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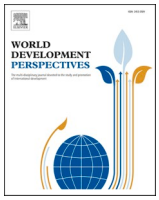

The history of hunger: Counting calories to make global food security legible

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ABSTRACT

The Prevalence of Undernourishment (PoU) is one of the most central indicators informing the international development agenda. Reported annually by the Rome-based UN agencies in their flagship report The State of Food Insecurity in the World, it is generally considered an authoritative statistic on world hunger. Based on archival research, this article chronicles and analyzes the development of its statistical model and the political and historical context of its revisions. We show that revisions to the PoU model have led to substantial changes in the estimates of the indicator and that this has underpinned shifting policy narratives and trends in the fight against hunger. Major changes in the statistical model inverted the PoU's trend lines towards the end of the Millennium Development Goals period. In 2020, the year after China's candidate became Director General of the Food and Agriculture Organization (FAO), the UN organization accessed new historical datasets from China and dramatically reduced PoU estimates for the country and consequently also the global figures. A number of ad-hoc revisions have been made to render food security crises - associated with inflation, economic recession, and the Covid-19 pandemic - legible. The indicator has thus been shaped by the political and economic structures within which FAO is situated, serving as an important tool to legitimize shifting ambitions and strategies of the post-World War II development agenda. At the same time, the lack of access to national household survey data from the countries with the highest measured undernutrition makes the PoU estimates fundamentally uncertain. At a technical level, this study highlights the need for greater transparency in the data and modelling basis for the PoU. The entanglement of technical and political factors illustrates the necessity of critical research on food insecurity quantification. More multifaceted approaches to measure food insecurity are needed.

1. Introduction

The Prevalence of Undernourishment (PoU) and its predecessors allowed the Food and Agriculture Organization (FAO) for the first time to report on the number and proportion of people in the world living in hunger. The United Nations (UN) agency started publishing such estimates following the end of the Second World War, but the model was not fully developed until 1961. The PoU has since been one of the most prominent international indicators. It was a key indicator in the Millennium Development Goals (MDGs) and it remains a key indicator for Sustainable Development Goal (SDG) 2.

Despite its status as a cornerstone of food security measurement, the value and validity of the PoU is contested. It has been criticized on technical grounds for having a too long reference period (Lappé et al., 2013), for assuming that the basal metabolic rate is the same across different regions (Hayter & Henry, 1994), and for overestimating the variability of consumption (Svedberg, 2002). Furthermore, the PoU is criticized for its inability to provide estimates below the national level, and for its narrow and technical conceptualization of food insecurity (Fukuda-Parr & Orr, 2014; Pogge, 2016).

Such technical and conceptual concerns also have a political dimension: namely that different ways of measuring food security are informed by and express different values and norms. These values and norms, in turn, may represent different 'theories of change' pertaining to how food insecurity can be reduced. While the history of global poverty statistics such as the dollar a day metric have been subject to significant scholarly attention and debate (Gordon et al., 2000; Jerven, 2018; Ravallion, 2015), the history of indicators of food security and nutrition have received almost no scrutiny. Standardized international data on hunger was assembled already in the 1930s by the League of Nations

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(Scott-Smith, 2020). The PoU and its forerunners however produced the first hunger estimates at the global scale (FAO, 1952).

An entanglement of technical, conceptional and geopolitical dimensions was illustrated by the FAO's substantial revision of the PoU in 2020. This followed the election of China's FAO Director-General candidate in 2019, despite a countercampaign by the United States (Chadwick, 2019). Following the change in leadership, FAO got access to new data which changed a key variable in the calculation of the PoU for China (Cafiero, Feng, & Ishaw, 2020). As seen in Fig. 1, this resulted in a significant downward revision of the Chinese (and therefore also the global) PoU estimates (FAO et al., 2020).

The new estimates for China were based on analysis of food consumption and food expenditure data obtained from two separate household surveys that covered the period between 2011 and 2017 (Cafiero et al., 2020). Previously the distribution of caloric intake for the Chinese population was based on survey data from 1996 (FAO, 1999). Thus, the figures on distribution of caloric intake in China had remained unchanged from 1999 to 2020. The new distribution coefficient of variation resulted in a reduction of the estimated proportion of undernourished people in China from 9.6 to less than 2.5 percent.[1] The revision was the major reason behind the global PoU reduction from 820 million people in 2018 to 690 million people in 2019 and consequently, a downward shift in hunger trend lines towards 2030 (FAO et al., 2019; FAO et al., 2020) (Fig. 1). As will become apparent, this was not the first time in the history of the PoU that technical and political factors have been intertwined.

Here we focus on the history of knowledge politics surrounding the PoU. Analyzing the entanglement of knowledge and politics is important not only to assess the validity of global statistics relating to hunger, and to understand how and why certain approaches and actors have come to dominate food systems, but also to identify alternative development pathways (Leach et al., 2020; Sumberg & Thompson, 2012; Taylor et al., 2021). The concept of legibility turns our attention to what we see and what we don't see when we measure complex phenomena with indicators, and whose interests the particular measure serves. Through this lens we study what kind of legibility the PoU has offered modern societies, and the interaction between the PoU and shifting development agendas.

This article proceeds as follows: In section 2, we detail the theory and methods of the article. In section 3, we outline the current methodology for calculating the PoU. Section 4 details the historical development of the PoU. Section 5 provides analysis and discussion of these findings before we provide a conclusion in section 6.

2. Theory and methods

The most common definition of food security stems from the 1996 World Food Summit (WFS): '*Food security exists when all people, at all times, have physical and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life*' (WFS, 1996). This definition encompasses four widely accepted dimensions of food security: *Availability* (adequate food supplies for a given population); *Access* (ability to access available food); *Utilization* (nutritional intake and absorption); and *Stability* (over time). Recently, the High-Level Panel of Experts of the Commission on Food Security suggested that *Agency* (decision power) and *Sustainability* (environmental resilience) should be added to this list of dimensions (Clapp, Moseley, Burlingame, & Termine, 2022; HLPE-CFS; HLPE-CFS, 2021). While the conceptualization of food security has expanded in scope over the years, the demand for quantification and metrics has remained constant (Barrett, 2010; Cafiero, 2019; Jones et al., 2013).

