*, respectively.

Therefore, given the assumption of a lognormal distribution for *X*, the evaluation of *pU* requires estimates of r_L, μ_X and CV_X. The estimation of each of these parameters is described below.

c. *Estimation of r_L*

The lower limit of distribution of *R*, i.e. r_L, is derived by considering the components of the variation of DER. Since DERs are normatively specified as averages by sex-age groups, the components of the variation are considered to be those due to the factors that determine the level of DER of individuals of given of sex and age, i.e. body-weight and physical activity, and a residual component reflecting the effect of unknown factors. Thus DER can be written as

$$R = BW + PA + \varepsilon \quad \text{..(10)}$$

where *BW* refers to the contribution of body-weight, *PA* the contribution of physical activity and ε the contribution of the unknown factors.

Consequently, assuming that *BW*, *PA* and ε are independent, the variance of *R* can be been written as follows:

$$Var(R) = \sigma^2_{BW} + \sigma^2_{PA} + \sigma^2_{\varepsilon} \quad \text{..(11)}$$

where σ^2_{BW} refers to the component of variation due to body-weight, σ^2_{PA} the component due to physical activity and σ^2_{ε} to the component due to unknown factors.

The component of variance due to unknown factors, i.e. σ^2_{ε}, is assumed to be a random variation associated with estimation or measurement error and therefore excluded in defining the variance parameter of the distribution of *R*. That is to say that variance of the distribution has been defined as follows:

$$\sigma^2_R = \sigma^2_{BW} + \sigma^2_{PA}$$

The *FAO/WHO/UNU Expert Consultation on Energy and Protein* that met in 1981 (WHO, 1985) in fact discontinued the practice of deriving energy requirements on the basis of the energy consumptions of reference man and woman and takes into account the existence of acceptable ranges for given sex and age groups. Energy requirement is defined as the consumption level that will balance energy expenditure when individuals have a body-weight and physical activity level that are consistent with good health and that will allow for the maintenance of economically necessary and socially desirable physical activity. In other words energy requirement was defined as the energy expenditure of an individual having a body-weight and a physical activity level that is consistent with the said health and economically and socially desirable criteria

In line with the above expenditure approach, the 1981 *FAO/WHO/UNU Expert Consultation* formalized the expression of energy requirement in terms of the energy expenditure for maintaining body-weight, expressed as the *Basal Metabolic Rate* (*BMR*), and a multiplying factor to take into account the needs for physical activity referred to as physical activity level *(PAL)* index. For the purpose of practical application, the Expert Consultation provided a set of regression equations for the estimation of the average *BMR* by sex-age groups on the basis of a linear equation linking *BMR* with body-weight (expressed in kg.) and three *PAL* indices reflecting light, moderate and heavy physical activity levels were given.[1] The *BMR* calculated on the basis of body-weight is considered to be an average over the variation of *R* due to the effect of the unknown factors, i.e. σ^2_ε. This new approach of estimating energy requirement was in recognition of the fact that there is a range of body-weight that can be considered to be consistent with good health and a range of physical activity levels that are consistent with the performance of the necessary and socially desirable physical activity.

The above approach enabled the direct estimation of r_L on the basis of the lower limit of the range of variation of body-weight (for the calculation of the average *BMR*) and the lower limit of the range of variation of the *PAL* index. In this connection the range of acceptable body-weights for attained height in the relevant WHO reference populations was taken as the range of weights that are consistent with good health and the *PAL* indices corresponding to light and heavy physical activities were taken to reflect the range of physical activity levels that are consistent with the performance of the necessary and socially desirable physical activity. Consequently the body-weight corresponding to the lower limit of the relevant WHO reference distribution of weight for attained height was used to calculate the average *BMR* and the *PAL* index corresponding to light activity was applied to the average *BMR* to arrive at the lower acceptable limit of the range of variation of *R* due to body-weight and physical activity. The resulting cut-off point thus reflects an estimate of the lower limit of the distribution of *R*. Hence it has been referred to as the minimum dietary energy requirement (*MDER*).

However, as the distribution of *X* in the present context refers to units that are free of the effect of differences due to age and sex, the MDER has to be calculated by sex-age groups and then averaged over the sex-age groups using the population sex-age structure as weight, in order to arrive at the estimate of r_L. The procedure for calculating the sex-age specific MDERs is formulated below.

The first step in the procedure is to calculate the average *BMR* on the basis of the lower limit of the range of variation of acceptable body-weights as follows:

$$\overline{BMR} = (a + b \times BW_L)$$

where *a* and *b* are the constants of the linear equations for *BMR* and BW_L is the lower limit of the range of variation of acceptable body-weights for attained height.

[1] The 1981 FAO/WHO/UNU Expert Consultation was not able to recommend the component energy expenditure approach for children below age *10*. For this segment of the population it provided a set of sex-age specific energy requirements per kg of body-weight that were based on the intakes of reference groups composed of healthy and well-nourished children in developed countries. However, this was remedied by the 2001 FAO/WHO/UNU Expert Consultation on Human Energy Requirements (FAO, 2004) which extended the expenditure approach to infants and children as well. But according to the new recommendations the approach based on the *BMR* and the *PAL* index has been limited to adults age 18 and above. For the infants, children and adolescents below age 18 the approach is to derive the Total Energy Expenditure (TEE) on the basis of body-weight and an allowance for physical activity (for those in ages 6 and above).

The next step is the calculation of the MDER by applying the *PAL* index corresponding to light activity to the estimated average *BMR* as follows:

$$MDER = PAL_L \times \overline{BMR} \quad (12)$$

where PAL_L refers to the *PAL* index for light physical activity level.

Thus, given the linear equations for estimating the average *BMR* and the *PAL* index, the key factor determining the level of the MDER is the lower limit of the range of acceptable weights for attained height in the WHO reference population distribution, i.e. BW_L. As this lower limit is in fact used since late 1970s as cut-off point in anthropometric indicators of nutritional status (Waterlow JC ***et al,*** 1977; WHO, 1995), the approach established a consistent link between the measurements of undernourishment (food deprivation) and undernutrition.

The country specific attained height figures by sex-age groups, needed to specify the range of weight for attained height in the WHO reference population distribution, are obtained from the anthropometric data collected in nutrition surveys or demographic and health surveys.

Finally the sex-age specific MDERs are averaged over the sex-age groups to arrive at the MDER corresponding to the average individual in the population represented by r_L as follows:

$$r_L = \Sigma_{ij}\, MDER_{ij} \times p_{ij} \quad (13)$$

where $MDER_{ij}$ and p_{ij} refer to the *MDER* and the proportion of the population respectively in age group *i* and sex *j*, reflecting the sex and age population structure.

It has to be pointed out that the above approach of deriving r_L reflects an attempt to circumvent the problem of absence of an estimate for σ^2_R and in essence does not depart from the idea behind consideration of r_L as the lower limit of the distribution of *R*.

d. Estimation of μ_X

The source of data for the estimation of μ_X is either the NHS or the food balance sheet (FBS). However, NHSs have been regularly carried out in a limited number of countries. Furthermore the interval between the surveys in these countries is generally 5 to 10 years. On the other hand FBSs are prepared and annually updated by FAO for practically all countries in the world. Hence, as the objective of FAO has been to derive estimates of the prevalence of undernourishment on a regular basis for as many countries as possible so as to monitor the food situation in the world, it has opted to take the mean DEC derived through the FBS as the estimate of μ_X. More recently, countries have shown interest for deriving estimates of the prevalence of undernourishment based on NHS data for the purpose of identifying who and where food insecure subnational population groups are and how to target them for interventions aimed at reducing hunger. Hence, they have opted to take the mean DEC derived through the NHS as the estimate of μ_X.

e. Estimation of CV_X

The NHS is the only source of data for estimating CV_X. In this context the problem relating to the long intervals between the surveys is not serious as, unlike the mean, the coefficient of variation, reflecting inequality, is a relatively stable measure. However, as will be discussed in Section IV, the distribution data from the NHS are subject to significant biases or errors so that they lead to overestimates of CV_X. In view of this, the past practice of using the household level data to estimate this measure has been abandoned by FAO. Instead, the differences between the means of the dietary energy consumption for households grouped according to income (or expenditure as a proxy) have been used. However, the estimate of the *CV* based on the differences between these group means refers to the component of CV_X due to income only. As individual dietary energy consumption is expected to vary also according to non-income factors such age, sex, body-weight and physical activity, i.e. the demographic and biological factors that determine the variation in dietary energy requirement, the CV of dietary energy requirement has been taken to reflect non-income component of CV_X. Thus, given the income and non-income components, CV_X is derived as follows:

$$CV_X = \sqrt{(CV^2_{X\,due\text{-}to\text{-}V} + CV^2_{X\,due\text{-}to\text{-}R})}$$

where $CV^2_{X\,due\text{-}to\text{-}V}$ refers to the variation component due to different income levels, *V*, and $CV^2_{X\,due\text{-}to\text{-}R}$ to the variation component due to different energy requirement levels, *R*.

$CV_{X\,due\text{-}to\text{-}R}$ is estimated on the basis of the range of variation of the dietary energy requirement of individuals in the population by specifying the lower and upper limits of the range. Attained height data by sex and age groups from available anthropometric surveys are used for deriving the acceptable range of body-weight for attained height, using the weight for height growth reference curves published by WHO. The range of weights combined with the range of physical activity levels implied by light and heavy physical activity norms and the variation due to estimation error of energy requirement equations permit the derivation of weighted (by the sex and age population structure) lower and upper limits of the range of variation of energy requirement. Having these two limits and assuming a log-normal distribution, the implicit $CV_{X\,due\text{-}to\text{-}R}$ is derived.

As regards the countries where NHS data are not available the problem of estimating $CV_{X\ due\text{-}to\text{-}V}$ has been addressed by resorting to imputed values based on the relationship with variables on which data are readily available.

III. THE IFPRI NON-PARAMETRIC APPROACH

This approach has been proposed following criticism of the FAO approach as being "biased towards food availability" and hence having "limited ability to capture access to food" (Smith and Aduayom, 2003). As the main reason advanced by the critics for the "bias towards food availability", was FAO's use of the mean DEC estimates from the FBS and the use of theoretical probability distribution (the lognormal distribution) to take into account the inequality in distribution, the IFPRI researchers have proposed the use of the individual household level data from NHS for making the inference regarding food inadequacy or food deprivation.

Thus the approach involves the comparison of estimates of DEC and DER corresponding to each of the households sampled in the NHS and identifying the energy deficit households. The total number of the individuals (household members) in the energy deficit households is then expressed as a proportion of the total number of individuals in all the households sampled to arrive at the estimate of the proportion of the population undernourished, i.e. *pU*. The methodology as applied by the researchers involves the following steps:

1. The conversion of the household food consumption data within a household reference period ranging from one-week to one-month period, which are usually expressed in terms of quantities of food items consumed, into dietary energy equivalents using food composition factors and thus deriving estimates of DEC *for each household*. In the cases where the data refer to the monetary expenditure corresponding to the food consumed, they are converted into food quantities based on market food prices prior to the conversion into dietary energy equivalents.
2. The calculation of the DER corresponding to each of the individuals in the household by taking into account the average (or median) body-weight of the corresponding sex and age group in the WHO reference population and light physical activity level and aggregating over the individuals to arrive at the household DER.[2]
3. The comparison of the DEC and the calculated DER corresponding to each of the households sampled and identifying the households having DEC level below the respective households' DER.
4. The aggregation of the individuals in the identified energy deficient households and dividing the total by the total number of individuals in all the households sampled in order to arrive at the estimate the proportion of the population undernourished.

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[2] We have assumed that WHO weight for given age and sex tables have been used as there is no reference in the IFPRI Research Report No. 146 (Smith LC Alderman H and Aduayom D 2006).

IV. THE INAPPROPRIATENESS OF THE NON-PARAMETRIC APPROACH

The above approach is claimed by the IFPRI researchers to be an improvement as compared to the FAO approach in the sense that the prevalence of undernourishment in the population is derived by aggregating inferences regarding food inadequacy made at the level of the individual households rather than a single inference made at the population level. However, as elaborated below, we consider it to be inappropriate from the perspective of the basic methodological framework and its reliance on the individual household level data from the NHS that are subject to biases and errors.

a. The Basic Methodological Framework

The IFPRI approach in fact considers the estimation of the prevalence of undernourishment in the population as a simple arithmetical exercise involving the comparison of the DECs of the households with their respective DERs, counting the number of individuals in the households with energy deficits and dividing the latter number by the total number of individuals in all households. This would indeed be quite appropriate if the DEC as well as the DER of all the households in the population was completely specified so that calculating both the number and proportion of individuals in the food deficit households is a straightforward exercise.

However, the fact of the matter is that the household level food consumption data from the NHS refer to a probability sampling design, different from a simple random design, taken from the population rather a complete enumeration. The non-parametric approach therefore ignores the sampling issue. Moreover, only the variation due to the sex and age of the individuals can be taken into account in specifying household DER. In other words household DER cannot be completely specified. By calculating the DER of the individuals in the household on the basis of the light activity norm, the variation due to physical activity also is taken into account. However, since the average (or median) weight for given age and sex in the WHO reference population has been used, the variations due to body-weight and the unknown factors (i.e. $\sigma^2_{BW} + \sigma^2_{\varepsilon}$) have not been taken into account.

As discussed in Section II(a), the fact that the NHS data refer to a probability sample from the population and the household DER cannot be completely specified, the estimation of the prevalence of undernourishment has to be carried within a probability distribution framework where the average individual in the population is the unit of assessment. It was also shown that the fact that the variation in DER due to bodyweight and physical activity is not random but systematic dictates the use of the lower limit of the range of variation i.e. the concept of MDER, in estimating the prevalence of undernourishment. The MDER refers to an energy requirement level based on body-weight corresponding to the lower limit of the acceptable range for attained height and physical activity corresponding to the light activity norm. This is in fact lower than the DER based on the average (or median) body-weight for a given sex and age group used by the IFPRI researchers. In fact by using this average, the variation in DER due to body-weight has been incorrectly assumed to be random. Thus the higher energy requirement in the approach proposed by the researchers, which leads to an overestimation of the prevalence of undernourishment, is a consequence of the failure to consider that the variation in DER due to body-weight reflects a systematic rather than random variation.

The main point being made here is that, because the sample data from the NHS actually refers to the probability distribution of households according DEC levels (rather than the actual distribution in the population) and the existence of variation in DER, it is not possible to directly classify an individual (or a household) in the undernourished category. However the proportion of such individuals (or households) in a population (or sub-population) can be estimated but this dictates an assessment within a probability distribution framework where the average individual (or household) in the population (or subpopulation) is the unit of assessment and (since the variation in DER due to body-weight and physical activity is systematic rather than random) the MDER corresponding to this unit is the criterion for estimating the prevalence of undernourishment in the population.

b. Reliance on Household Level Data that are subject to Biases and Errors

In the previous sub-section it has been illustrated that the basic methodological framework underlying the approach proposed by the IFPRI researchers is not correct from a theoretical viewpoint and secondly, since account has not been taken of the fact that the variation in DER due to body-weight is systematic rather than random, the concept of DER used would overestimate the prevalence of undernourishment. In this sub-section we shall address the overestimation arising from the use of the household level data that are subject to biases and errors.

It may be recalled that the main objective of IFPRI's research was to demonstrate the application of a methodology that relies on the individual household level estimates of dietary energy consumption from the NHS. Instead, the FAO method uses grouped NHS data only: households are grouped by income level and the DEC mean is calculated for each group, so that the variation estimated from the NHS data is limited to the component of CV_X, due to income, i.e. $CV^2_{X\ due\text{-}to\text{-}V}$. As indicated in Section II (e), the reason for not using the individual household level data is that they are subject to biases or errors mainly due to the fact that, as discussed below, the principal aim of the surveys is to obtain reliable estimates of the population mean.

1) The application of sampling designs that departs from the equal probability of selection method

The sample selection in most of the household surveys departs from the equal probability of selection method (epsem) with the consequence that the estimate of the variance and other measures of inequality based on the household level data are subject to bias (Scott C, 1992; Arbia G, 2003; Srivastava AK Rai A and Ramasubramanian V, 2003). The non-epsem sample designs provide for the derivation of unbiased estimates of the mean (and its variance or the sampling error) but not of the distribution and hence the variance and related measures of inequality pertaining to a variable. This is an indication that, in adopting *epsem* sample designs, the aim is to obtain, for a given sample size, more precise estimates of the mean (as reflected by lower sampling error) rather than the distribution or variance of the variable of interest.

2) The practice of spreading the sample evenly over the survey year

Most, if not all, NHSs collect data on household consumption and expenditure referring from one-week to one-month period. This approach reflects an attempt to remove the effect of day-to-day variation and thus represent the "usual" situation. However consumption and expenditure are also affected by seasonal variation. Thus in order to account for this variation also, a common practice is to spread the sample households evenly over the period of a year. This yields an unbiased estimate of the mean that is free of the effect of seasonal variation but the individual households data are biased in the sense that they refer to different time periods and hence seasons during the year.

3) The effect of non-sampling errors

The non-sampling errors are due to well-known factors such as recall, under or over-reporting, non-completeness of data collection forms, interview effects, etc. To the extent that these errors are random, they may not affect the mean but they certainly distort the consumption levels of the different households. In addition to this, the common practice of data "cleaning" process involving the exclusion of certain households, replacement of data by imputed values or "correction" of data, may reduce the number of the extreme values but in no way can this lead to a reflection of the true values. In fact the main purpose of such "cleaning" is to detect "outliers" and prevent their undue effect on the mean. In other words the focus again is on the precision of the mean rather than the individual household data.

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The last two points discussed above, i.e. 2) and 3), are by far the most important since they lead to overestimation of the variance and hence the CV and other measures of inequality. This issue has been studied by Scott (1992) in the context of household consumption expenditure data referring to a one-month period. He has shown that the upward bias in the estimate of the variance based on the household level data from the NHS is twice the covariance between the monthly estimates even under the assumption of equal dispersion across months. He also indicated that the upward bias could be as high as 36 per cent of the standard deviation.

A similar study referring to household food consumption data with shorter reference periods (one day and one week) was conducted by FAO in connection with the Sixth World Food Survey (FAO, 1996). The study was based on household per person food consumption data (expressed in terms of kilocalories) from five small sample surveys carried out by IFPRI in certain rural areas of Bangladesh, Kenya, Pakistan, the Philippines and Zambia. The uniqueness of these surveys is that they repeated food consumption measurements with one-day or one-week recalling periods during the survey year and thus enabled the estimation of the average per person household consumption that is free of the effect of seasonal variation. These data sets made possible the assessment of the difference between the standard deviation based on the average household per person consumption during the year and that based on all the one-day or one-week observations during the year. These results showed that the standard deviations based on the annual household averages were smaller than the standard deviations based on all individual household observations (which refer to different periods during the year) by 46 to 75 per cent and thus indicating an upward bias in the measure of variance ranging from 25 to 54 per cent of the standard deviations.

The overestimation of the variance means that the dispersion of the household data around the mean is wider than what it should be with the consequence that the individuals in some of households of the lower tail of the distribution would be wrongly classified as undernourished. Therefore the use of the individual household level data runs the risk of overestimating the prevalence of undernourishment.

V. UNDERNOURISHMENT ESTIMATES FROM THE TWO APPROACHES AND THE SOURCES OF THE DIFFERENCES

As indicated in Section I, the approach proposed by the IFPRI researchers has been applied to 12 countries in Sub-Saharan Africa. The resulting estimates of p*U* as well as the FAO estimates for the 12 countries are presented in Table 1 below.

Table 1
Prevalence of Undernourishment according to FAO's and IFPRI researchers' estimates

Country	Year	FAO estimate (%)	IFPRI estimate (%)
Burundi	1998	66	75
Ethiopia	1999	44	76
Ghana	1998	15	51
Guinea	1994	31	45
Kenya	1997	43	44
Malawi	1997	32	73
Mozambique	1996	63	60
Rwanda	2000	41	65
Senegal	2001	24	60
Tanzania	2000	43	44
Uganda	1999	21	37
Zambia	1996	45	71
Average		39	58

The table shows that, with the exception of Mozambique, the estimates derived through the non-parametric approach proposed by the IFPRI researchers are all higher than the FAO estimates. However, in the case of Mozambique, Kenya and Tanzania, the estimates are quite close. In 8 of the 12 countries the former estimates are higher by more than 10 percentage points. In terms of the average for the countries as a whole the estimate derived by the IFPRI researchers is higher by 19 percentage points.

Given the large divergences between the two estimates for the majority of the countries, the IFPRI researchers attempted to explain the sources of the differences by estimating the three parameters involved in the FAO methodology, i.e. μ_X CV_X and r_L, on the basis of the household level data used for applying the non-parametric approach and comparing them with those underlying the FAO estimates (Smith LC Alderman H and Aduayom D, 2006). In commenting on the differences the authors played down the issues relating to the parameter values derived on the basis of the household level data or relegated them to further research. Then, using the FAO lognormal distribution framework, the contribution of the difference in each of the three parameters to the divergences between the two estimates was assessed. In this connection it was noted that when the parameter values calculated on the basis of the household level data used by the IFPRI researchers' were applied in the FAO methodological framework as described in Section II(b), the results of the prevalence of undernourishment were practically the same as those obtained through the non-parametric approach. This was interpreted by the IFPRI researchers as an indication that the differences noted in the estimates in Table 1 were not due to the FAO methodology itself but to the underlying parameters used. However, in this section, we shall interpret the results of the comparative analysis undertaken by the IFPRI researchers from the perspective of the observations made in Section IV.

a. Differences between the Underlying Parameters

The differences in the estimates of μ_X and CV_X, which have been presented in Tables 5.3 and 5.4 in the IFPRI researchers' report, are reproduced here in Table 2. The differences with respect to r_L, presented in Table 5.2 of the report, are reproduced in Table 3.

Table 2
FAO and IFPRI estimates of μ_X and CV_X

Country	Year	FAO μ_X (kcal/person/day)	IFPRI μ_X (kcal/person/day)	FAO CV_X	IFPRI CV_X
Burundi	1998	1628	1592	0.29	0.75
Ethiopia	1999	1801	1648	0.32	0.39
Ghana	1998	2525	2328	0.27	0.62
Guinea	1994	2194	2510	0.33	0.58
Kenya	1997	1981	2579	0.26	0.62
Malawi	1997	2047	1614	0.32	0.79
Mozambique	1996	1826	2059	0.31	0.70
Rwanda	2000	2058	1860	0.32	0.66
Senegal	2001	2277	1967	0.26	0.56
Tanzania	2000	1958	2454	0.28	0.57
Uganda	1999	2334	2636	0.29	0.52
Zambia	1996	1958	1764	0.30	0.73

For ease of reference, the values of each of the three parameters underlying the FAO estimates of the prevalence of undernourishment has been referred to as "FAO estimates" while those based on the household level data underlying the application of the non-parametric approach has been referred to as "IFPRI estimates".

Table 3

FAO and IFPRI estimates of r_L

Country	Year	FAO r_L (kcal/person/day)	IFPRI r_L (kcal/person/day)
Burundi	1998	1790	2025
Ethiopia	1999	1720	2035
Ghana	1998	1850	2058
Guinea	1994	1830	2026
Kenya	1997	1820	2069
Malawi	1997	1800	2060
Mozambique	1996	1890	2048
Rwanda	2000	1750	2043
Senegal	2001	1850	2066
Tanzania	2000	1810	2053
Uganda	1999	1770	2039
Zambia	1996	1820	2042

1) Differences in estimates of μ_X

With exception of Burundi, the differences between the two sets of estimates of μ_X are large. However the differences are not systematic; while in seven countries FAO's estimates are larger than IFPRI's, in the remaining five countries the converse is true. The FAO estimates have been derived through the FBS mainly on the basis on national food production and trade statistics (the other statistics taken into account are changes in stocks, wastages up to the retail level and non-food uses) while the IFPRI estimates have been derived on the basis of the food consumption data collected in the NHS. In discussing the reliability of the estimates from these two sources there has been a tendency for critics to point out the possibility of significant underestimation in the estimates from the FBS particularly for the African countries where the food production statistics are believed to underestimate subsistence production. The estimates derived from the NHS data, presumably because they are based on scientific surveys geared to yield reliable estimates of the mean consumption levels, are considered to be free of this underestimation. Yet we note that that in seven of the 12 African countries the estimates derived through the FBS are higher than those based on the NHS data. The fact of the matter is that estimates from both sources have their own merits and limitations and it is not possible to make general conclusions as to which is the more reliable one. The fact that the differences between the two sets of estimates are not systematic complicates the matter.

As indicated in Section II(d), FAO's choice of the estimates from the FBS was dictated by its mandate to prepare estimates of the prevalence of undernourishment covering all the countries rather than a rejection of the NHS estimates. Actually, in specific country studies involving sub-national estimation of the prevalence of undernourishment, FAO uses the estimates from the NHS.

2) Differences in CV_X

The IFPRI estimates of CV_X are systematically much larger than FAO's. In fact, with the exception of Ethiopia, the IFPRI estimates are nearly double or more than double the size of FAO's. In discussing this issue, the IFPRI researchers have considered the FAO estimates to be referring to food consumption whereas their estimates refer to food acquisition or availability. They also indicated that there are reasons (not specified by the authors) to believe that FAO's CV_X are underestimates.

However, the fact of the matter is that the IFPRI estimates are unrealistically high because they are based on household level data that are subject to biases and errors as discussed in Section IV(b). This indicates that the higher estimates of CV_X are a source of systematic overestimation in the IFPRI estimates of the prevalence of undernourishment. This point is demonstrated later in sub-section (c).

3) Differences in r_L

Table 3 shows that the IFPRI estimates of r_L are systematically higher than FAO's across all the 12 countries. This a reflection of the fact that in the IFPRI researchers' approach DER is calculated on the basis of the average (or median) weight for a given sex and age-group while in the FAO approach it is calculated on the basis of the lower limit of the range of weight for attained height. In both approaches, the light physical activity level has been considered.

It is clear that, with the two other parameters remaining the same, the higher estimates of r_L would lead to higher estimates of the prevalence of undernourishment. In discussing this point the IFPRI researchers have indicated that the issue of which DER level is the more appropriate one in the present context is a subject of further research. However, as indicated in Section IV(a), the fact that the variation in DER due to body-weight and physical activity is systematic rather than random dictates the use of the lower limit of the range of variation, i.e. the concept of MDER, in estimating the prevalence of undernourishment. Thus, the higher concept of DER used represents another source of systematic overestimation in the IFPRI estimates.

b. The Flaw in the Distribution based on CV_X Estimated on NHS household level data

As indicated earlier, the IFPRI researchers have considered the differences between the FAO and IFPRI estimates of the prevalence of undernourishment as being mainly due to the differences in the estimates of the three parameters. However, it is noted that in 3 of the 12 countries, namely Mozambique, Kenya and Tanzania, the FAO and IFPRI estimates of pU are quite close despite the differences in each of the three parameters. In each of these cases, IFPRI's estimates of not only CV_X and r_L but also μ_X are higher than FAO's. This obviously means that the effects of overestimation by the systematically higher CV_X and r_L have been more or less compensated by the effect of the higher μ_X. Because of this compensatory effect, the issue of inflated CV_X cannot be viewed independently of μ_X. In other words the issue has to be considered in the context of the reliability of the distribution of X underlying the estimates of μ_X and CV_X. Furthermore, since the inflated CV_X means that the two tails of the distribution are extended beyond their true limits, the problem has to be viewed from the perspective of not only the overestimation of the prevalence of undernourishment but also that of overnourishment i.e. $P(X>R)$. This is important particularly in the light of FAO's plans to also estimate the prevalence of overnourishment.

Thus the issue actually boils down to assessing the extent of overestimation in the prevalence of undernourishment and/or overnourishment resulting from the distribution of X underlying IFPRI's estimates of μ_X and CV_X as compared to that resulting from the FAO distribution. Since the true limits of the distribution of X are unknown, it is not possible to assess the true extent of the over-estimation. However we can obtain an idea by looking at the proportion of unrealistically low and unrealistically high consumption levels implied by the distribution. Thus, for this purpose, we have taken 850 kcal/person/day as the level below which all values of X can be considered to be unrealistically low and 4500 kcal/person/day as the level above which all values of X can be considered to be unrealistically high. Then, using the FAO lognormal distribution framework and IFPRI's estimates of μ_X and CV_X, the percentage of the distribution below 850 kcal/person/day as well as the percentage above 4500 kcal/person/day have been calculated for the 12 countries. For the purpose of comparison these calculations have been repeated on the basis of distributions corresponding FAO's estimates of μ_X and CV_X for the 12 countries. The results of these calculations are presented in Table 4.

Table 4
Percentage below 850 kcal/person/day and above 4500 kcal/person/day in FAO and IFPRI distributions of *X*

Country	Year	Below 850 kcal/person/day		Above 4500 kcal/person/day	
		FAO Distribution	IFPRI Distribution	FAO Distribution	IFPRI Distribution
Burundi	1998	2	27	0	3
Ethiopia	1999	1	6	0	0
Ghana	1998	0	7	1	7
Guinea	1994	0	4	0	13
Kenya	1997	0	5	0	11
Malawi	1997	0	28	0	3
Mozambique	1996	1	14	0	6
Rwanda	2000	0	16	0	4
Senegal	2001	0	9	0	3
Tanzania	2000	0	4	0	8
Uganda	1999	0	2	1	9
Zambia	1996	0	21	0	4

It is noted that the percentage of the distribution below 850 kcal/person/day as well as above 4500 kcal/person/day are significantly above 0 in the case of practically all the IFPRI distributions but not in the case of the FAO distributions. This means that the IFPRI researchers' estimates of the prevalence of undernourishment are based on flawed distributions of X such that, if used within the framework of FAO methodology, they would lead to overestimates of the prevalence of undernourishment, irrespective of the level of r_L. The two sets of estimates of the prevalence of undernourishment are therefore not comparable.

VI. CONCLUDING REMARKS

The IFPRI approach does not represent an improvement over the FAO approach for estimating the prevalence of undernourishment on both theoretical and practical grounds. In fact, mainly because of its reliance on the household level consumption data that are subject to many sources of "undesirable" variation or error, it is likely to overestimate the variation of the energy consumption and hence the prevalence of undernourishment.

The FAO approach has the comparative advantage of enabling a) the use of either the NHS data or the FBS data for the mean, μ_X, and b) the use of the survey data in a manner that only the component of the CV_X that is not affected by the "undesirable' variation or errors in the household level data is captured. In view of the above, we conclude that the FAO approach is still the only one available for estimating the prevalence of undernourishment.

It should be mentioned here that the FAO approach, apart from being theoretically superior, has a distinct analytical advantage. By formulating the exercise within the lognormal distribution framework, the estimate is linked to the two key measures involved in distribution analysis, i.e. the mean and the measure of inequality represented by the CV. This is convenient since it facilitates the assessment of the differential effects of growth and changes in inequality on the prevalence of undernourishment.

The implication of the above findings is that investment should focus more on better utilization of the food consumption and income data in existing NHSs and improvement of future household surveys. These actions will improve the inputs for the estimation of the distribution parameters involved in the FAO approach.

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