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Measuring food insecurity: Global estimates*

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Abstract

Food insecurity is a complex development issue dealing with physical and economic constraints to safe and nutritious food to maintain healthy living. This paper proposes a new approach to measuring food insecurity. Households or individuals are deemed food insecure if their access to food sufficient to meet their nutritional needs is limited by lack of resources. This paper estimates the per capita monetary cost of a food basket that provides a balanced diet through adequate nutrients including calories, protein, fat and carbohydrates to maintain good health. The per capita monetary cost of food is calculated in terms of U.S. dollars based on the 2005 Purchasing Power Parity to compare estimates across countries. The findings reveal substantial progress in reducing global food insecurity during 2002–2011. In just one decade, the percentage of food insecure people, who are likely to suffer from hunger, notably decreased from 21.59% in 2002 to 10.98% in 2011, with more than 455 million people lifted out of food insecurity. Despite such progress, some 626 million people in the globe are still food insecure. Among the regions, Sub-Saharan Africa suffers from severe hunger. This paper estimates that with its trend growth rate, Sub-Saharan Africa will need almost three decades to eradicate food insecurity.

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1. Introduction

Food is a basic necessity. But in some parts of the world, having three meals or even two meals a day is a luxury. This injustice illustrates the concept of food insecurity. Food insecurity is about some people not knowing if and when their next meal will come, and not being able to afford the food they want to eat. People will be food secure if they can always buy the basic food they are accustomed to.

The 2009 Declaration of the World Submit on Food Security states that "food security exists when all people, at all times have physical, social and economic access to sufficient, safe and nutritious food, which meets their dietary needs and food preferences for an active and healthy life." This definition has been widely accepted by the international community, with the Food and Agriculture Organization (FAO) using this definition to derive several indicators of food security as presented in its flagship publication, *The State of Food Security in the World*.

Food insecurity can be viewed as an extreme form of poverty. The relationship between the two is evident from Rowntree's (1901) work on measuring the absolute poverty line, which he defined as the cost of maintaining a minimum standard of living. He first estimated the minimum monetary costs for food, which would satisfy the average nutritional need of families of different sizes. To these costs, he added the rent paid and minimum amounts for clothing, fuel, and sundries to arrive at a poverty line of a family of given size. A family is classified as poor if its total earnings are less than its absolute poverty line. The idea of food insecurity is closely related to Rowntree's food poverty line, defined as the minimum money cost of food that would satisfy the average nutritional needs of families of different size and composition. A family can be classified as food secure if its total earnings are not less than the food poverty line. The world would be food secure when all families and individuals are classified as food secure. This definition of food security is very similar to that of the 2009 World Summit on Food Security.

In 2011-2013, 12% of the global population, equivalent to 842 million, suffered from chronic hunger, according to FAO. FAO is the only international organization that regularly produces the estimates of hunger in the world. It defines hunger in terms of prevalence of undernourished people whose caloric intake is less than their minimum energy requirements.

FAO's measure of hunger is derived exclusively from the inadequacy of caloric needs, meaning that it does not measure undernutrition (or malnutrition). Maintaining good health requires intake of other basic nutrients such as protein, fat and carbohydrates. Thus, FAO's measure of hunger does not inform whether people are becoming nutritionally better or worse. The widely-used definition of food security in the 2009 World Summit on Food Security clearly emphasizes that all people should have access to nutritious food at all times. Thus, FAO's measure of hunger does not provide what it is intended to measure.

This paper proposes a new methodology of measuring food insecurity. Households or individuals are deemed food insecure if they do not command enough resources to buy food sufficient to meet their nutritional needs. This definition is of more relevance to the 2009 World Summit on Food Security's definition.

The main contribution of this paper is to estimate the per capita monetary cost of food that provides adequate nutrients including calories, protein, fat and carbohydrates (balanced diet) to maintain good health. The cost of food is measured in terms of the US dollars based on the 2005 Purchasing Power parity (PPP) to allow for comparison across countries.[2] Per capita household expenditure is also measured in 2005 PPP US dollars. A household is identified as food insecure if its per capita expenditure is less than the estimated per capita cost of food. Moreover, if a household is classified as food insecure, then all household members belonging to the household are assumed to be food insecure. It is standard assumption commonly used in the measurement of poverty.

The World Bank uses household surveys to monitor global poverty counts through its interactive program, called POVCAL. Having estimated the cost of food based on the 2005 PPP, the POVCAL program has been utilized to estimates the percentage of population deemed food insecure in 127 countries, covering a total population of nearly 6 billion in the globe.

2. Distinction between Food and Nutritional Security

While food and nutritional security are closely related concepts, they are not the same. According to FAO, food security consists of four dimensions: (i) food availability, (ii) economic and physical access to food, (iii) food utilization, and (iv) stability (vulnerability and shocks). Each dimension is described by specific indicators. Based on this view, food security is a broad concept encompassing production, consumption, access, and utilization of food. Food utilization is the only dimension of food security that focuses on nutrition. This also means that nutritional security is a component of food security. They are, therefore, related but two distinct concepts.

Food contains a number of basic elements such as carbohydrates, proteins, fats and alcohol. These elements all produce different quantities of energy when burnt. The amount of energy produced when one gram of any of these elements is burnt is known as its calorific value. Food is the primary source of nutrients required to remain healthy. Food security should, therefore, be concerned with whether people have access to food, which meets their nutritional requirements. To directly measure food security, one needs to measure the extent to which people are able to acquire food that meets their nutritional requirements. This approach, as will be discussed below, is related to Sen's (1981) entitlement approach to measuring food deprivation in the population. Food security is influenced by factors such as poverty, food prices, social protection, unemployment, and earnings, among others.

Nutritional security, on the other hand, is concerned with adequacy of nutrients required to remain healthy. Although food is the main source of nutrients, nutritional security also depends on the efficiency with which individuals are able to convert food into nutrients. Nutritional

[2] The costs of food basket in local currencies do not allow us to compare them across countries. The costs have thus to be measured in some international currency such as U.S. dollar. The conversion of local currency to U.S. dollar is accomplished using purchasing power parity exchange rates, which account for differences in the costs of living across countries.

insecurity is commonly measured by the prevalence of undernourishment and undernutrition (malnutrition).

Undernourishment is measured by the percentage of population unable to meet its dietary energy requirement. Energy needs are determined by metabolic rates, which vary from one person to another. Hence, nutritional needs differ substantially across people. A person's energy requirements depend on age, gender, and activity level. Even if such differences are taken into account, there still exist inter-personal variations due to an individual's metabolic rates, which cannot be measured. As will be discussed below, the energy requirements are also known to vary intra-individually—i.e., for the same individual over time.[3] These conceptual problems make the measurement of undernourishment highly problematic.

The processes through which malnutrition comes to afflict households or a community are also very complex. In addition to inadequate entitlement to food, such processes include health care, lack of nutritional education, unhygienic environment and how food is prepared. Osmani (1992a) points out that the nutritional status of a person is almost the outcome of a complex interaction between nutrient intake and disease environment. Given such complexities, it is almost impossible to directly measure undernutrition. Indirectly, however, we can measure the existence and magnitude of that deprivation. The most common set of indicators used in this context are the percentage of children under-5 years of age affected by wasting, underweight, and stunted. But they cannot tell us the many possible constraints that may have led to that deprivation.

This paper will explore the measurement of food insecurity, which is viewed as food deprivation when people cannot acquire sufficient food. Nutritional security is indirectly measured by constructing a food basket that provides the basic nutrients for maintaining good health.

3. Prevalence of Undernourishment

FAO's measure of food deprivation – also referred to as food insecurity – is the prevalence of undernourishment. It is based on a comparison of usual food consumption expressed in terms of dietary energy (kilo/calories) with certain energy requirement norms. FAO measures food insecurity through the percentage (or number) of population whose dietary energy intake is below the energy requirement norm. As argued in the previous section, food security is not the same as prevalence of undernourishment. They are determined by different factors. The prevalence of undernourishment may be called nutritional insecurity of which its measurement is far more complex than food insecurity's.

Suppose x is the energy intake of an individual and r is his energy requirement (need), then the percentage of population deemed to be food insecure is given by

$$U = Pr(x < r) = \iint_{x<r} f(x,r)dxdr \quad (1)$$

[3] For an excellent discussion of inter- and intra-personal variations, see Osmani (1992b).

where $f(x, r)$ is the joint density function of x and r.

The degree of undernourishment can be easily estimated if we know the joint density function $f(x, r)$. A critical question is whether we can estimate $f(x, r)$ from household surveys or any other data sources. To answer this question, a brief overview of the debate on energy deficiency is provided in Section 4.

Equation (1) can at best measure the percentage of population unable to meet their dietary energy requirement. However, this FAO's measure does not take undernutrition (or malnutrition) into consideration. Maintaining good health also requires the intake of other basic nutrients such as protein, fat, and carbohydrates. As such, the FAO's measure given in (1) does not inform whether people are becoming nutritionally better-off or worse-off. FAO in its flagship publication, *The State of Food Security in the World*, calls this measure as a measure of chronic hunger.