There are many ways to theorize the need for and use of metrics in politics. Scott (1998) argued that a central project for the modern state is to make objects and activities more 'legible' (or readable, distinguishable, visible). Scott traces this to the Enlightenment which inspired an administrative ordering of nature and society that greatly improved the overview and control of the modern compared to the pre-modern state, with the latter knowing little about its subjects or assets. Expanded legibility in turn supported classic state functions such as taxation and conscription while enabling modern large-scale social engineering. It

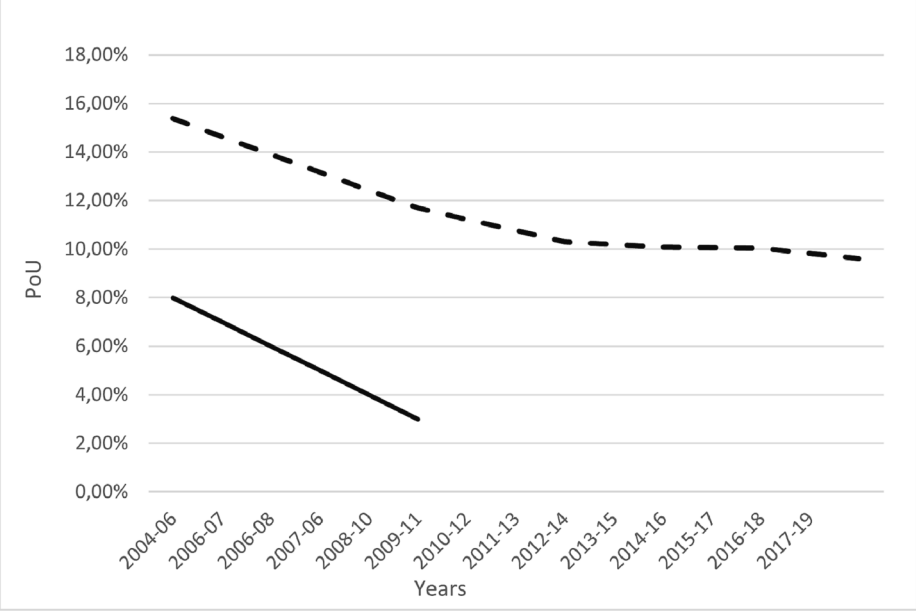

Fig. 1. Prevalence of Undernourishment in the population of mainland China before and after the revision of PoU. The dashed line shows the PoU before the 2020 revision, while the solid line shows the new estimates. Hunger below 2.5 percent of the population cannot be measured by the PoU. According to the new estimates, there has been no undernourishment in China since the 2009/2011 period. Adapted from Cafiero et al. (2020).

[1] 2.5 percent is the lowest value that the PoU can report.

was ensured by processes as varied as the creation of permanent last names, land registries, standardization of law, language, weights and measures, cadastral surveys, tenure reform and the design of cities (Scott, 1998, p. 2).

We seek to understand how quantification of hunger can be seen as a legibility process and what effect that has had on our understanding hunger itself. Legibility refers to a state or organization's capacity for rendering people and assets visible to itself. It highlights how such organizations require the simplification and reduction of complex systems, individuals, and concepts.

Numbers are particularly amenable to being framed as objective, neutral and universal, as has been well demonstrated by Theodore Porter (1995). Taking this further, Sally Engle Merry (2016) therefore suggested emphasizing the history and genealogy of quantitative methodologies in order to investigate the development of particular quantitative indicators, which actors and institutions promote and finance them, and how and when they become settled. This paper does this for the PoU, a key indicator of international hunger. The research is archival, and first and foremost based on documents in the FAO library. From 1946 through 1996 FAO published estimates of international hunger in its World Food Survey reports. This report series has with the exception of the Sixth World Food Survey (1996) not been digitized earlier. We have also digitized and analyzed the reports outlining the historical efforts of FAO and later World Health Organization and the United Nations University to make quantitative thresholds for under- and malnutrition at the group level. The digital versions of these documents are now available from the FAO library.[2] Since 1999, these estimates have become a central feature of the annual State of Food Insecurity and Nutrition in the World (SOFI) reports, which are also analyzed. A list of reviewed documents is included in the electronic supplementary material.

That the precision in the global hunger estimates is limited is indicated by FAO, who warns that one should not compare PoU-estimates published in different years due to frequent methodological tweaks and adjustment of trend lines (FAO et al., 2020). There is, however, much to learn from comparing estimates across time with regards to investigating the stability of the PoU's lens. The article therefore compares different time series as well as yearly estimates presented in different report series. Furthermore we draw on information and data from national household surveys used to calculate the PoU which hereto have not been publicly available.

3. The current methodology for determining the PoU

The PoU is an estimate of the proportion of undernourished people in a population, with undernutrition defined as a condition of '*continued inability to obtain enough food*' (FAO et al., 2021). In the absence of data on the real caloric intake distribution of the individuals in a population, the PoU is a proxy that utilizes data on total availability of calories and a weighted average of caloric requirements, as well as estimates of the distribution (variation) of calory intake within the population. The PoU is given by Equation 1, which presents a notation used by FAO in the recent SOFI reports (FAO et al., 2018; FAO et al., 2022).

$$PoU = \int_{x<MDER} f(x|DEC; CV)dx$$

Equation 1. The PoU.

In Equation 1, x represents the caloric intake of the average individual. The average individual takes the population structure into account by integrating weighted distributions of sex, age, body mass and physical activity levels. f(x) constitutes the postulated probability density function of caloric intake for this average individual.

The equation defines the PoU as the cumulative density function of caloric intake from 0 up to the threshold value for caloric requirement, the so-called MDER, the Minimum Dietary Energy Requirement. In other words, the PoU is the proportion of the area under the density function to the left of the MDER threshold (Fig. 2).

An important rationale of this model lies in the scarcity of precise and

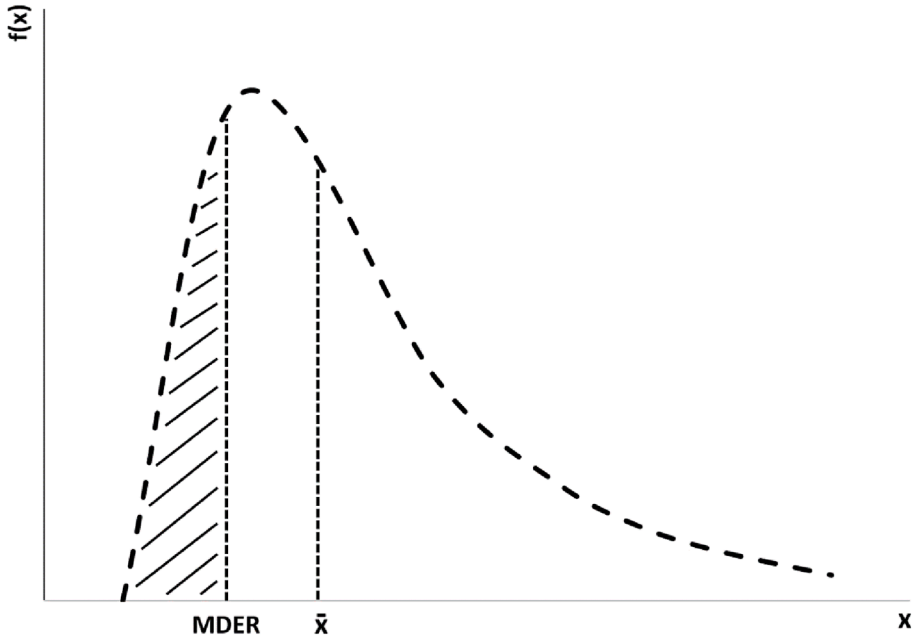

Fig. 2. The lognormal probability density function of the PoU. x̄ is the mean of the distribution. The PoU equals the (shaded) aggregate area to the left of the MDER. Adapted from Naiken (2002).

[2] These documents can be accessed online through the FAO document repository and physically through FAO's David Lubin Memorial Library.

reliable household survey data on the caloric intake distribution in a population (FAO et al., 2019, p. 149). Equation 1 massively reduces the need for information because it states PoU merely as a function of MDER and the choice of f(x) and its parameters. Currently, the choice of f(x) is the lognormal distribution, which is a two-parameter distribution. In Equation 1, the two parameters are determined by DEC and CV. We shall now turn to how MDER, DEC and CV are estimated.

The MDER is defined as the level of dietary energy (calories) considered necessary for an (average) individual with a normal active and healthy life. The threshold for the entire population is defined as the weighted average of the threshold of the different age or sex groups in the population (FAO, 2003). Demographic data on population structure by sex and age and median height is also used to calculate the MDER (FAO et al., 2022).

DEC is the Dietary Energy Consumption, which is an estimate of the total supply of calories for the national population. DEC divided by the number of individuals in the population is taken to represent the mean individual intake (x in Fig. 2). Estimates of the total caloric supply is taken from FAO's food balance sheets. These include sources of supply and means of utilization for a range of food items. The total quantity of food production and stocks is added to the net food import. It also defines several sources of utilization, such as livestock feed, seeds, manufacture for food or non-food purposes, losses, and food supplies available for consumption (FAOSTAT, 2022).

CV is the coefficient of variation (CV) taken to represent the relative standard deviation of caloric intake. It provides a measure for inequality in food consumption within the population. The CV has two components: 1) CV|y is estimated from variability in food consumption attributed to differences in income, and 2) CV|r is estimated from variability that comes from non-socioeconomic factors such as such as sex, age, body mass and physical activity (Wanner, Cafiero, Troubat, & Conforti, 2014). CV|y is estimated using nationally representative household survey data on income, expenditure, or food consumption. When no suitable survey data is available, the indicator Food Insecurity Experience Scale (FIES) is used to calculate the CV|y (FAO et al., 2022).

4. The contested history of the PoU

Measuring food production and food security has been a central task of the FAO since its inception. Table 1 provides an overview of milestones in the development of its estimation methods. We proceed to give a chronological account of the development of FAO's estimates of global undernutrition and their methodological techniques. The story largely revolves around the estimation of national availability of calories, the caloric intake distribution in the population, and caloric requirement thresholds (which the DEC, CV and MDER from equation 1 are intended to calculate).

4.1. Early estimation of global undernutrition

Fig. 3 provides an overview of its estimates of the proportion of undernourishment globally from start of the World Food Survey-series until its end in 1996 and replacement by the SOFI reports. The SOFI-series will be covered in the last section of the analysis.

One of FAO's first major accomplishments was the publication, only a few months after its establishment, of the First World Food Survey (FAO, 1946). The data included in the report covered 70 countries and about 90 percent of the world population. Even though the League of Nations had similar ambitions (Scott-Smith, 2020), this represented the first time facts and figures had successfully been assembled to estimate global hunger (FAO, 1952). Pre-war data were used to estimate average per capita calorie availability (see DEC in equation 1), but for many countries information on population and food supply were little more that guesswork (FAO, 1963). Populations were divided into groups

Table 1
Methodological milestones in the development of global estimates of undernutrition. The most recent estimates are often predictions of the recent past or contemporary situation. The SOFI 2009 estimate was calculated using the global population estimate provided in the report, as it did not provide percentage estimates for 2009.

Year	Report	Development	Scope	Undernutrition in population
1946	WFS-1	First global estimates of undernutrition Invariable caloric thresholds No estimation of distribution of caloric intake	World	50%
1952	WFS-2	First use of food balance sheets to estimate caloric intake First application of reference man technique for estimating caloric thresholds for undernutrition No estimation of distribution of caloric consumption	World	59%
1963	WFS-3	First application of Sukhatme's (1961) technique in WFS-series due to estimation of distribution of caloric intake. Attained basic structure of PoU	World	10 % to 15 %
1974	SOFA	Used caloric thresholds specified by BMR Estimates minimum proportion of undernourished. Introduction of theoretical probability distribution (beta) of caloric intake in population	Developing countries	25 %
1977	WFS-4	First systematic publication of country-level data Distribution of caloric intake calculated based on survey data on food consumption and income and expenditure data.	Developing countries	25 %
1987	WFS-5	Changed to log-normal probability distribution of caloric intake. Applies two unique undernutrition threshold BMR-values	Developing countries	15 % or 23 %
1996	WFS-6	PoU largely assumed its contemporary form and terminology Applied survey reference period equal to one year Last of WFS-report	Developing countries	20 %
1999	SOFI	Launch of the annual State of Food Insecurity (SOFI)-report series	Developing countries	18 %
2009	SOFI	Largest estimate of global undernourishment in absolute terms (1020 millions undernourished) Use of data from USDA to provide forecast for 2009	World	15,7 %
2012	SOFI	Including estimates of food loss at retail levels Skew-normal probability distributions introduced replacing lognormal distribution	World	14,9 %
2017	SOFI	Introduction of FIES as alternative global indicator Used to support calculation of CV|y where preferred kinds of household data is missing	World	11 %
2020	SOFI	China revision drastically reduces number of undernourished in China and globally. Skew-normal distribution replaced by lognormal	World	8,9 %
2021	SOFI	Use of FIES data to project 2020 estimates in order to project consequences of COVID 19-pandemic Presents values in both point estimates and range	World	9.2 % to 10.4 % (9,9 % middle value)

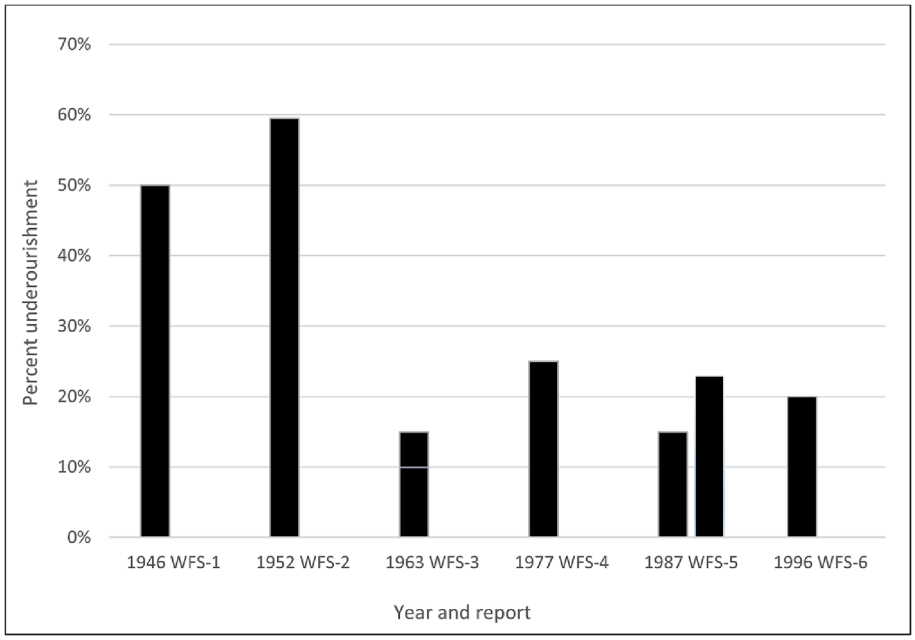

Fig. 3. Undernutrition measured globally by World Food Surveys in the period 1946–1996. WFS-1 and WFS-2 operated with fixed caloric thresholds for global estimates. PoU's methodology introduced from WFS-3 also provided its estimates in a range, as indicated by the line striking through the WFS-3-bar. WFS-5 published estimates using two different caloric thresholds.

consuming above 2750 calories, between 2250 and 2750 calories, and below 2250 calories. The data that was used was not adjusted for variability in caloric needs or consumption within these groups or across different countries. For countries with lower average food availability than 2250 calories, the whole population was thus counted as undernourished.

The Second World Food Survey (FAO, 1952) made use of data from the postwar period. It incorporated some innovation both in terms of data sources and methods. FAO's new Food Balance Sheets were used to estimate prewar and postwar food supplies available for human consumption. WFS-2 also used household survey data in order to triangulate its estimates of food supplies.

However, the second survey's most substantial innovation was probably its new calorie requirement scale. This scale took mean environmental temperature, body weight and distribution by age and sex in a population into account when defining caloric thresholds, similar to the modern MDER (see equation 1). This was the beginning of nationally determined calorie requirements, in contrast to the uniform caloric standards applied by WFS-1 (FAO, 1950). The scale was based on defining a 'reference' man and woman of a specific age and weight, living a healthy and active life in a specific mean annual temperature. With the exception of physical activity level, the scale adjusted for all these factors in different national contexts. The actual per capita requirement for each country was obtained by multiplying the requirement of each age and sex group by the proportion of the people in different groups. This requirement scale was applied for national estimates, but not for the global estimation, which still relied on a fixed caloric threshold of 2200 calories (FAO, 1952, p. 11).

4.2. The making of the PoU

In 1961, FAO's chief statistician, Pandurang Vasudeo Sukhatme, published a pioneering estimate of the extent of hunger in the world that represented the introduction of the PoU. While there have been important developments in the PoU that will be elaborated upon in the coming sections, its basic structure remains largely unchanged. The critical innovation was the application of population-level caloric intake distributions (example provided in Fig. 3). They were added to the food balance sheets (used to estimate the DEC) and caloric requirement scale used in WFS-2 (Sukhatme, 1961).[3]

As explained in section 3, this distribution added a measure of inequality in caloric intake in the population, caused in part by socio-economic differences. Data used to establish the new caloric intake distributions were derived from household surveys based on either recall of food consumed in a reference period, or actual weighing of foodstuffs. Sukhatme (1961) employed the previously described 'reference man' technique to calculate quantitative thresholds for undernutrition (Fig. 4).

The indicator developed by Sukhatme (1961) was at its introduction praised not mainly for the certainty of its estimates, but because it endowed international estimates of undernutrition with scientific authority. Although the estimates were critiqued for their uncertainty and for being presented with too little epistemic humility (George, 1961, p. 509), the model's methodological innovations were praised for opening up a new frontier for statistics (Searle, 1961, p. 514). Statistics such as national income were at the time considered to entail important '*demonstration effects*' for industrialized countries that newly decolonized countries also aspired to (Seers, 1959, p. 38). One commentator hailed the new mode of legibility offered by the PoU by referring to the historical impact of such economic statistics: '*if we consider the early history of National Income and Expenditure Statistics it seems clear that unless a start had been made with what would now be regarded as limited data such work would not now be considered of fundamental importance to efficient government policy making*' (Moss, 1961, p. 518). The reference to statistics' ability to set governance agendas seems prescient in hindsight.

This debate further shows that numbers are used not only because of their ability to describe the world, but also because of their ability to configure politics (Porter, 1992). Sukhatme (1961, p. 464) put his work in the context of the Freedom From Hunger Campaign (FFHC). This campaign was a global information campaign on hunger, and an

[3] The MDER and CV concepts were introduced later, and have slightly different meanings, even though they are also tools to calculate the variable national caloric thresholds and the shape of the distribution of caloric intake in the population.

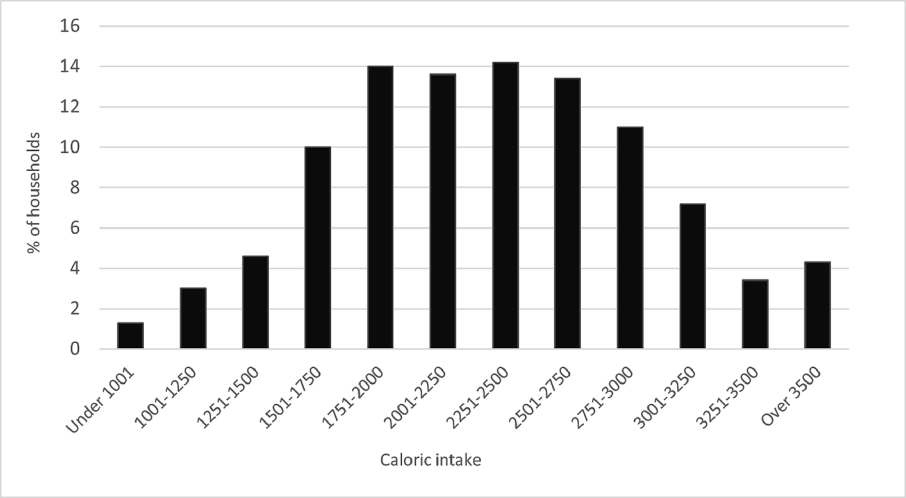

Fig. 4. Distribution of caloric intake from survey of 843 households in colonial India. No theoretical probability distribution is applied. Figure by the authors based on data presented in Sukhatme (1961).

essential precursor to the modern development movement (Bunch, 2007). It was largely motivated by a sentiment that the world hunger problem was getting worse and that rapid population growth compounded the problem. The FFHC sought to promote research, education, and action on global hunger.

The Third World Food Survey, which for the first time utilized the new methods to measure international undernourishment, was a key part of the Campaign. WFS-3 was orchestrated by FAO Director-General Binay Ranjan Sen, who also initiated the FFHC. As the first WFS report based on the PoU, WFS-3 has been framed as the first accurate and scientific documentation of hunger and undernourishment in the WFS series (Bunch, 2007, p. 45). WFS-3 covered the prewar, postwar, and contemporary periods, and provided the first estimates of global undernutrition using the methodology established by Sukahtme in 1961. It used food balance sheet data for over 80 countries covering some 95 percent of the world population to calculate the DEC (see equation 1), and drew more heavily and directly than earlier WFS editions on household surveys of food consumption. As seen from Fig. 3, its estimate of global undernutrition was far lower than in previous reports. The integration of caloric intake distributions made it possible to differentiate between varying consumption in different parts of national populations, triggering a significant reduction of estimates compared to previous surveys.

At its peak, the FFHC had more than 100 national committees all over the world, with broad participation by groups and individuals from all parts of the social and political spectrum. A pioneering element of the campaign was the collaboration with NGOs, industry, and youth movements. The WFS-3 thus played a key part as a knowledge resource in a campaign that would be important in spurring the formation of international development as we know it today (Bunch, 2007, p. 47), in particular through promoting broad partnerships. In this way it helped bridge a gap between philanthropy, activism, and official development programmes. The campaign was also an important means of transforming FAO, then a mainly technical organization, into a broader development agency.

4.3. Further development of the PoU

The State of Food and Agriculture (FAO, 1974) and WFS-4 (FAO, 1977) represented ambitious attempts to further improve the estimation of undernutrition. The reports have perhaps therefore been regarded as the first proper application of a model that closely resembles the version of the PoU in use today (Cafiero et al., 2014), despite the cautious application of the Sukhatme-model already in WFS-3.

The State of Food and Agriculture (FAO, 1974) report concluded that the PoU had declined in many countries following the Second World War. A main methodological update was adjustments to the notion of the 'reference man' in line with the suggestions provided by the joint Ad Hoc Expert Committee on Energy and Protein Requirements of FAO and WHO (1971). The committee advised that the Basal Metabolic Rate (BMR) should be used to denote thresholds for undernutrition, since most of the energy utilized by the body is basal metabolism. The chosen BMR rate made no allowance for physical activity beyond rest and essential activities in order to remove risk of overestimation. In contrast to the WFS-3 from 1963, the State of Food and Agriculture (FAO, 1974) (p. 150) explicitly stated that it reported the *minimum* proportion of undernourished in the population. Caloric intakes were compared to the lowest limit of requirements rather than average requirements. The real number of undernourished people was therefore considered likely to be much higher.

In the same report, a beta probability distribution was applied to the calorie intake for each country. Using a beta distribution rather than the more common normal distribution requires the settlement of lower and upper limits of the caloric intake range for individuals in a fixed interval. The beta distribution thus enabled some standardization by warding off extreme and unrealistic values of caloric intake. The use of theoretical probability distributions in general also provided a framework for generating such distributions when data were lacking, reducing the role of scarce survey data in calculating the distribution of caloric intake in the population (FAO, 1987, p. 63).

The Fourth World Food Survey (FAO, 1977) largely employed the technical framework presented in the State of Food and Agriculture with some important adaptations. WFS-4 estimated undernutrition for 70 countries covering 90 percent of the world population, for the first time publishing national data for a comprehensive group of countries. The distribution of caloric intake was meanwhile for the first time calculated not only based on household food consumption surveys. When food consumption data was unavailable, data on income and expenditure was introduced.

The Fifth World Food Survey (FAO, 1987) abandoned the beta probability distribution in favor of the two-parameter log-normal distribution which remains in use today (FAO et al., 2022). Its methodology section showed that the log-normal distribution gave the highest scoring representation of empirical data of caloric intake distributions. The '*fitting*' of a log-normal distribution onto each country requires the estimation of the standard deviation of per capita calorie intake to calculate the CV, as specified in equation 1.

Based on reviews of human nutritional requirements by FAO, the

World Health Organization and United Nations University (FAO et al., 1985), WFS-5 also introduced adjustments to caloric requirements. The report applied used two different BMR thresholds, reflecting different interpretations of observed variation of weight maintenance requirements. Estimates using both thresholds showed a slight increase in absolute numbers of undernourished in developing countries during the 1970s, while the proportion of undernourished declined.

The Sixth World Food Survey (FAO, 1996), the last of the series, came out just before the landmark World Food Summit and helped frame the summit's debates and deliberations. From 1999, the series would be replaced by the annual flagship reports State of Food Insecurity (SOFI). In WFS-6, the PoU largely assumed its contemporary form and terminology, despite several tweaks made after the end of the WFS-series. Due to the availability of new data following the end of the cold war, China and what were referred to as the former 'Asian centrally planned economies' were included in the survey after decades of exclusion. The WFS-6 also included anthropometric indicators like wasting, stunting and body mass index to triangulate alternate measures of undernutrition.

For the first time a standardized survey reference period, equal to one year, was used. For an individual to count as undernourished, s/he should thus have experienced lack of average daily sufficient caloric intake for an entire year. WFS-6 also tried to take seasonal variation into account, and to avoid unrealistic values by imposing upper and lower limits in the calculation of the CV. Some important changes were introduced in the calculation of caloric thresholds. WFS-6 introduced the MDER-term described in equation 1. It still used the BMR for denoting caloric cutoff points, while employing a weighted average of sex-age group specific cutoff points to establish caloric thresholds. The group-specific cutoff-points equaled the lowest level of an acceptable range of acceptable caloric intake, calculated following guidelines established by FAO et al. (1985). The BMR and MDER now included an allowance for light physical activity.

4.4. SOFI and the 1 billion hungry

Since its first publication in 1999 until now, the State of Food Insecurity (SOFI) report series published annually by FAO and its partner agencies has been the home of the PoU. There were no significant methodological changes in the PoU from 1999 until after 2010 (Wanner et al., 2014). The SOFI reports published between 2003 and 2007 showed that the PoU had been on the rise since the mid-90 s, which was claimed to be a historical low point (FAO, 2003; FAO, 2004; FAO, 2006; FAO, 2007). The SOFIs of 2008, 2009 and 2010 continued this narrative of increasing hunger, underpinned by an increasing PoU, emphasizing how rapidly increasing food prices, financial crisis and economic recession apparently had devastating effects on undernutrition (FAO, 2008b; FAO & WFP, 2009; FAO & WFP, 2010).

The late 2000s food price crisis was said to have further increased the number of undernourished people from 848 million in 2006 to 923 million in 2007 (FAO, 2008b). Then in 2009, the SOFI announced a further jump to 1,020 million (FAO & WFP, 2009). For its 2009 estimate, FAO used projections from a food security model developed and operated by the United States Department of Agriculture (USDA) Economic Research Service. By referring to these projections, FAO claimed that the impact of the financial crisis was expected to increase the number of undernourished by 9 percent from the previous year, on top of an increase of 2 percent due to other factors. The model projected caloric intake in 70 low-income countries, on the basis of commodity groups. The projections used in SOFI (FAO & WFP, 2009) were based on a modelled scenario that integrated a 25 percent cutback in capital flows for low-income countries as well as reduced export incomes and food imports.

The estimate of 1 billion was explained by both the food price and financial crises. According to the Director-General of FAO, *'a dangerous mix of the global economic slowdown combined with stubbornly high food prices in many countries'* had pushed some 100 million more people into chronic hunger and poverty – the highest number of hungry people ever to walk the earth – leaving one sixth of humanity undernourished (FAO, 2009). References to one billion hungry began appearing in speeches, media reports and advocacy campaigns around the world, while millions signed an online petition prompting governments to address the '*1 billion hungry*' (Provost, 2012).

There was, however, considerable external skepticism about FAO's estimates. Following a presentation of the 2010 SOFI, the Committee of World Food Security (CFS) agreed that an external evaluation of the PoU's estimation methods was needed. The evaluation had a particular emphasis on data quality and quantity, but also urged FAO to improve its parameters and its underlying probabilistic model by performing new tests of probability distributions (CFS, 2011a; CFS, 2011b). Following the evaluation, CFS *'strongly recommended'* FAO to improve upon its estimates of undernourishment with a particular emphasis on the '*timeliness and reliability of the underlying data and parameters*' (CFS, 2011c, p. 13). The PoU was further criticized for using a narrow definition of food insecurity, neglecting welfare losses due to the sacrifice of other essential consumption to maintain minimum caloric intakes, and for not considering micronutrients (Wanner et al., 2014). Following this critical evaluation, FAO chose not to release new figures in 2011, and removed the 2009 and 2010 estimates (FAO & WFP, 2011). The development of a core set of complementary food security indicators that could capture different elements of food insecurity was recommended (FAO, 2012). The PoU's role and reputation as the leading indicator of international food security was coming under serious scrutiny.

In the SOFI 2012 FAO introduced a number of changes to the methodology and data basis for estimation (FAO et al., 2012). The most impactful change was the lowering of caloric intake with empirically estimated coefficients that reflected national food loss at retail level (FAO, 2011). It had not been previously integrated and implied a significant reduction of available calories across the board. New skew-normal theoretical probability distributions that allowed for more asymmetry in caloric intake were introduced. In line with these new distributions, household survey data was used to estimate a new parameter of skewness of the distribution, that could reflect asymmetry in the distribution of caloric intake. In 2020 FAO returned to using a lognormal distribution (FAO et al., 2020), after a period of applying both probability distributions selectively.

The new methodology was used from 2012 and onwards and applied retroactively to the period covering the MDG era. The net effect of these methodological changes increased the estimated number of undernourished at the start of the time series when compared to the pre-adjustment trend line, while decreasing estimates from 2000 and onwards (FAO et al., 2012). A wide range of new data was added. National food balance sheets used to estimate the DEC were re-estimated up to 2009. FAO used more income and expenditure surveys to recalculate distributions of caloric intake. Height data was adjusted leading to a re-estimation of the threshold MDER for each country which led to a reduction of estimates across the board. Population data revisions with significant changes in populous countries like China and Bangladesh further increased the baseline number of undernourished.

FAO would declare a 45 percent reduction in hunger in developing countries by the end of the MDG era in 2015, compared to the baseline in 1990. Thus, the goal of reducing the proportion of hungry people by 50% had very nearly been reached. FAO thus drastically revised its method for estimating undernourishment towards the tail end of the MDG era, changing estimation techniques and revising its estimates back to the start of the MDG monitoring period. The outcome was an inverted trend line and narrative of global hunger. This is visualized in Fig. 5 and Fig. 6.

The old technique suggested that the food crises pushed a historic 1 billion into hunger in 2009, with enormous increases from 2007 to 2009. The new method, however, suggested that there were no significant effects of the crisis or of the 'great recession' that followed. On the

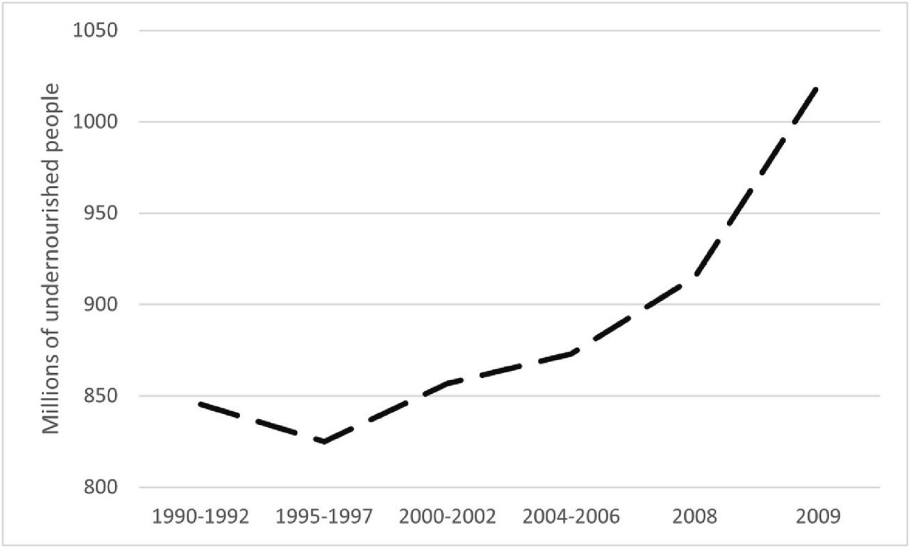

Fig. 5. Prevalence of Undernourishment reported in the period 1990–2009 in SOFI (2009). The 2009 value is a projection based on an ad-hoc revision of the statistical method done in connection with the 2007–2008 food prize crisis. Figure developed by the authors based on data from SOFI 2009.

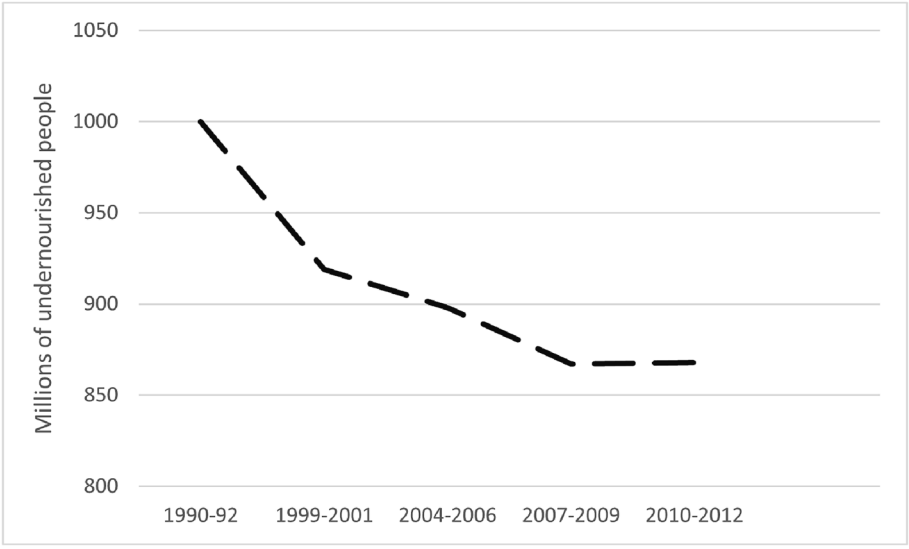

Fig. 6. Prevalence of Undernourishment reported by FAO in the period 1990–2012 after the 2012 revision of the methodology. Figure developed by the authors based on data from SOFI 2012.

contrary, the new estimates showed a reduction in the number of undernourished – from 885 million in 2004 to 2006 to 852 million in 2007 to 2009. The negative effects of the food and financial crises, which were at center stage in previous SOFI-reports (FAO, 2008b; FAO & WFP, 2009), were thus expunged from a trend line that now supported a clear narrative of progress in the fight against hunger and poverty during the MDG period (Pogge, 2016). The new PoU estimates told a story of significant reduction in hunger since 1990, a story that was entirely consistent with MDG ambitions.

We end our historical account by describing the PoU's loss of hegemony as a technology for rendering international food insecurity legible. In 2017, the experience-based indicator FIES was included in SOFI with global estimates of the number and proportion of 'food secure or marginally insecure' or 'severely food insecure' (FAO et al., 2017). As of 2019, SOFI also included FIES estimates of 'moderate or severe food insecurity' (FAO, et al., 2019). It is available in individual and household versions.

FIES' estimates have also been heavily used to support the calculation of the CV|y of the PoU. For countries where no suitable household survey data is available, the CV|y is currently indirectly estimated using changes in severe food insecurity as measured by the FIES where its data is available (FAO et al., 2022). The indicator has also been used in forecasting the most recent estimates of the PoU, as FIES' estimates tend to be available earlier than the preferred sources of household data (FAO et al., 2018).

This has particularly made it crucial in forecasting the impact of the Covid 19-pandemic (FAO et al., 2021; FAO et al., 2022). Normally the changes of CV|y can be derived from changes in the three-year averages of FIES. However, the pandemic in 2020 and the years that followed were considered so exceptional that the estimate for 2020 was used on its own and contrasted to the average estimate from 2017 to 2019. FAO furthermore carried out a sensitivity analysis of how much changes in severe food insecurity as measured by FIES is caused by changes in CV|y. The outcome was a broad interval between one third and one, prompting FAO to publish the overall PoU-estimates in a range (FAO, 2021). FAO's two leading methodologies for measuring international

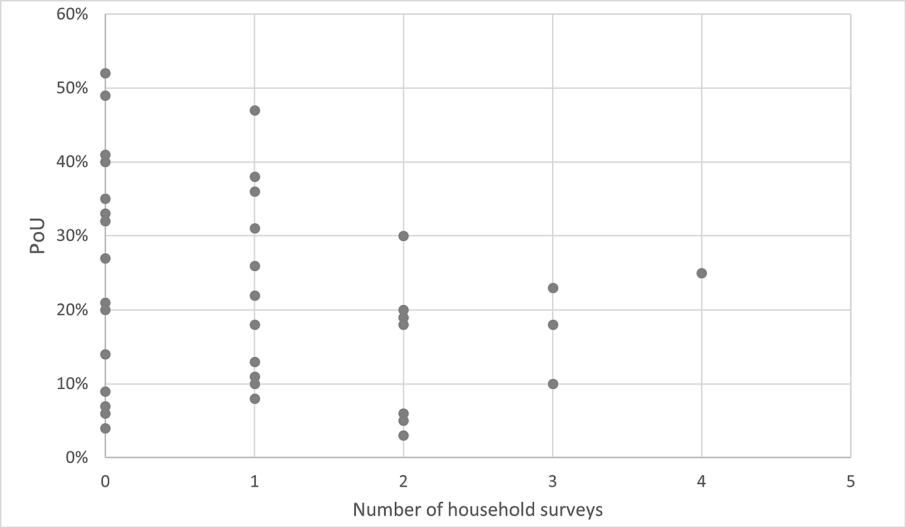

Fig. 7. Number of household surveys and PoU in LDCs. Estimates extracted from SOFI (2022). Missing data from Guinea, Burundi, Burkina Faso, Eritrea, Mozambique, Somalia, South Sudan, Tuvalu, Uganda.

food security are thus becoming increasingly integrated.

4.5. The current data basis for determining the PoU

The increasing availability of survey data produced by different international agencies and national authorities has been a crucial enabler of the international estimates of the PoU. However, getting access to sufficient survey data remains a significant challenge for FAO. If China lacked updated socioeconomic survey data for two decades, how can we trust that the data basis is much better for other countries? Estimating global undernutrition will always be very difficult. It is therefore particularly important that estimates are publicly transparent with regards to their exact estimation technique and data basis.

FAO in the recent SOFI reports gives a very general mathematical formula for its modelling (see equation 1). It has defended the MDG reversal by pointing out that new data had revealed so far unknown progress in efforts against hunger, but the sources of these data and the basis for their calculation were and still are unavailable for public scrutiny.[4] This is particularly the case for the household survey data used to estimate the CV|y, which are mostly carried out and owned national governments.

FAO has made progress on data transparency in recent years. It for instance publishes some aggregated information on household surveys. In 2022, the agency stated that it uses 118 surveys from 60 countries to calculate the socioeconomic distribution of intake (FAO et al., 2022).[5] The agency does however not publish complete lists of which surveys are used, what kind of surveys they are, their sample size, or when they were undertaken. This lack of transparency breaks with the recommendations of a recent report authored by the High Level Panel of Experts on Food Security and Nutrition for international organizations and other relevant actors to '*comply with open access principles for data analysis and tools, ensuring access to and reproducibility of relevant research results*' (HLPE-CFS, 2022).

The household data are particularly scarce for countries that are highly food insecure. FAO has survey data for only 24 out of 46 countries commonly regarded as Least Developed Countries (LDCs), which tend to be the worst affected by food insecurity. