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## **Indicators on food deprivation and income deprivation at national and sub-national levels: Methodological issues**

*SIBRIAN, Ricardo*

FAO of the UN, Statistics Division  
Viale delle Terme di Caracalla  
00153 Rome - Italy  
E-mail: Ricardo.Sibrian@fao.org

### **Abstract**

Indicators to measure income and food deprivations have been useful for understanding food insecurity at national level and within countries. This paper discusses two indicators: the prevalence of food deprivation (undernourishment) and the prevalence of critical food poverty. Both indicators use nutritional underlying criteria as a base, also derived from food consumption and income data collected in household surveys. The prevalence of food deprivation is the Millennium Development Goal indicator number 5, which uses the distribution of energy consumption as a base, while the prevalence of critical food poverty is a new indicator that links food deprivation with income deprivation, based on the distribution of income.

The link is the concept of minimum dietary energy requirement used in the FAO methodology as the cut-off value in the distribution of energy consumption for estimating undernourishment. The critical food poverty line for estimating the prevalence of critical food poverty is the cost of the minimum energy requirement, based on energy-yielding nutrient prices for a macro-nutrient balanced diet accessible to low income population groups. The macro-nutrient balanced diet uses the recommendations from a Joint WHO/FAO Expert Consultation on Diet, Nutrition and the Prevention of Chronic Diseases held in Geneva in 2002 as its point of reference. Examples which follow illustrate the results of both indicators for a sample of countries in different continents.

**Key words:** food poverty, undernourishment, food insecurity, food security

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## **1. BACKGROUND**

FAO has been monitoring food deprivation continuously on request since the 1996 World Food Summit (WFS) and the 2000 Millennium Declaration. These are expressed in terms of the WFS target and Millennium Development Goals (MDG) target on hunger reduction. The MDG target refers to the reduction in the proportion of the population suffering from food deprivation, while the WFS target refers to the reduction in the number of people suffering from food deprivation. The WFS target is more challenging than the MDG target. Reducing the number of food deprived, as in the WFS target, implies reducing the proportion of food deprivation. However, halving the proportion of food deprivation as in the MDG target does not necessarily imply reducing the number of hungry persons.

In 2002 FAO convened the International Scientific Symposium (ISS) on Measurement and Assessment of Food Deprivation and Undernutrition. The ISS reviewed the current methodologies available for monitoring food deprivation and undernutrition. The ISS recognized that food insecurity is a multifaceted and complex phenomenon and no perfect single measure captures all aspects. It also recommended the use of a suite of indicators to understand determinants of food insecurity, such as food availability, access and utilization as well as vulnerability. All these dimensions are inter-related by reciprocal causal or associative links and a suite of indicators may help to give an understanding of why people are food insecure and to better target and design informed policies and actions.

For this purpose the FAO Statistics Division has developed statistical procedures for estimating a suite of food security statistics (FSS) using the software named Food Security Statistics Module (FSSM). The FSSM produces many FSS at national and sub-national levels using food consumption and income data collected in national household surveys (NHS), including the prevalence of food deprivation and the number of undernourished in total population. It is the use of these two indicators that allows the monitoring of the MDG and WFS targets on food deprivation (hunger) reduction.

The statistical procedures in the FSSM include new expert recommendations on energy requirements, as well as statistics derived from a Technical Expert Workshop on Energy Requirements for Estimating Food Deprivation and Food Excess (January 2005, Rome, Italy). There is also the inclusion of a report on a Joint FAO/WHO/UNU Expert Consultation on Human Energy Requirements published recently (FAO, 2004) for calculating the minimum energy requirements in estimating the prevalence of food deprivation.

## **2. OBJECTIVES**

The main objective of this paper is to critically examine the indicators used for measuring food deprivation (hunger), for example, those used for monitoring the WFS and MDG targets as well as a new indicator on income deprivation (critical food poverty). These indicators are the prevalence of food deprivation (undernourishment) in total population (consuming not enough food to meet the minimum energy requirements) and the prevalence of critical food poverty (not having enough income to acquire food to meet the minimum energy requirements). Both indicators use the same nutritional underlying criteria and derive from food consumption and income data collected in household surveys.

## **3. METHODOLOGICAL ISSUES**

Several methodological issues, in estimating the prevalence of food deprivation and critical food poverty, concern the use of the underlying theoretical distribution for both dietary energy

consumption and income or proxy total expenditure. In this section the discussion will focus on the statistical framework for both indicators on food deprivation and on income deprivation.

### *Statistical framework for estimating food deprivation*

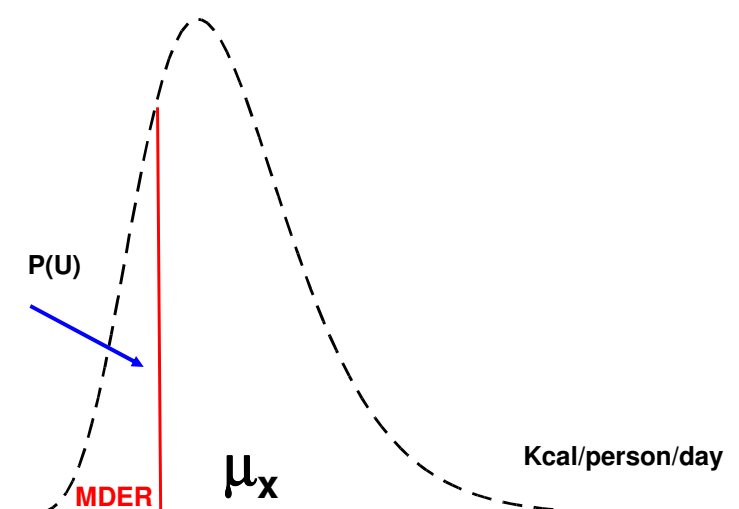
The prevalence of food deprivation is the proportion of the population below the minimum level of dietary energy consumption (minimum dietary energy requirement).

Please find the probability distribution framework defined as follows:

$$P(U) = P(X < MDER) = \int_{x < MDER} f_x(x) dx = F_x(MDER)$$

where:

P(U) is the proportion of food deprivation in total population;  
(x) refers to the dietary energy consumption (Kcal/person/day);  
MDER is a cut-off point reflecting the minimum acceptable level of energy consumption (Kcal/person/day);  
f(x) is the density function of energy consumption depicted by the graph to the right; and  
F<sub>x</sub> is the corresponding cumulative distribution function of dietary energy consumption.



The curve f(x) depicts the proportion of the population corresponding to different per person dietary energy consumption levels (x) represented by the horizontal line. The area under the curve up to the minimum dietary energy consumption (MDER), represents the proportion of the population not consuming enough food to meet the minimum level of energy requirement, P(U). The estimation of the prevalence of food deprivation has involved the use of several approaches, P(U). The most commonly used are described as it follows.

The first approach is the adequacy of energy consumption which is the ratio of energy consumption to energy requirement expressed as a percentage. This is also of use to estimate inadequacy of consumption of macro-nutrients, such as protein and micro nutrients like vitamin A. This indicator depends on the following: If the household dietary energy consumption adequacy is below, for example 70 percent, this puts all household members into the category of food deprived in terms of dietary energy. The prevalence of food deprivation in total population is then the number of members of households falling in this category divided by the number of members in all sampled households expressed as a percentage. Although still in practice, the mid 80's saw the abandonment of this approach, due to the fact that it does not take into consideration the distribution of energy consumption within the population that is the inequality in the access to food; however, still many practitioners are using this indicator for the purpose of food insecurity assessments. The 70 percent inadequacy cut-off value, which is an implied minimum dietary energy requirement, yields the same prevalence of food deprivation in different populations with the same average energy consumption but with different inequalities in the distribution of energy consumption.

The second approach recently proposed by researchers (Smith, Alderman and Aduayom, 2006) from the International Food Policy and Research Institute (IFPRI), is a direct comparison of

household energy consumption of each sampled household in a NHS with the household energy requirement. The latter derives from the summation of energy requirement of all members in the household, based on their median reference body-weights in the WHO growth standards that correspond to their sex and age for light physical activity. Each household whose total energy consumption is below the respective total energy requirement gets the classification of undernourished. The prevalence of food deprivation in the population is the total number of individuals in the households classified as food deprived divided by the total number of individuals in all the sampled households. This approach takes into consideration the inequality in access to energy consumption within the population as explained below. Unfortunately this approach has several flaws, for example, in deriving the household energy requirement to each of the individuals in the household, it does not comply with the nutritional expert groups' recommendation about the necessity of applying energy requirements to groups and not single individuals of given sex and age (WHO, 1985; FAO, 2004). Another flaw is that in deriving the IFPRI-MDER the value obtained is not a minimum acceptable level of energy requirement, since it takes the median reference body-weight which is the 50th percentile of the distribution of WHO growth standards for a given sex and age group with light physical activity or sedentary lifestyle. The estimated IFPRI-MDER using this approach is an average energy requirement for light physical activity or sedentary lifestyle and not a minimum in concept. A third flaw of this approach, as well as for the first approach discussed above, is the direct comparison of household energy consumption, which refers to a very short household-reference period and ignores the effect of seasonal variations and other undesirable sources of variations on implied inequality of energy consumption. Over-estimation of the prevalence of food deprivation results due to an over-estimated implicit variation in the distribution within the population and to an over-estimated MDER as documented elsewhere (Sibrian, Naiken and Mernies, 2007) and electronically available at [http://www.fao.org/faostat/foodsecurity/Papers\\_en.htm](http://www.fao.org/faostat/foodsecurity/Papers_en.htm).

FAO methodology has used the third approach. In estimating the prevalence of food deprivation this approach uses a parametric distribution framework under the assumption that dietary energy consumption per person per day follows a log-normal distribution. The FAO Statistics Division has tested the log-normality assumption against other distributions using household surveys from countries in different continents. The approach depends on three key parameters for each population group: the average dietary energy consumption (DEC) per person per day (total energy consumed by the entire population divided by its population size), the level of inequality in access to the energy consumption within the population and the MDER for the population group. Two components measure the inequality in access to energy consumption: the coefficient of variation of energy consumption due to income and the coefficient of variation of energy consumption due to biological factors (sex, age and physical activity). The former reflects the variation between means of energy consumption by income deciles grouped on a per person basis. The latter reflects variations of the sex and age composition structure data collected in population census, as well as variations in body-weight for attained heights collected in anthropometric surveys. The FAO/WHO/UNU Expert Consultation in 2001 on energy requirements, and published in 2004 for given age and sex population groups, derived the MDER. The body-weight is the minimum acceptable weight for attained-height (fifth percentile of the WHO growth standards) and the minimum acceptable physical activity level is that of a sedentary lifestyle.

Taking into consideration the three approaches discussed above, it is the parametric approach that provides the best statistical framework. It takes into account the amount of dietary energy consumed, the inequality in access to energy consumption within the population due to biological and income factors, as well as a nutritionally grounded MDER. The estimating procedures of this approach have been given in detail elsewhere (FAO, 2003) and are electronically available at [http://www.fao.org/faostat/foodsecurity/Files/undernourishment\\_methodology.pdf](http://www.fao.org/faostat/foodsecurity/Files/undernourishment_methodology.pdf).

## Statistical framework for estimating critical food poverty

The prevalence of critical food poverty is the proportion of the population below the minimum level of income to acquire food to meet the MDER, which is the same cut-off value for estimating the prevalence of food deprivation. The definition of the prevalence of critical food poverty, using a probability distribution framework, is similar in manner to that of the prevalence of food deprivation as follows:

$$P(CFP) = P(V < MDERcost) = \int_{v < MDERcost} g_v(v) dv = G_v(MDERcost)$$

where:

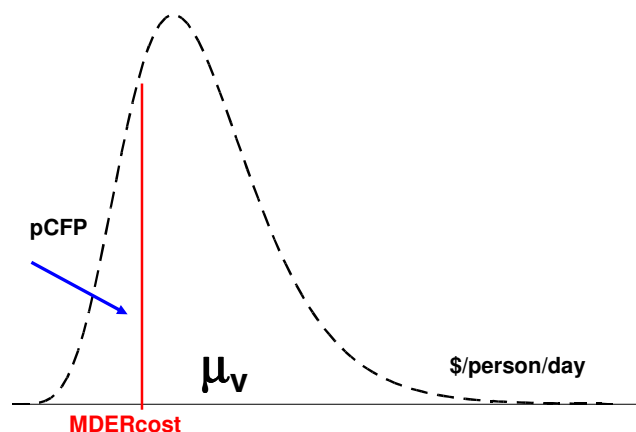
P(CFP) is the proportion of critical food poverty in total population;

(v) refers to income (\$/person/day);

MDERcost is a cut-off point reflecting the cost of food (\$/person/day) providing the MDER;

$g(v)$  is the density function of income or proxy total expenditure depicted by the graph to the right; and

$G_v$  is the corresponding cumulative distribution function of income.



In the graph above, the curve  $g(v)$  depicts the proportion of the population corresponding to different per person per day income levels (v) represented by the horizontal line. The area under the curve up to the MDERcost, represents the proportion of the population not having enough income to acquire food to meet the MDER, pCFP. The linkage between the P(U) and the pCFP is the MDER. In the case of estimating the P(U) MDER is in energy value, while in the case of the PCFP it is in monetary value, that is, the cost of the MDER (MDERcost).

The proposed pCFP uses the parametric approach with three key parameters for each population group, similar to the P(U): the average income per person per day, the level of inequality in access of income within the population and the MDERcost.

The average income per person per day is the total income in the entire population divided by its population size. The coefficient of variation of income measures the inequality of income, which under the log-normality distribution assumption is a one-to-one function of the traditional Gini coefficient. Estimation of the MDERcost takes place by using food prices consumed by households in the lowest income quintile ranked on income per person per day basis. Derivation of the dietary energy unit value for estimating the MDERcost comes from the nutritionally balanced contributions to total energy from proteins (12.5 percent), fats (22.5 percent) and carbohydrates (65 percent), using protein, fat and carbohydrate unit values as in the recommendations from a Joint WHO/FAO Expert Consultation in 2002.

## 4. DATA REQUIREMENTS

The data needed to estimate both indicators, the P(U) and the pCFP, are as follows: a. food consumed in quantities and monetary value; b. income or proxy total expenditure; c. the sampled population by age and sex; and d. the average height by age and sex.

It is necessary, preferably, to record the food items consumed in local monetary values corresponding to standard measurement units (kilo-grams, grams, litres or millilitres). It is also necessary to have well described, and as detailed as possible, descriptions of the food items consumed in the sampled households, to help the identification of such items in the food composition tables in order to estimate the level of energy and main energy-yielding nutrient (proteins, fats and carbohydrates) consumption. The energy, protein, fat and carbohydrate consumption levels and the food monetary value allow the estimation of the energy and macro-nutrient monetary unit values to take place. The estimation of the monetary value of the balanced-MDER takes place using these unit values, that is, the cut-off value MDERcost. The food quantities and monetary value should refer to the food consumption (and not to food acquisition) by the members of the sampled households within the household reference period, regardless of the moment of acquisition or production of the food consumed.

Estimation of the income data takes place by using an aggregated value of all income components by all members of the sampled household based on the concepts and definitions in the United Nations Manuals. Defining the household income deciles is possible by ranking households on an income per person per day basis. The average income estimates by income deciles permit the estimation of the coefficient of variation of income. The average energy consumption estimates by income deciles permit the estimation of the coefficient of variation of energy consumption due to income. One assumes the coefficient of variation of energy consumption due to biological factors to be constant at 20 percent, or it is possible to estimate this from available anthropometric data based on an induced distribution of energy requirements derived from the observed distribution of body-weight for attained-height in the population group.

The data on height and population by age and sex permit estimation of the MDER using the recommendations by the 2001 Joint FAO/WHO/UNU Expert Consultation on human energy requirements. The WHO growth standards, using the average attained-height given age and sex derived from anthropometric surveys, provide the minimum acceptable reference weight for height given age and sex. Countries have conducted these surveys in the form of Demographic and Health Surveys (DHS) on children and women at reproductive age, or in Multiple Indicator Cluster Surveys (MICS) on children, as well as other national nutritional surveys. The NHS for various specific population groups permits the derivation of the age and sex population structure.

## 5. ESTIMATING PROCEDURES

### *Estimating the prevalence of food deprivation*

Evaluation of the proportion of population below the MDER takes place as follows:

$\Phi [ (\log_e \text{MDER} - \mu) / \sigma ]$  where  $\Phi$  = standard normal cumulative distribution.

One assumes the distribution of dietary energy consumption,  $f(\mathbf{x})$ , as indicated previously, to be log-normal with the estimation of the parameters  $\mu$  and  $\sigma$  in the expression above taking place by using the mean dietary energy consumption and coefficient of variation of dietary energy consumption  $CV(x)$  as follows:

$$\sigma = [ \log_e (CV^2(x) + 1) ]^{0.5} \quad \text{and} \quad \mu = \log_e \mu(x) - \sigma^2 / 2 .$$

The average dietary energy consumption per person per day is

$$\mu(x) = \sum_{j=1}^k f_j(x|v)_j / \sum_{j=1}^k f_j$$

and the standard deviation of dietary energy consumption due to income is

$$\sigma(x|v) = \sqrt{\left[ \sum_{j=1}^k f_j (x|v)_j^2 - \frac{(\sum_{j=1}^k f_j (x|v)_j)^2}{\sum_{j=1}^k f_j} \right] / (\sum_{j=1}^k f_j - 1)}$$

where  $k$  is the number of income decile and  $f_j$  is the number of sampled households and  $(x|v)_j$  is the average dietary energy consumption per person per day of the  $j$ th income or proxy total expenditure decile.

Formulation of the coefficient of variation of dietary energy consumption due to income  $CV(x|v)$  takes place as follows:

$$CV(x|v) = \sigma(x|v) / \mu(x).$$

Thus, the data required for estimating the  $CV(x|v)$  are the averages of dietary energy consumption per person per day, the average household size by income household groups using deciles of income (or total expenditure) household per person per day.

The formulation of the  $CV(x)$  of the dietary energy consumption is as follows:

$$CV(x) = \sqrt{CV^2(x|v) + CV^2(x|r)},$$

The  $CV(x|r)$  is the coefficient of variation of dietary energy consumption due to biological factors, that on average has been estimated as 20 percent; however, if height data is available for the entire population for given age and sex, it is possible to estimate this based on the induced distributions of weight for attained height and physical activity levels for the population groups.

<p>The table to the right presents the average dietary energy consumption and number of members by deciles of household total expenditure, from a recent self-weighted sampling NHS (sample of 10000 households). It shows the prevalence of food deprivation for aggregated data from a hypothetical example. The estimates of parameters <math>\mu</math> and <math>\sigma</math> are 7.495 and 0.244 respectively, derived from estimates of the coefficient of variation of dietary energy consumption due to income, <math>CV(x v)</math>, and the average dietary energy consumption, <math>\mu(x)</math>, as indicated above. This paper treats the estimate of the MDER as exogenous. The estimated prevalence of food deprivation is 45.5 percent.</p> <p>Estimation of the MDER takes place using the attained-height data collected in a representative sample of individuals in the given age and sex population.</p>	<b>Estimating P(U) from 10000 sampled households</b>		
			average dietary energy
	income decile	average	consumption
	(\$/person/day)	persons	(Kcal/person/day)
	1	6.5	1500
	2	6.0	1600
	3	5.5	1700
	4	5.0	1800
	5	4.5	1900
	6	4.0	2000
	7	3.5	2100
	8	3.0	2200
	9	2.5	2300
	10	2.0	2400
<b>all</b>	<b>4.3</b>	<b>1853</b>	
CV(due to income)	0.146		
CV(x)	0.248		
sigma	0.244		
mu	7.495		
mder	1750	exogenous	
P(U)	45.5	percent	

The procedure involves using the minimum reference weight-for-height (5<sup>th</sup> percentile in the WHO growth standards) derived from the collected on attained-height data and the energy requirement per kilo-gram which differs by age and sex in children, adolescents and adults. The procedure for deriving the MDER for the total population weighs by the age and sex population structure of the population under study. Details on the procedure for estimating the MDER and the  $CV(x|r)$  have been given elsewhere (Sibrian and Naiken, 2007).

### Estimating the prevalence of critical food poverty

The estimating procedure for the prevalence of critical food poverty (pCFP) is similar to that for estimating the prevalence of food deprivation, except that it takes the income distribution as its base and the minimum cost of macro-nutrient balanced MDER. The process of evaluation of the pCFP is as follows:

$\Phi [ (\log_e \text{MDERcost} - \mu) / \sigma ]$  where  $\Phi$  = standard normal cumulative distribution.

One assumes the distribution of income or proxy total expenditure,  $\mathbf{g}(\mathbf{v})$ , as indicated previously, to be log-normal with parameters  $\mu$  and  $\sigma$  estimated on the basis of the mean income (or proxy total expenditure) and coefficient of variation of income  $CV(\mathbf{v})$  as follows:

$$\sigma = [ \log_e (CV^2(\mathbf{v}) + 1) ]^{0.5} \quad \text{and} \quad \mu = \log_e \mu(\mathbf{v}) - \sigma^2 / 2 .$$

The average income per person per day is

$$\mu(\mathbf{v}) = \sum_{j=1}^k g_j(\mathbf{v})_j / \sum_{j=1}^k g_j$$

and the standard deviation of income is

$$\sigma(\mathbf{v}) = \sqrt{ \left[ \sum_{j=1}^k g_j(\mathbf{v})_j^2 - \left( \sum_{j=1}^k g_j(\mathbf{v})_j \right)^2 / \sum_{j=1}^k g_j \right] / \left( \sum_{j=1}^k g_j - 1 \right)}$$

where  $k$  is the number of income decile and  $g_j$  is the number of sampled households and  $(\mathbf{v})_j$  is the average income (or proxy total expenditure) per person per day of the  $j$ th income (or proxy total expenditure) decile.

The formulation of the coefficient of variation of income  $CV(\mathbf{v})$  is as follows:

$$CV(\mathbf{v}) = \sigma(\mathbf{v}) / \mu(\mathbf{v}) .$$

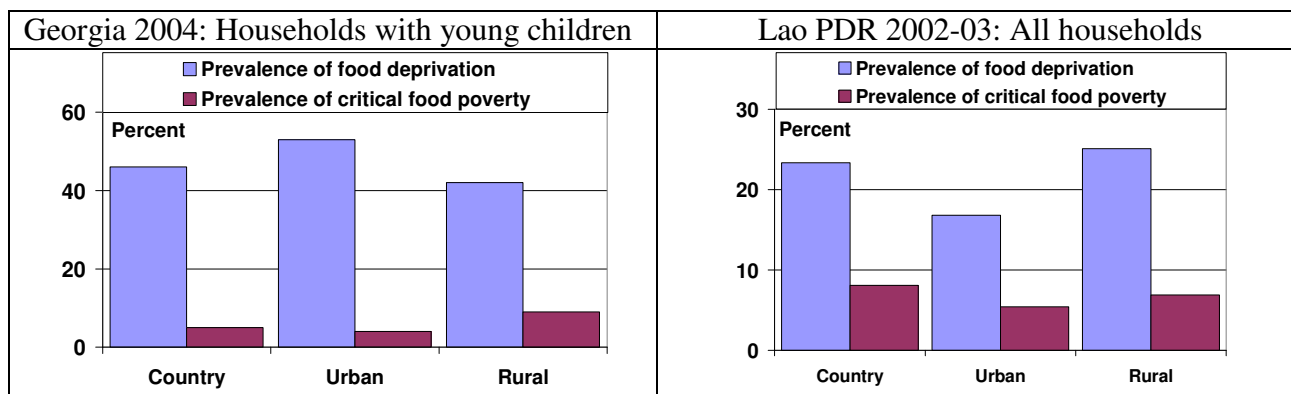
Thus, the data required for estimating  $CV(\mathbf{v})$  are the averages of income (or proxy total expenditure) per person per day, the average household size by household per person per day income or expenditure decile.

<p>The table to the right presents the average income (or proxy total expenditure) per person per day and number of members by deciles of household income (or proxy total expenditure) per person per day from the self-weighted sampling NHS used for estimating food deprivation. It shows the prevalence of critical food poverty for aggregated data from a hypothetical example. The estimates of parameters <math>\mu</math> and <math>\sigma</math> are 0.243 and 0.951 respectively, derived from estimates of the coefficient of variation of income, <math>CV(\mathbf{v})</math>, and the average total expenditure, <math>\mu(\mathbf{v})</math>, as indicated above. The estimate of the MDERcost is 0.61 for the balanced-MDER. The estimated prevalence of critical food poverty is 21.7 percent.</p> <p>Estimation of the MDERcost takes place by using the MDER and the cost of protein, fat and carbohydrates from households in the lowest income (total expenditure) quintile.</p>	<b>Estimating pCFP from 10000 sampled households</b>		
	income decile (\$/person/day)	average persons	average income (\$/person/day)
	1	6.5	0.45
	2	6.0	0.55
	3	5.5	0.65
	4	5.0	0.90
	5	4.5	1.20
	6	4.0	1.80
	7	3.5	2.50
	8	3.0	4.00
	9	2.5	7.00
	10	2.0	10.00
	<b>all</b>	<b>4.3</b>	<b>2.00</b>
	<b>cv</b>	<b>1.21</b>	
sigma	0.951		
mu	0.243		
mdercost	0.61	exogenous	
pCFP	21.7	percent	



## 6. EXAMPLES

Many countries have estimated both indicators when assessing food insecurity derived from NHS data. The boxes below illustrate results of both indicators for two countries: Georgia (Georgia 2007) and Lao PDR (LAO PDR, 2007).



## 7. CONCLUSION and REMARKS

1. Countries are able to monitor MDG targets on poverty and hunger reduction based on NHS data on food consumption and income at national and subnational levels.
2. The indicators of food deprivation and critical food poverty discussed above can be useful to assess magnitude and trends obtained by using standard estimating procedures from NHS for the identification of food insecure population groups and evaluation of the social and economic impact of policies and interventions that aim at food security improvement.

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