4. A brief Overview of the Debate on Nutritional Deficiency

There has been a heated debate among economists and statisticians over how to estimate the joint density function defined in (1) and a consensus has yet to be reached.[4]

FAO has been concerned with the issue of determining the average dietary energy requirements of individuals among different age and gender groups that would allow them to maintain the required physical efficiency. It periodically publishes the average calorie requirements separately for men and women of different ages including children. Many attempts have been made to measure undernourishment using these norms. This approach classifies a person as undernourished if his calorie intake is below the required average norms [see Ojha (1970) and Dandekar and Rath (1971) for India and later Reutlinger and Selowsky (1976) and FAO (1977) at global level]. This approach has been severely criticized by Sukhatme (1981) and Srinivasan (1981), among others.

Much of the controversy centers around the problems in using the "average" requirement norm in a situation where requirements are known to vary interpersonally—i.e. from person to person even controlling for age, gender and activity level—and intra-individually—i.e. for the same individual at different points in time. Sukhatme (1961) argued that intra-individual variation is by far the more important source of variation than inter-individual variation. Nutritionists, however, are deeply divided on this issue, many of them holding opposite view that intra-individual variation is of a minor order of magnitude (Gopalan 1992, Payne 1992, Srinivasan 1992, Osmani 1992).

Sukhatme's main argument for intra-individual variation has been that an individual can "adapt" to a low calorie-intake level without suffering any impairment to health—in other words, when his calorie intake falls, then his calorie requirement also falls in line with calorie intake. The individual will suffer undernourishment only when his calorie intake falls much below the "average" calorie requirement norm.

[4] See particularly Sukhatme (1977, 1982), Srinivasan (1981), Seckler (1982, 1984), Sukhatme and Morgan (1982), Lipton (1983), Payne (1985, 1992), Gopalan (1992), and Kakwani (1986, 1992).

Sukhatme (1961) suggested the following formula for estimating the proportion of undernourished individuals with the same age, gender, body weight, and activity level:

$$U = Pr(x < r_L) = \int_{x<r_L} f(x)dx \quad (2)$$

where $f(x)$ is the marginal frequency distribution of dietary energy intake and r_L is a cutoff point reflecting the lower limit of the marginal distribution of energy requirement.

The existence of intra-individual variation suggests that there is a positive correlation between calorie intake and calorie requirement. Naiken (1998) has theoretically shown that the general measure of undernourishment defined in (1) reduces to the cutoff point formula given by equation (2) assuming that the marginal distributions are unimodal and continuous, and a positive correlation exists between energy intake and requirement. Following this seminal work, FAO has adopted this lower cutoff point in the calculation of undernourishment.

The idea of correlation is not different from Sukhatme's thesis of adaptation mechanism. The positive correlation between calorie intake and calorie requirement implies that if a person is unable to consume the required calories, his body adjusts to a lower requirement so he or she does not suffer any health impairment. Given this adaptation mechanism, the cutoff point could be set at a much lower level of dietary energy requirement of a healthy person. However, the existence of such correlation does not inform which way the causation runs: does low calorie intake lead to a lower requirement or the other way around? If a person is constrained to consume lower calories because of his inability to acquire food, he or she should not be identified as food secure because his body is adapting to a lower calorie requirement.

How should this cutoff point be determined? In his 1961 article, Sukhatme had taken the cutoff point as corresponding to the lower limit of the 99 percent confidence interval: $r_L \cong \mu_r - 3\sigma_r$, where μ_r and σ_r are the mean and the standard deviation of the requirement distribution, respectively. Later in 1982, he set the cutoff at the 95 percent confidence interval, $r_L \cong \mu_r - 2\sigma_r$. An implication of this change can be enormous because the estimate of undernourishment is highly sensitive to the cutoff. To get an idea of this sensitivity, we quote a study by the World Bank in 1986 that calculated the percentage of undernourished persons based on the following assumptions:[5]

- 80% of FAO's norm of calorie requirement should prevent stunted growth and serious health risks.
- 90% of FAO's norm of calorie requirement should prevent impairment of an active working life.

The study found that in 1986, 340 million (16% of the population) in the developing countries were suffering from nutritional deprivation, which could lead to stunted growth and serious health risk. It also found that 730 million (34% of the population) were not able to lead an

[5] These are just assumptions and not based on any scientific study.

active lifestyle because of calorie deficiency. These figures show that a slight change in the cutoff point can make a major difference in the magnitude of undernutrition in the world.

Sukhatme's justification for a lower cutoff point is that an individual can "adapt" to a low calorie-intake level without any impairment to health. This process of adjustment occurs through changes in metabolic efficiency, i.e. the efficiency with which food is converted to energy.

In his writings, Sukhatme tends to assume that this lower limit is the same for all individuals. But this is not the case. The lower limit is determined by an individual's metabolic ability to regulate his energy expenditure. There is no reason to expect that all individuals have the same capacity for metabolic regulation: the lower limit need not be the same for every individual. Thus, the problem of inter-individual variation in requirement cannot be avoided.

The conceptual problems with the estimation of people suffering from undernourishment are serious. Moreover, there are uncertainties of the quality of data used, which we have not yet discussed. A pertinent question is whether it is at all possible to obtain credible estimates of the number of undernourished population around the world. FAO does accomplish this task every year in its flagship publication, *The State of Food Insecurity in the World*. The 2013 *State of Food Security in the World* estimates (with the methodology described above) that 842 million people, or 12% of the global population, were unable to meet their dietary energy requirement. The methodology behind such numbers has attracted considerable criticism. The next section will provide a brief review of FAO's methodology of estimating global hunger.

5. The FAO Method of Measuring Hunger

FAO's estimates of global hunger are widely used by different development agencies to track progress towards the Millennium Development Goal of halving poverty and hunger by 2015. This section assesses how reliable these estimates are in monitoring global hunger, and also discusses the FAO's methodology for its hunger estimates.

A person is identified as suffering from hunger if his calorie intake is less than a cutoff point of calorie requirement – called the minimum dietary energy requirement (MDER). If the distribution of calorie intake and the MDER are known, it is then easy to identify whether or not the person is suffering from hunger. The most direct method of deriving the distribution of calorie intake is from household expenditure surveys (HESs). The HESs collect data on all food acquired by households including their food purchase, food consumed from their own production, and food received in kind. There are a large number of such surveys that provide the estimates of quantities of food acquired by households. These food quantities can be converted into calories by means of food calorie conversion factors, which are available for almost all countries in the globe.

Given the quantities of food consumed by each sample household in HESs, we could compute the actual calorie intake of each sample household by multiplying the quantities by the calorie conversion factors. Dividing the calorie intake of each household by its size would give us each household's per capita calorie intake. Thus, the entire distribution of calorie intake can be estimated from HESs. Each sample household has an associated population weight. Given the cutoff point of calorie requirement, the percentage of undernourished or hungry persons can be accurately estimated by the weighted average of per capita calorie intake with the weight proportional to the population weight associated with each sample household. The total number of undernourished persons in a country can then be obtained by multiplying the percentage of undernourished persons by the country's total population.

FAO follows a rather approximate method of estimating hunger in the world. It assumes that the distribution of calorie intake – denoted by $f(x)$ – follows a two-parameter lognormal distribution. This implies that $ln(x)$ is normally distributed with mean μ and variance σ^2.[6] It follows from the lognormal distribution that

$$\sigma^2 = ln(CV^2 + 1) \qquad (3)$$

and

$$\mu = ln(\bar{x}) - \sigma^2 \qquad (4)$$

where $\bar{x}$ and s^2 are the mean and variance of calorie intake, respectively and $CV = s/\bar{x}$ is the coefficient of variation of calorie intake. Together, these two equations show that the lognormal distribution can be characterized by mean $\bar{x}$ and coefficient of variation, CV.

Using the lognormal distribution, the estimation of the percentage of undernourished population requires only two parameters: average calorie intake ($\bar{x}$) and coefficient of variation (CV). Suppose $\bar{x}$ = 2,414 calorie intake per person per day and CV = 0.29, which on substituting in (3) and (4) immediately gives $\sigma = 0.2842$ and $\mu = 7.7487$.

Assuming the MDER, which is the cutoff point of the calorie requirement intake, equal to 1,680 per person per day, then the probability that a person is undernourished is given by

$$Pr[x < 1{,}680] = Pr[ln(x) < ln(1{,}680)] = N\left[\frac{ln(1{,}680) - 7.7487}{0.2842}\right] = N(-1.1335)$$

where $N(X)$ is the standard normal cumulative distribution. Utilizing the standard cumulative normal tables gives $N(-1.1335) = 0.1285$, and thus the percentage of undernourished population in this hypothetical country would be 12.85. If the total population of the country is 100 million, then the number of undernourished persons is about 13 million.

6. Limitations of FAO's Method

Based on FAO's estimates, the distribution of calorie intake follows a lognormal distribution.[7] This model is convenient from an analytical point of view but not flexible enough to capture the

[6] Recently, the FAO has adopted a more flexible model of skewed normal and log-normal distributions introduced by Azzalini (1985) with the results published in *The State of Food Security in the World 2012*. It is not reported how well these distributions fit to the data. The loss of efficiency due to grouping still remains.

[7] An elaborate history and analytical properties of log-normal distribution are presented by Aitchison and Brown (1957).

variation at the bottom end of the distribution. Nevertheless, it gives reasonable fit in the middle range of the distribution covering about 60% of the population. Since undernourishment basically occurs at the lower end of the distribution, the lognormal distribution will underestimate the percentage of population suffering from undernourishment because of its limited flexibility.

The lognormal distribution was popular in the 1950s and 1960s, during which national statistical offices did not release unit-record data for household surveys, providing only the group data so the data analysis was carried out using some distribution model. The lognormal model was found to be analytically simple, and its close relationship with normal distribution provided ready access to efficient procedures and statistical inference.[8] India's five-year development plans extensively utilized the lognormal distributions to project consumer expenditures. Today, household unit-record data are readily available and the use of lognormal distribution has become rather obsolete. Poverty and inequality measures are now directly and more efficiently estimated from household surveys, which provide the entire distribution.

FAO has somehow continued the practice of estimating the distribution of calorie intake from the group data using the lognormal distribution. The main justification for such a practice is that direct estimates of deficiency in calorie intake captures excessive variability and does not provide the variance of habitual food consumption in the population. The excessive variability in calorie intake is, therefore, controlled by calculating the CV of calorie consumption of a representative individual. However, FAO's methodology does not inform how such representative individual is defined; is it a person with an average calorie intake? It does, nevertheless, inform how the CV of calorie intake for a representative individual can be calculated. The procedure is as follows:

Household surveys provide information on per capita expenditure and per capita calorie consumption for each sample household along with household weights. From this information, the CV of calorie intake can be directly and more accurately estimated. Instead, all these unit-record data are grouped into by per capita expenditure classes, with each class giving the median value of per capita dietary energy consumption. The CV is then estimated from the median values for each expenditure class. However, the resulting CV completely ignores within-group variation in calorie consumption, thus underestimating the total variation in calorie consumption. The degree of underestimation will depend on how many expenditure classes are constructed. It is thus difficult to understand why the CV calculated from the grouped data will provide habitual consumption of dietary energy for the representative individual. The calculation of CV from the grouped data will only amount to loss of efficiency.

Although the CV is estimated from household surveys, FAO estimates the mean calorie intake from Food Balance Sheets (FBSs), which provide the quantities of different food items available in a country from the country's production data. The calculation of FBS is performed by adding national food production and imports, and subtracting exports, food losses, food used for seeds, animal feed and stock changes. Food quantities are then converted into calories by means of food calorie conversion factors. Combining this with population data provides the total calories available for human consumption per person in each country.

[8] Iyenger (1960) extensively used log-normal distribution to analyze consumption patterns in India.

Estimates of average calorie intake obtained from FBSs may be less reliable than those obtained from household expenditure surveys. Some economists at the World Bank[9] raise a few concerns about these estimates of food availability. First, as food availability is residual, any errors in reported production, trade and stocks will affect the estimates of national food availability. Second, production and trade data for grain crops are potentially reliable since it is feasible to measure production with sample plots and a real mapping, among others. However, the same is not true for root crops such as potatoes, sweet potatoes and cassava, which are important sources of nutrition for the poor. In addition, there are problems associated with storage, food fed to animals and crops kept for seeds. Given these practical problems, it is difficult to ascertain the amount of food grains available for human consumption.

The MDER is a crucial factor in FAO's methodology to estimate undernourishment, as it establishes a cutoff point (or threshold) to estimate the prevalence of undernourished population in a country. When the threshold changes, so does the prevalence of people estimated to be undernourished. As noted earlier, the estimates for the undernourished population are highly sensitive to the threshold. A small error in the estimation of the cutoff point can have a substantial impact on the estimates for the undernourished.

FAO compiles the MDER for the individuals by age and gender. As Naiken (2002) points out, the gender-age-specific MDERs have been derived not by Sukhatme's formula $\mu_r - 2\sigma_r$, but by directly considering the energy expenditure corresponding to the lowest acceptable weight-for-height and the lowest acceptable activity level. There is a range of body weights that is considered to be healthy. Similarly, there is a range of physical activity levels (PALs) that is deemed performing economically necessary activity. The cutoff point is the lowest value in the range. It will vary with age and gender of the population. Thus, the MDER is calculated separately for each gender and age group.

The cutoff point for a population is derived by aggregating gender- and age-specific MDERs using the proportion of the population in the different gender and age groups as weights. Since the gender-age distribution of the population changes over time, the cutoff point is updated annually to reflect changes in the demographic structure of the population.

There is considerable uncertainty regarding the actual requirement level of the individuals. This uncertainty stems from the fact that energy requirement is specified as the average for a group of individuals, and consequently, the actual requirement for each individual in the group is not known. In addition, calorie requirements are known to vary inter-personally–i.e. from person to person– and intra-individually–i.e. for the same individual at different points in time. As such, the assumption is that all individuals whose calorie intake is above the MDER can "adapt" so that their calorie intake always matches their respective requirements and therefore are not undernourished. The accurate estimation of the MDER is crucial. Naturally, its estimation involves normative judgments at various stages, thereby making the task more challenging.

7. Food Insecurity as Entitlement Failure

[9] See De Weerdt, Beegle, Friedman, and Gibson (2014).

According to FAO, food insecurity is viewed from a perspective of nutritional deprivation. This might be valid as undernourishment could lead to severe health problems. Undernourished people tend to have low immunity and thus susceptible to infections. Children under-5 years of age are the most affected segment of the population from undernourishment. They are wasted (low weight for height), stunted (low height for age) and underweight (low weight for age). But undernourishment among people is a consequence of not being able to consume sufficient amount of food that meets their dietary needs. Thus, the direct method of measuring food security is to capture the extent to which people are able to acquire food that meets their nutritional requirements. This method is closely related to Sen's (1981) entitlement approach to measuring food deprivation in the population. A brief description of it is as follows.

According Sen (1989), every individual is endowed with a bundle of resources, which he can exchange for food and any other commodities. A person's entitlements depend on what he owns initially and what he can acquire through exchange. If the entitlement set does not include a commodity bundle with an adequate amount of food, the person would go hungry and become food insecure. This, according to Sen, is an entitlement failure.

An entitlement failure can occur due to many reasons. For instance, if food prices go up sharply, entitlements of some individuals may cease to include an adequate bundle of food. Such individuals will thus suffer from food deprivation. Similarly, people can suffer from food insecurity due to sickness, unemployment, or death of bread-winner. Given this, an alternative definition of food security is proposed:

Food security exists when all people, at all times have entitlement to sufficient and nutritious food, which meets their dietary needs.

This definition of food security emphasizes the entitlement to food, whereas the definition proposed by the 2009 Declaration of the World Summit on Food Security emphasizes access to food (or actual consumption of food). Individuals make their own choices on what food they want consume, so policy makers can only ensure that people have necessary resources to consume sufficient and nutritious food. Thus, the entitlement approach is more realistic than the access approach. This entitlement approach is directly linked to income or employment generation, food production, food prices, and social security, all of which have an important impact on food security. For instance, following the 2008 global financial crisis, many households lost their source of livelihood and may have suffered a severe failure of entitlement to food. Thus, the measurement of food security based on the entitlement approach will inform how much was the contribution of such shocks to food insecurity and what policies could be designed to reduce or even prevent food deprivation.

8. Measuring Household Food Security: A Proposed Method

This section proposes a new method of measuring food security for households. It is based on Sen's (1981) entitlement approach. Since this approach only deals with food security among households, the issue of intra-household food security is not addressed. Given data limitation, it is generally not possible to measure food deprivation within households.

In a market economy, a person can exchange whatever he owns for other goods including food. This exchange can take place through monetary income at given market prices. The person's income in the reference period can be used as a composite measure of his entitlement. A household's composite index of its entitlement can similarly be measured by its per capita income (or consumption), which is denoted by y_i for the ith household. Suppose z_i is the per capita cost of food bundle for the ith household that meets the nutritional needs of all its members. Given this, the ith household is defined as food secure if at all times y_i is greater than z_i. If y_i is less than z_i at all times, then the ith household is chronically food insecure.

A household's food bundle that is sufficient, safe and nutritious for all members of the household should meet the following requirements.

- The food bundle should meet the average dietary energy needs for all household members.
- The food bundle should meet the average basic requirements of protein, fat and carbohydrates for all household members.

9. Households' Per Capita Minimum Dietary Requirement

To construct a food bundle that meets the dietary energy needs of household members, we need to know the energy requirement norms or standards, adopted at the international level. The report of the FAO/WHO/UNU Expert Consultation on Energy and Protein Requirements has defined energy requirements as follows:[10]

The energy requirement of an individual is the level of energy intake from food that will balance energy expenditure when an individual has a body size and composition and level of physical activity, consistent with long-term good health; and that will allow for the maintenance of economically necessary and socially desirable physical activity. In children and pregnant or lactating women the energy requirement includes the energy needs associated with the deposition of tissues or the secretion of milk at rates consistent with good health.

These norms are different across individuals depending on age, gender, weight, and activity level. HESs provide information on the age and gender of each individual within a household, but the activity level and body weight of each individual are not available in these surveys. Thus, we can control for age and gender of individuals, but not weight and activity level.

In determining calorie norms, we assume that the reference person has the median height and weight to give a body mass index (BMI) of 21.5 for adult females and 22.5 for adult males. Table 1 presents the estimated amounts of calories required to maintain energy balance for various gender and age groups at three different levels of physical activity. Estimates are rounded to the nearest 200 calories.

Table 1: Calories needed to maintain energy balance by gender and age groups

[10] See FAO, WHO, and UNU (1985).

	Age	Sedentary[a]	Moderately[b]	Active[c]
Child	1-3 years	1,000	1,000	1,000
Female	4-8years	1,200	1,600	1,800
	9-13years	1,600	2,000	2,200
	14-18years	1,800	2,000	2,400
	19-30years	2,000	2,200	2,400
	31-50years	1,800	2,000	2,200
	51+ years	1,600	1,800	2,200
Male	4-8years	1,400	1,600	2,000
	9-13years	1,800	2,200	2,600
	14-18years	2,200	2,800	3,200
	19-30years	2,400	2,800	3,000
	31-50years	2,200	2,600	3,000
	51+ years	2,000	2,400	2,800

Source: These levels are based on Estimated Energy Requirements from the Institute of Medicine Dietary Reference Intakes Macronutrients Report, 2002.
[a] Sedentary means a lifestyle that includes only the light physical activity associated with typical day-to-day life.
[b] Moderately active means a lifestyle that includes physical activity equivalent to walking about 1.5 to 3 miles per day at 3 to 4 miles per hour, in addition to the light physical activity associated with typical day-to-day life
[c] Active means a lifestyle that includes physical activity equivalent to walking more than 3 miles per day at 3 to 4 miles per hour, in addition to the light physical activity associated with typical day-to-day life.

The calorie requirements for different gender and age groups can be aggregated by means of weighted average, with the weight proportional to the population in each group. The population in each gender and age group is available from household surveys. The aggregate requirement will be different across countries given disparities in their gender and age composition. With the unit-record data for nine countries in Asia and using the calorie norms given in Table 1, we can calculate the average calorie norms for each of the nine countries. The estimates for three alternative activity levels are presented in Table 2.

Table 2: Aggregate caloric norms for three levels of activity

Country	Year	Sedentary	Moderately	Active
India	2007-08	1,835	2,137	2,420
Indonesia	2014	1,839	2,134	2,417

Bangladesh	2000	1,788	2,086	2,362
Pakistan	2007-08	1,773	2,066	2,340
Sri Lanka	2009-10	1,829	2,122	2,419
Bhutan	2007	1,823	2,122	2,405
Nepal	2010	1,776	2,067	2,344
Philippines	2011	1,827	2,128	2,412
Vietnam	2008	1,867	2,170	2,466

Source: Author's calculations.

Table 2 shows that the average calorie norms vary with activity levels. The variation is much larger across activity levels than across countries. We cannot measure the activity levels of all individuals in the country. Hence, the determination of undernourishment by comparing individuals' calorie intake with their calorie needs will be highly unstable and unreliable. But if food insecurity is measured using income or consumption space at the household level, the variation in individuals' calorie requirements will not be that large. The estimates will be more stable because different caloric needs of individuals within households will be averaged out.

In the construction of food basket, we assume that, on average, individuals within households have moderate activity level, a lifestyle that includes physical activity equivalent to walking about 1.5-3 miles per day at 3-4 miles per hour, in addition to the light physical activity associated with typical day-to-day living. Table 2 also shows that the calorie norms with moderate activity are around 2,100 kilo/calories per person per day.

The U.S. Department of Agriculture uses the average energy requirements for each country, which average about 2,100 calories per person per day for 67 developing countries. If a household has access to food, providing a minimum of 2,100 kilo/calories per person per day, it will be highly unlikely that the household faces chronic hunger. It is true that some household members may have caloric needs greater than 2,100 kilo/calories but others may have less; on average, the household is unlikely to suffer hunger.

FAO's (1996) recommended calorie requirements are about 300 calories less than the average calorie requirements of a healthy person. FAO's lower cutoff point is justified on the ground that the human body can adapt to low calorie intake without any adverse effect on health. Even if humans can adapt, households may still feel food-deprived if they purchase food with no more than about 1,800 kilo/calories per person (i.e., 300 calories less than the calorie an average healthy person would require). Food insecurity is not only about meeting dietary energy needs, but also having adequate amount of protein, fat, carbohydrates and other micronutrients. If households limit their consumption to only 1,800 kilo/calories per person, they may not meet other nutritional needs. In the next section, we calculate the cost of the food basket, which provides 2,100 kilo/calories per person per day and meets the recommended requirements of protein, fat and carbohydrates.

10. What is the Cost of a Nutritious Food Basket?

The cost of a nutritious food basket is calculated in international dollars so that it can be applied to all countries. The PPP exchange rates are used to convert local currencies into U.S. dollars. The cost of the food basket is calculated in the 2005 PPP dollars.

The cost of the nutritious food basket is estimated using FAO data for 30 countries (32 spells). The data were downloaded the following variables from the FAO website:

i. Per capita household expenditure (in local currency)
ii. Per capita household food expenditure (in local currency)
iii. Per capita daily kilo/calorie intake
iv. % share of calories obtained from protein
v. % share of calories obtained from fat
vi. % share of calories obtained from carbohydrates

Per capita food and total expenditures in local currency are converted to the U.S. dollars using the 2005 PPP. These estimates are presented in Table A.1 in the Appendix. Per capita household expenditure measured in the 2005 PPP provides a measure of average standards of living that is comparable across countries. From the list of 30 countries, countries with the lowest standards of living are Mozambique and Nepal, where their per capita expenditures are \$1.15 and \$1.28 daily in the 2005 PPP, respectively. On the other hand, the richest country in the list is Hungary, with its per capita expenditure of \$11.57 per day. As shown in Table A.1, standards of living vary substantially from one country to another.

While calories are derived from food, there is no one-to-one relationship between calorie intake and food expenditure. This is because individuals consume various types of food, providing different quantities of calories. Hence, we cannot expect a one-to-one relationship between the two variables. In this paper, we estimate this relationship using a cross-country regression model. A theoretical, plausible relationship between per capita calorie intake (*C*) and per capita food expenditure (*F*) is specified to take on the semi-logarithmic form:

$$C = \alpha + \beta ln(F) \tag{5}$$

where $\beta > 0$ and which gives:

$$\frac{\partial C}{\partial F} = \frac{\beta}{F} \text{ and } \frac{\partial^2 C}{\partial F^2} = -\frac{\beta}{F^2}$$

which implies that as food expenditure increases, calorie intake also increases but at a decreasing rate—in other words, the rate of increase in calorie intake slows as people become more affluent. Instead of consuming more calories, they consume types of food with more protein and fat. The regression model in (5) was estimated using 32 observations given in Table A.1, with each country as an observation. Such cross-country regressions have been widely used in the literature (Reutlinger and Selowsky 1976). One potential drawback of using cross-country data for estimating the regression model (5) is that they may have a limited range of variation in per capita food expenditure as compared to using household data. Fortunately, countries used in the current study provide sufficient variability to reasonably estimate regression coefficients. The estimated equation is:

$$C = 2090.4 + 361.5\, ln(F),\quad R^2 = 0.44 \qquad (6)$$
(42.8) (5.1)

The t-values in the bracket show that the coefficients are highly significant. This equation can be used to calculate the cost of food basket that provides on average 2,100 kilo/calories per person per day. Substituting C = 2,100 in (6) gives F=1.03. Therefore, the cost of food basket that gives on average 2,100 kilo/calories per day per person is $1.03 in the 2005 PPP. Accordingly, the estimated cost of calorie is equal to $0.49 in the 2005 PPP per 1,000 kilo/calories.

The calorie cost is obtained by dividing total food expenditure by the number of calories derived from the food. The calorie cost varies with household's standards of living; the richer the household, the higher the cost of calories (Kakwani 2010). This is because richer households tend to consume a greater variety of food containing more protein and other nutrients, while the poor are likely to consume more carbohydrates, which are less expensive than protein, for example.

Using equation (6), the calorie elasticity with respect to food consumption is estimated at 0.172. To measure the impact of food consumption on calorie cost, we estimate the following semi-logarithm form based on the data presented in Table A.1:

$$Ccost = 0.49 + 0.65 ln(F) \quad R^2 = 0.94 \qquad (7)$$
(24.8) (22.4)

This equation estimates that the calorie-cost elasticity with respect to food consumption is 1.33 at the point where the calorie cost is 0.49 per 1,000 kilo/calories. The low calorie-food elasticity has been of much concern in the literature.[11] An important policy implication drawn in the literature is that if the elasticity of calories is low, either general economic development will never eliminate hunger or the problem of hunger in the world would remain for a long time (Deaton 1997).

The greater-than-1 calorie-cost elasticity suggests that people incur greater calorie costs as their incomes increase because they buy better quality of food, which provides them with better nutrition. The poor suffer from undernutrition because they cannot afford to buy nutritious food. They can only consume calorie-intensive food and are deprived of other nutrients, which are necessary for good health. Similar to MDERs, we should also have a requirement of minimum calorie costs (MCC), which on average provide a balanced diet that meets nutritional needs to maintain good health. In this context, a pertinent question would be whether a food basket with the estimated calorie cost of $0.49 in 2005 PPP per 1,000 kilo/calories will be able to provide a balanced diet. The next section attempts to answer this question.

11. A Balanced Food Basket

[11] Alderman (1993) has provided an excellent review of econometric techniques, which have been used in the literature to estimate the calorie-intake elasticity.

Food contains a number of basic nutrients such as carbohydrates, proteins, and fats. These nutrients all produce different quantities of energy when burnt. The amount of energy produced, when one gram of any of these nutrients is burnt, is known as its calorific value.

Proteins are complex nitrogen-containing compounds that build and repair body tissue. A deficiency in the intake of protein can retard growth and development and inhibit the body's ability to fight infection. The recommended daily requirement for protein is about 10%–15% of the daily calorie requirement, according to the Healthy Diet Plans.

Carbohydrates are the main source of energy for the human body. Carbohydrates are obtained from food such as whole-grain cereals and breads, pasta, corn, beans, peas, potatoes, fruit, vegetables, and milk products. It is recommended that carbohydrates should contribute 60%–70% of the total calories in a day's diet.

Fats are the most concentrated source of energy in our diet. Fat plays several important roles in diet. It is important for the absorption of fat-soluble vitamins such as vitamins A, D, E and K. Fats also provide essential fatty acids, which are important for the structure and function of cells. Fat also cushions the vital organs and protects the body from extreme cold and heat. Fats should contribute the remaining 15%–30% of the total calories in a day's diet.

A balanced food basket is, therefore, defined as the one that provides 2,100 kilo/calories per person per day, which is obtained from protein, carbohydrates and fats, with their recommended contributions in the ranges 10%–15%, 60%–70% and 15%–30%, respectively. The calorific values for one gram of the three basic nutrients are:

- Carbohydrate = 4 Calories
- Protein = 4 Calories
- Fat = 9 Calories

Using these calorific values, a balanced food basket with the calorie consumption of 2,100 kilo/calories per person per day is estimated to provide the three nutrients in the following ranges: protein 52.5-78.7 grams, fats 35-70 grams, and carbohydrates 315-367grams.

Holding the daily calorie requirements constant, the calorie cost becomes the main determinant of quantities of the three nutrients (protein, carbohydrates and fats) as sources of calories. To calculate these quantities, we fitted the following three cross-country semi-logarithmic regressions using the 32 observations from Table A.1:

$$pc\_protein = \underset{(32.7)}{71.2} + \underset{(5.0)}{18.4} ln(Ccost) \qquad R^2 = 0.45 \tag{8}$$

$$pc\_carb = \underset{(32.8)}{353.1} - \underset{(-1.86)}{33.7} ln(Ccost) \qquad R^2 = 0.10 \tag{9}$$

$$pc\_fat = \underset{(18.2)}{67.4} + \underset{(6.6)}{41.2} ln(Ccost) \qquad R^2 = 0.59 \tag{10}$$

where pc_protein = per capita consumption of protein; pc_carb = per capita consumption of carbohydrates; pc_fat = per capita consumption of fats; and Ccost = calorie cost per 1,000 kilo/calories in the 2005 PPP. Equation (9) shows that the *t*-value for the coefficient of *ln*(*Ccost*) is 1.86, which is not statistically significant at the 5% level of significance. This indicates that an increase in calorie cost has insignificant impact on the consumption of carbohydrates.

The estimated calorie cost of the food basket is $0.49 in the 2005 PPP, which upon substituting in (8), (9) and (10) gives the estimates for per capita quantities of protein, carbohydrates and fat, respectively. Thus, our proposed per capita food basket, costing $1.03 in the 2005 PPP, provides the following nutrients:

- Dietary energy = 2,100 kilo/calories per person per day
- Protein = 58 grams per person per day
- Carbohydrates = 377 grams per person per day
- Fats = 38 grams per person per day

The quantities of the three nutrients lie in the ranges of nutrient requirements for a healthy person—except carbohydrates, which is slightly higher by 9 grams. This food basket provides the required nutrients for a healthy person and, therefore, can be regarded as a balanced diet of an average person. A household will be identified as food insecure if its entitlement measured by per capita expenditure is less than the cost of basket estimated to be $1.03 in the 2005 PPP.

As noted earlier, FAO's (1996) recommended calorie requirements are about 300 calories less than the average calorie requirements for a healthy person. Following this recommendation, the food basket should only provide 1,800 kilo/calories per person per day and the calorie cost calculated from (6) will be $0.25 in the 2005 PPP per 1,000 kilo/calories. Substituting this value of calorie cost in (8), (9) and (10) provides the nutritional value of the basket as follows:

- Dietary energy = 1,800 kilo/calories per person per day
- Protein = 46 grams per person per day
- Carbohydrates = 400 grams per person per day
- Fats = 10.2 grams per person per day

Except in carbohydrates, this food basket is deficient in both protein and fats, with their values lying outside the range of nutrient requirements for a healthy person. Even if the human body can adapt to low dietary energy intake, households may consume excessive carbohydrates and experience severe deficiency in both protein and fats. In this case, households will not meet their nutritional needs and consequently suffer chronic malnutrition. Therefore, adopting a lower threshold, based on FAO's minimum dietary energy requirement, will not provide a balance diet.

12. Global Estimates of Food Insecurity

FAO measures food insecurity in the dietary energy space by comparing energy intake with requirement. The method proposed in this paper builds upon the entitlement approach, which compares per capita household expenditure with per capita food cost, and provides the nutrients required for good health. The per person cost of such a food basket has been estimated at $1.03 per day in the 2005 PPP.

The international poverty line of $1.25 per person per day in the 2005 PPP is widely used to measure extreme poverty in the world. The POVCAL program has been utilized to produce global estimates of food insecurity for 124 countries, covering 5.7 billion in the globe. In calculating the incidence of food insecurity, the poverty line is set at $1.03 in the 2005 PPP.

The threshold for food insecurity was estimated by incorporating the cost of calorie intake, which has never been considered by earlier studies in this field. To this extent, this study factors in the demand side of the problem neglected in the past.

Any supply-side interruptions, whether natural or man-made, will automatically be reflected in food prices that affect calorie cost and consequentially food insecurity. Thus, the proposed method implicitly incorporates both supply and demand sides of food production/availability as important determinants of food insecurity.

Rich, industrialized countries have been excluded from the study because they are not expected to suffer from food deprivation. Table A.2 in the Appendix provides the estimates for individual countries by selecting individual countries in the POVCAL program for 2011. Aggregated estimates from individual countries are presented in Table 3 for six major regions in the world. These aggregated estimates are directly obtained from the POVCAL program. The aggregation is performed by the weighted average method, with weights proportional the countries' population.

Table 3 shows that the world has made impressive progress in reducing the overall food insecurity in just one decade, 2002–2011. The percentage of food insecure has reduced from 21.59% in 2002 to 10.98% in 2011. Similarly, the number of food insecure persons has fallen by 455.41 million. This reduction has occurred despite the serious food crisis in 2007-08 when food prices skyrocketed.

Meanwhile, Figure 1 shows that improvement in food security is broad-based. In East Asia alone, the number of people suffering from food insecurity decreased from 309.21 million to 76.64 million. The incidence of food insecurity is thus reduced to about 4%. One of plausible explanations for such an impressive reduction could be due to rapid economic growth as experienced by many East Asian countries such as China. The next section will explore the linkage between economic growth and hunger.

South Asia's performance in reducing food insecurity is equally commendable. The percentage of food insecure people declined from 28.88% in 2002 to 12.99% in 2011, lifting 198.64 million out of food insecurity.

In comparison, Sub-Sahara Africa suffers from extreme food insecurity, where 47.39% of the population in the region were found to be food insecure in 2002. This percentage declined to 37.37% in 2011. However, the population of the African region increased from 667.97 million in 2002 to 847.84 million in 2011, resulting in the increased number of food insecure people from 316.48 million in 2002 to 316.84 million in 2011. Consequently, there was a net increase in food insecure people by 0.36 million.

Food insecurity is not much of an issue in Europe and Central Asia and Middle East and Caribbean, where the percentage of food insecure people is less than 1%. In Latin America, the percentage of food insecure people is 3.58% in 2011. Therefore, the two regions for concern in terms of food insecurity are South Asia and Sub-Saharan Africa. In South Asia, as the number of food insecure people has been falling rapidly, it could take only a few more years to eliminate food insecurity in the region. However, given the current trend, food insecurity is likely to persist in Sub-Saharan Africa for many years.

Despite the impressive progress in ensuring food security, some 626 million around the globe were unable to meet their minimum food requirements in 2011. These people are more likely to suffer from chronic hunger. One of the United Nations' new agenda of Sustainable Development Goals is to end hunger and achieve food security and improved nutrition by 2030. To achieve this goal, 625 million should be made food-secure so that they escape from hunger. The next section will discuss whether this goal can be achieved.

Table A.2 provides the estimates of food insecurity for individual countries. Of 120 countries, 60 have less than 3% of their populations being food insecure. These countries can be regarded as having no serious issues on food insecurity. But there are many countries where food insecurity is severe. Rwanda, Liberia, Malawi, Zambia, Burundi, Congo Democratic Republic, and Madagascar have more than 50% of their populations suffering from food insecurity. The global development community needs to commit greater resources to address food insecurity in these countries.

China has been able to reduce food insecurity from 20% of its population in 2002 to 3.2% in 2011; consequently, 213 million have been lifted out of food insecurity. China's performance in reducing malnutrition of children is often compared with India's. It is generally perceived that India's performance in providing adequate amount of food to its population is poorer than China's. But the results presented in Table A.2 show that India has reduced the percentage of food insecure people from 28.78% in 2002 to 12.87% in 2011; As a result, almost 193 million have been lifted out of food insecurity. In addressing food insecurity, India's progress is not that much behind China's.

Severe malnutrition among children is widely prevalent in India, but this may not be only due to food deprivation. Other factors such as poor public hygiene, low rate of immunization and low access to basic health services may also influence malnutrition. As the recent issue of Economist (July 2015) points out, "one reason Indians are less well-nourished than Africans is that more Indians defecate outdoors so more contract diarrhea and other diseases that makes it harder for children specially, to absorb the nutrients they consume."

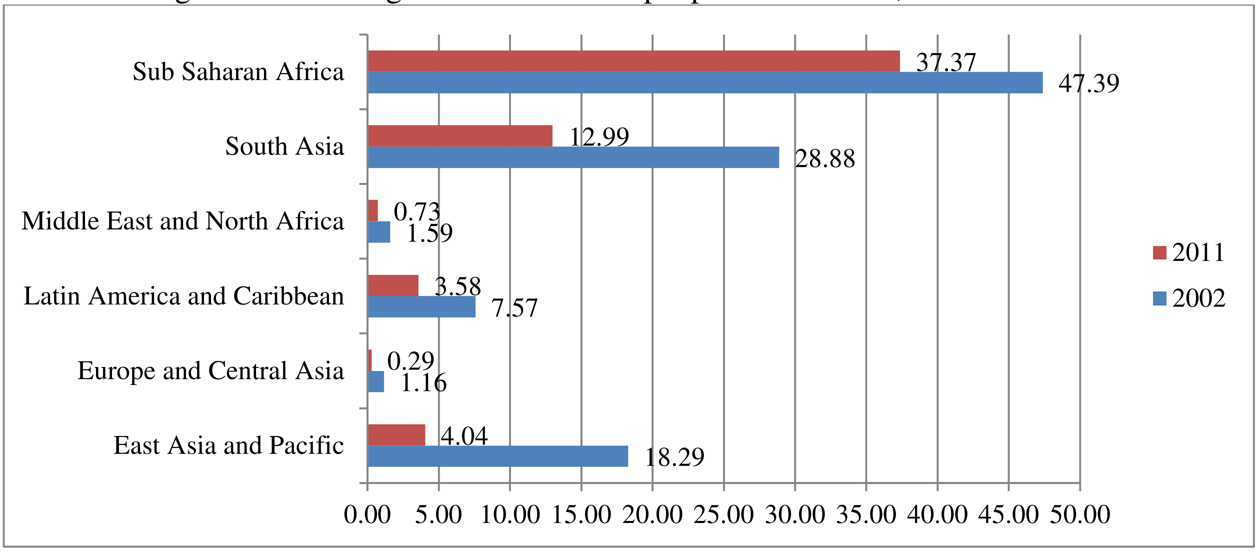
Table 3: Percentage and number of food insecure persons in the world

	2002	2011	Change

Region	Percentage	Number	Percentage	Number	Percentage	Number
East Asia and Pacific	18.29	309.21	4.04	76.64	-14.25	-232.57
Europe and Central Asia	1.16	5.09	0.29	1.27	-0.87	-3.82
Latin America and Caribbean	7.57	39.65	3.58	20.95	-3.99	-18.70
Middle East and North Africa	1.59	4.40	0.73	2.36	-0.86	-2.04
South Asia	28.88	406.41	12.99	207.77	-15.89	-198.64
Sub-Saharan Africa	47.39	316.48	37.37	316.84	-10.02	0.36
Total	21.59	1081.24	10.98	625.83	-10.61	-455.41

Source: Authors' calculations based on POVCAL.

Figure 1: Percentage of food insecure people in the world, 2002 and 2011



Source: Authors' calculations based on POVCAL.

13. Linkage between Economic Growth and Food Insecurity

Growth generates additional goods and services enjoyed by the population. The total amount of goods and services produced within a year is measured through the gross domestic product (GDP), which is regarded as the most comprehensive measure of an economy's total output. Per capita GDP measures the total output that on average is available to each person. But the entitlement to the output produced varies from one person to another depending on the "patterns of growth".

The pattern of growth determines how much the impact of growth on poverty would be, how much inequality of income would change over time, or whether opportunities that people can avail to enhance their well-being are expanded. The level and pattern of growth can also influence food security in a country.

Table 4 presents the annual growth rates of per capita GDP between 2002 and 2011 by different regions of the world. As expected, East Asia and Pacific is the fastest growing region where per capita real GDP increased at an annual rate of 7.41% in the given period. South Asia is the second fastest growing region with its annual growth rate in per capita real GDP of 5.3%. The annual growth rate of per capita real GDP for the developing world as a whole is estimated at 4.36%.

In linking growth to food insecurity, the relevant question is how effective growth would be to reduce food insecurity. One method to tackle this question could be through the idea of growth-food insecurity elasticity. This elasticity measures the growth effectiveness of reducing food insecurity (GERFI):

$$GERFI = \frac{\Delta Food\ Insecurity}{\Delta ln(Per\ Capita\ GDP)}$$

which is the ratio of change in food insecurity to the growth rate of per capita GDP. For instance, for East Asia and Pacific, this elasticity is -0.19, which implies that a 1% growth in per capita GDP reduces the percentage of people suffering from food insecurity by 0.19 percentage points. By contrast, a 1% growth reduces food insecurity by -0.41 percentage points in Sub-Saharan Africa. The results suggest that growth is more effective in reducing food insecurity in Sub-Saharan Africa than in the other regions examined. A slower progress in reducing food insecurity in Sub-Saharan Africa is due to the fact that the region has the lower growth rate in per capita GDP.

We now pose a practical question as to how many years it will take to eliminate food insecurity in the world. In making such a projection, we need to make some assumptions: (i) the regions continue to have the same growth rate as in the past and (ii) the GERFI is constant. Our reference year is 2011. The calculations are illustrated for South Asia as an example.

The population of South Asia suffering from food insecurity in 2011 is 12.99%, which is projected to be reduced to 0%. The GERFI for the region is -0.30, which gives the total growth rate required to eliminate food insecurity to 0% equal to 43.33%. As shown in Table 4, the annual growth rate in per capita GDP for South Asia is 5.30%. Using the compound interest formula, $\left(1+\frac{5.3}{100}\right)^n = \left(1+\frac{43.3}{100}\right)$, and solving for n will yield the number of years equal to 6.97.[12]

In Sub-Sahara Africa, the population with food insecurity is 37.37%, which is extremely high as compared to other regions. More importantly, if it continues with the same growth rate of per capita GDP, it will take almost three decades to eliminate food insecurity.

Table 4: Growth Effectiveness to Reducing Food Insecurity in the World, 2002-2011

Region	Per capita	Per capita	Annual growth rate for	GERFI	Years

[12] The authors are grateful to Jacques Silber for suggesting the compound interest formula to be used to estimate the number of years for this study.

	GDP in 2002	GDP in 2011	2002-2011		
East Asia and Pacific	3.63	7.62	7.41	-0.19	2.70
Europe and Central Asia	12.28	18.24	3.96	-0.02	3.49
Latin America and Caribbean	12.61	16.03	2.40	-0.17	8.06
Middle East and North Africa	5.04	6.59	2.68	-0.03	8.24
South Asia	1.62	2.76	5.30	-0.30	6.97
Sub-Saharan Africa	2.21	2.83	2.45	-0.41	26.77
Total	4.64	7.18	4.36	-0.24	8.83

Note: GERFI = growth effectiveness of reducing food insecurity.
Source: Authors' calculations.

14. How Is Food Insecurity Related to Extreme Poverty?

Extreme poverty is measured by the poverty line of $1.25-a-day in the 2005 PPP. This poverty line was adopted to monitor the Millennium Development Goal of halving extreme poverty in 25 years between 1990 and 2015. An estimated 1.9 billion lived below $1.25 in 1990-1992, which declined by 835.5 million to 1.065 billion in 2015.

FAO estimated that about 991 million suffered from hunger in 1990 and declined to 775 million in 2015, reducing by 216 million in 25 years. The decline in the number of hungry people by 216 million between 1990 and 2015 was only about a quarter of the estimated decline in the number of extreme poor at 835.5 million in 2015.

Lele (2015) in her recent blog "Measuring Poverty and Hunger can Raise More Questions than Answers" raised a pertinent question: why is there no link between hunger and poverty, as measured by FAO and the World Bank, respectively? To solve this puzzle, she suggested that the World Bank and FAO need to spend more resources than the two institutions currently deploy. Progress in hunger reduction seems underwhelming relative to the reported absolute levels and rates of decline in poverty. This puzzle can be understood given the following justification.

Poverty is measured in income or expenditure space. As economic growth increases people's incomes, there is bound to be a reduction in poverty because poor people also benefit from growth if not in the same proportion as the non-poor. FAO measures hunger in calorie intake space, which is compared with a fixed value of calorie requirement. With economic growth, as shown in this study, calorie intake increases very slowly even among the poor and may at some point remain the same. As such, when calorie requirement is fixed, it is expected that the reduction in hunger will be very slow. With prosperity, people tend to buy more quality food, which has high contents of protein and other micro-nutrients, and also opt for more fresh and hygienic food. FAO's measure of undernourishment is only based on calorie consumption, which fails to inform whether people are becoming nutritionally better or worse.

Like poverty, food insecurity in this study is measured in the expenditure space. There is almost a one-to-one relationship between the two as is evident from the following cross-country regressions:

$$ln(hfood2002) = -.87 + 1.13 ln(hpoor2002) \quad R^2 = 0.96 \tag{11}$$
(-5.2) (24.3)

$$ln(hfood2011) = -.71 + 1.05 ln(hpoor2011) \quad R^2 = 0.98 \tag{12}$$
(-11.7) (46.2)

where

hfood2002 = % of population suffering food insecurity in 2002
hfood2011 = % of population suffering food insecurity in 2011
hpoor2002 = % of population suffering extreme poverty in 2002
hpoor2011 = % of population suffering extreme poverty in 2011

Food insecurity or hunger is extreme forms of poverty. They should be closely related. Equations (11) and (12) establish an almost one-to-one relationship between the two.

15. Concluding Remarks

This paper has proposed a new methodology of measuring food insecurity. Households or individuals are considered to be food insecure if they have inadequate resources to buy food that sufficiently meets their nutritional needs.

This paper has calculated the per capita monetary cost of a food basket that provides a balanced diet with the following nutrients:

- Dietary energy = 2,100 kilo/calories per person per day
- Protein = 58 grams per person per day
- Carbohydrates = 375 grams per person per day
- Fats = 37 grams per person per day

This paper has estimated that the above food basket costs $1.03 in the 2005 PPP. To allow for comparison across countries, the per capita monetary cost of food is estimated in U.S. dollars based on the 2005 PPP.

In constructing such nutritious food basket, the paper first identified the energy requirement norms adopted at the international level. For the calorie norms, the reference person is assumed to be of median height and weight with a body mass index (BMI) of 21.5 for adult females and 22.5 for adult males. Moreover, on average, individuals within households are assumed to have moderate activity lifestyle that includes (i) physical activity equivalent to walking about 1.5-3 miles per day at 3-4 miles per hour, as well as light physical activity associated with typical day-to-day living. The estimated regression models showed that the calorie norm with moderate activity is around 2,100 kilo/calories per person per day.

Based on the U.S. Department of Agriculture, the average energy requirements for 67 developing countries is about 2,100 calories per person per day. A household is likely to avoid chronic hunger if it has access to food, which provides a minimum of 2,100 kilo/calories per person per day. While some household members will have caloric needs greater than 2,100 kilo/calories, others will have less; on average, the household will not suffer from hunger.

The food basket proposed by this study contains protein, fats and carbohydrates, the quantities of which lie in the ranges of nutrient requirements for a healthy person—except carbohydrates, which is marginally higher by 9 grams. Hence, this food basket provides a balanced diet of an average person as it contains the required nutrients for a healthy person. A household will be identified as food insecure if its entitlement, as measured by per capita expenditure, is less that the cost of basket estimated to be equal to $1.03 in the 2005 PPP.

FAO's (1996) recommended calorie requirements are about 300 calories less than the average calorie requirements for a healthy person since the human body can adapt to lower dietary energy intake. Except in carbohydrates, this food basket that adheres to FAO's calorie requirements is found to be deficient in protein and fats requirements for a healthy person. The household will consume excessive carbohydrates but may suffer from severe deficiency in both protein and fats. The household will not meet its nutritional needs and consequently suffer chronic malnutrition. Thus, adopting a lower cutoff based on FAO's minimum dietary energy requirement will not provide a balanced diet.

This paper has found significant progress in combating global food insecurity during 2002-2011. In just one decade, the percentage of food insecure people was notably slashed from 21.59% in 2002 to 10.98% in 2011. The number of food insecure persons decreased by more than 455 million between 2002 and 2011 despite the serious food crisis in 2007-08.

In East Asia alone, the number of food insecure people decreased from 309.21 million to 76.64 million. China's impressive economic growth in per capita GDP largely accounts for this reduction. Similarly, South Asia's performance in reducing food insecurity is commendable with the percentage of food insecure people decreasing from 28.88% in 2002 to 12.99% in 2011, lifting 198.64 million people out of food insecurity. Given such a rapid reduction in the number of food insecure people in South Asia, it will only be a matter of few years before food insecurity is eliminated in the region.

Food insecurity is also not much of an issue in Europe and Central Asia and Middle East and Caribbean, where the percentage of food insecure people is less than 1%. In Latin America, the percentage of food insecure people is 3.58% in 2011.

In contrast, extreme food insecurity is prevalent in Sub-Sahara Africa, where 47.39% people were food insecure in 2002 and declined to 37.37% in 2011. However, the region's total population increased from 667.97 million 2002 to 847.84 million in 2011. Consequently, the number of food insecure people in the region increased from 316.48 million in 2002 to 316.84 million in 2011, resulting in a net increase in the number of food insecure people by 0.36 million. With little or no sign of decline in the number of food insecure people, food insecurity will remain as a concern in Sub-Saharan Africa for a long time. Given the same growth rate of per capita GDP, it will take almost three decades to eliminate food insecurity in the region.

Based on FAO's estimates, about 991 million suffered from hunger in 1990 and declined to 775 million in 2015. Hence, only 216 million people were lifted out of hunger in 25 years. The decline in the number of hungry people by 216 million between 1990 and 2015 was only about a quarter of the estimated decline in the number of extreme poor at 835.5 million in 2015.

How is food insecurity associated with poverty? Poverty is measured in terms of income or expenditure. Economic growth increases people's incomes and thereby reduces poverty because poor people also benefit from growth if not in the same proportion as the non-poor. FAO measures hunger in calorie intake, which is compared with a fixed value of calorie requirement. Calorie intake increases very slowly with growth even among the poor. At some point, it may remain the same so when calorie requirement is fixed, it is expected that the reduction in hunger will be very slow. As people become more prosperous, they are likely to buy more quality food, which has high contents of protein and other micro-nutrients, as well as more fresh and hygienic food. FAO's measure of undernourishment is only based on calorie consumption, which does not inform whether people are becoming nutritionally better or worse.

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APPENDIX

Table A.1: FAO data on food and nutrition consumption

Country	Survey year	Per capita expenditure	Per capita food	Per capita kilo calorie	Per capita protein	Per capita fats	Per capita carbohydrates
Azerbaijan	2006	6.04	3.13	2856	78.31	76.1	448.62
Bangladesh	2000-01	1.61	0.83	2195	56.52	29.98	411.04
	2005	1.88	0.91	2119	49.61	26.43	417.26
Bolivia	2003-04	4.99	1.81	1866	63.54	38.85	305.11
Cambodia	2004	1.60	1.14	2014	55.09	29.33	370.41
	2009	2.25	1.59	2055	63.12	36.65	352.75
Chad	2009	2.05	1.44	2461	82.11	52.25	393.75
Côte d'Ivoire	2002	3.66	1.11	2105	63.69	46.74	343.89
Guatemala	2006	5.93	2.17	2290	65.02	50.12	379.11
Haiti	1999-2000	2.68	1.54	2324	57.5	61.76	384.96
Hungary	2004	11.57	2.96	2450	79.91	107.5	280.79
Kenya	2005-06	2.84	1.30	1799	52.4	41.94	301.02
Lao PDR	2008	2.82	1.55	2571	69.09	24.98	502.75
Lithuania	2002	9.41	4.38	2811	86.5	123.74	319.43
Malawi	2004-05	1.57	1.03	2237	74.32	47.51	375.7
Mali	2001	1.76	1.15	2276	63.49	44.73	396.68
Mexico	2004	10.68	2.89	2170	78.51	68.78	290.68
Moldova	2006	5.90	3.21	2690	92.62	90.08	364.37
Mozambique	2002-03	1.15	0.63	1955	51.6	41.83	341.26
Nepal	1995-96	1.28	0.77	2231	50.51	25.06	434.63
Niger	2007-08	2.17	0.68	1938	56.73	33.99	336.82
Pakistan	2005-06	1.93	1.05	1949	59.67	51.49	298.67
Panama	2008	11.24	3.38	2371	83.66	78.51	314.92
Papua New Guinea	1996	4.00	1.93	2003	47.61	43.54	334.42
Paraguay	1997-98	8.14	3.18	2837	84.06	94.09	388.31
Philippines	2003	3.38	1.57	1900	53.17	33.56	346.27
Sri Lanka	1999-2000	2.85	1.38	2182	56.42	47.29	372.32
Sudan	2009	2.78	1.70	2238	69.37	54.32	343.77
Tajikistan	2007	5.70	3.63	2617	69.55	71.93	408.85
Togo	2006	1.66	1.06	2159	66.41	37.65	385.94
Uganda	2002-03	1.84	0.84	2159	50.08	28.77	394.05
	2005-06	1.97	0.84	2006	47.48	25.15	365.78

Source: FAO and Authors' calculations.

Table A.2: Percentage and number of food insecure persons for 124 countries, 2002 and 2011

Countries	2002		2011		Change	
	Percentage	Number	Percentage	Number	Percentage	Number
Cambodia	24.15	3.07	3.23	0.47	-20.92	-2.60
China	20	256.08	3.2	43.01	-16.80	-213.07
Fiji	22.68	0.19	1.37	0.01	-21.31	-0.18
Indonesia	15.72	33.80	7.96	19.41	-7.76	-14.39
Lao PDR	27.34	1.52	19.64	1.28	-7.70	-0.24
Malaysia	0.26	0.06	0	0.00	-0.26	-0.06
Papua New Guinea	18.51	1.05	2.84	0.20	-15.67	-0.85
Philippines	15.86	12.84	10.81	10.27	-5.05	-2.57
Thailand	0.61	0.39	0.07	0.05	-0.54	-0.34
Timor-Leste	23.69	0.21	19.84	0.23	-3.85	0.02
Vietnam	28.05	22.31	1.94	1.70	-26.11	-20.61
Albania	0.22	0.01	0.12	0.00	-0.10	-0.01
Armenia	7.19	0.22	0.81	0.02	-6.38	-0.20
Azerbaijan	0	0.00	0.18	0.00	0.18	0.00
Belarus	0.26	0.03	0	0.00	-0.26	-0.03
Bosnia	0.23	0.01	0.01	0.00	-0.22	-0.01
Bulgaria	0.6	0.05	1.71	0.04	1.11	-0.01
Croatia	0.02	0.00	0	0.00	-0.02	0.00
Czech Rep.	0.04	0.00	0.03	0.00	-0.01	0.00
Estonia	0.38	0.01	0.9	0.01	0.52	0.00
Georgia	9.59	0.42	11.43	0.43	1.84	0.01
Hungary	0	0.00	0.04	0.00	0.04	0.00
Kazakhstan	1.54	0.23	0.02	0.00	-1.52	-0.23
Kyrgyz Rep.	18.11	0.90	2.71	0.15	-15.40	-0.75
Latvia	0.3	0.01	0.91	0.01	0.61	0.00
Lithuania	0.06	0.00	0.74	0.00	0.68	0.00
Moldova	7.84	0.28	0.06	0.00	-7.78	-0.28
Montenegro	0.25	0.00	0.21	0.00	-0.04	0.00
Poland	0.01	0.00	0	0.00	-0.01	0.00
Romania	1.21	0.26	0	0.00	-1.21	-0.26
Russia	0.25	0.36	0.01	0.01	-0.24	-0.35
Serbia	0.19	0.01	0	0.00	-0.19	-0.01
Slovak	0.14	0.01	0.3	0.02	0.16	0.01
Slovenia	0.04	0.00	0	0.00	-0.04	0.00
Tajikistan	24.32	1.56	2.84	0.22	-21.48	-1.34
Turkey	0.05	0.03	0	0.00	-0.05	-0.03
Turkmenistan	12.96	0.60	2.38	0.12	-10.58	-0.48
Ukraine	0.19	0.09	0	0.00	-0.19	-0.09
Argentina – Urban	9.35	3.52	1.16	0.47	-8.19	-3.05
Belize	8.06	0.02	8.25	0.03	0.19	0.01

Bolivia	18.95	1.68	5.47	0.56	-13.48	-1.12
Brazil	6.47	11.61	3.77	7.42	-2.70	-4.19
Chile	1.36	0.22	0.57	0.10	-0.79	-0.12
Colombia	7.86	3.24	3.58	1.69	-4.28	-1.55
Costa Rica	4.32	0.18	0.98	0.05	-3.34	-0.13
Dominican Rep.	3.36	0.30	1.33	0.13	-2.03	-0.17
Ecuador	9.56	1.25	3.05	0.47	-6.51	-0.78
El Salvador	12.39	0.74	1.43	0.09	-10.96	-0.65
Guatemala	16.43	1.93	9.45	1.39	-6.98	-0.54
Guyana	6.07	0.05	3.55	0.03	-2.52	-0.02
Haiti	54.41	4.82	43.49	4.36	-10.92	-0.46
Honduras	22.84	1.48	12.65	0.98	-10.19	-0.50
Jamaica	0	0.00	0	0.00	0.00	0.00
Mexico	1.84	1.96	0.57	0.68	-1.27	-1.28
Nicaragua	7	0.37	4.7	0.28	-2.30	-0.09
Panama	8.53	0.27	2.41	0.09	-6.12	-0.18
Paraguay	9.68	0.54	2.99	0.20	-6.69	-0.34
Peru	8.57	2.29	1.72	0.51	-6.85	-1.78
St. Lucia	13.38	0.02	7.86	0.01	-5.52	-0.01
Suriname	11.63	0.06	7.73	0.04	-3.90	-0.02
Trinidad and Tobago	1.38	0.02	0.64	0.01	-0.74	-0.01
Uruguay	0.3	0.01	0.14	0.00	-0.16	-0.01
Venezuela	12.19	3.09	4.61	1.36	-7.58	-1.73
Algeria	2.22	0.72	0.51	0.19	-1.71	-0.53
Djibouti	12.16	0.09	5.85	0.05	-6.31	-0.04
Egypt, Arab Rep. of	0.75	0.51	0.73	0.58	-0.02	0.07
Iran, Islamic Rep. of	0.73	0.49	0.4	0.30	-0.33	-0.19
Iraq	3.12	0.79	1.4	0.44	-1.72	-0.35
Jordan	0.33	0.02	0.03	0.00	-0.30	-0.02
Morocco	1.99	0.58	0.84	0.27	-1.15	-0.31
Syria	0.63	0.11	0.09	0.02	-0.54	-0.09
Tunisia	0.86	0.08	0.37	0.04	-0.49	-0.04
West Bank	0.23	0.01	0	0.00	-0.23	-0.01
Yemen	5.36	0.99	1.97	0.46	-3.39	-0.53
Bangladesh	39.82	54.56	25.28	38.64	-14.54	-15.92
Bhutan	19.09	0.11	0.96	0.01	-18.13	-0.10
India	28.78	309.88	12.87	157.16	-15.91	-152.72
Maldives	6.94	0.02	0	0.00	-6.94	-0.02
Nepal	42.4	10.22	14.81	4.02	-27.59	-6.20
Pakistan	20.28	30.36	4.39	7.73	-15.89	-22.63
Sri Lanka	6.69	1.27	0.95	0.20	-5.74	-1.07
Angola	65.65	9.78	33.54	6.77	-32.11	-3.01
Benin	35.6	2.64	41.01	4.01	5.41	1.37

Botswana	18.25	0.33	6.42	0.13	-11.83	-0.20
Burkina Faso	44.39	5.46	29.43	4.71	-14.96	-0.75
Burundi	75.45	5.31	70.25	6.70	-5.20	1.39
Cabo Verde	14.55	0.07	6.46	0.03	-8.09	-0.04
Cameroon	16.4	2.75	16.21	3.43	-0.19	0.68
Central African Rep.	51.76	1.95	48.17	2.14	-3.59	0.19
Chad	50.89	4.56	28.79	3.48	-22.10	-1.08
Comoros	37.19	0.21	40.33	0.28	3.14	0.07
Congo Democratic Rep.	86.29	42.73	77.7	49.67	-8.59	6.94
Congo Republic	46.79	1.53	24.52	1.04	-22.27	-0.49
Cote d'Ivoire	20.56	3.43	28.6	5.55	8.04	2.12
Ethiopia	34.36	24.03	24.44	21.85	-9.92	-2.18
Gabon	2.9	0.04	2.53	0.04	-0.37	0.00
Gambia, The	32.96	0.43	25.88	0.45	-7.08	0.02
Ghana	26.72	5.29	12.26	3.04	-14.46	-2.25
Guinea	44.59	4.04	29.48	3.29	-15.11	-0.75
Guinea-Bissau	36.44	0.48	36.21	0.59	-0.23	0.11
Kenya	31.56	10.41	29.15	12.25	-2.41	1.84
Lesotho	47.19	0.89	38.64	0.78	-8.55	-0.11
Liberia	59.17	1.82	57.92	2.36	-1.25	0.54
Madagascar	76.24	12.76	82.35	17.85	6.11	5.09
Malawi	71.96	8.58	62.2	9.62	-9.76	1.04
Mali	49.64	5.40	37.8	5.45	-11.84	0.05
Mauritania	17.22	0.50	15.74	0.58	-1.48	0.08
Mauritius	0.16	0.00	0.25	0.00	0.09	0.00
Mozambique	66.14	12.78	44.88	11.03	-21.26	-1.75
Namibia	31.02	0.61	14.12	0.31	-16.90	-0.30
Niger	48.76	5.76	26.06	4.30	-22.70	-1.46
Nigeria	53.49	69.12	49.9	81.93	-3.59	12.81
Rwanda	68.19	6.13	52.81	5.88	-15.38	-0.25
Sao Tome and Principe	20.9	0.03	30.46	0.05	9.56	0.02
Senegal	32.5	3.38	24.87	3.32	-7.63	-0.06
Seychelles	0.08	0.00	0.11	0.00	0.03	0.00
Sierra Leone	51.29	2.30	43.22	2.54	-8.07	0.24
South Africa	20.05	9.18	2.83	1.46	-17.22	-7.72
Sudan	22.33	6.52	10.69	3.89	-11.64	-2.63
Swaziland	33.49	0.36	31.95	0.39	-1.54	0.03
Tanzania	70.51	25.25	30.9	14.32	-39.61	-10.93
Togo	43.7	2.24	43.51	2.82	-0.19	0.58
Uganda	45.62	11.83	26.85	9.44	-18.77	-2.39
Zambia	52.29	5.56	66.46	9.06	14.17	3.50
Total	21.70	1103.55	10.98	625.55	-10.71	-478.00

Source: Authors' calculations using POVCAL.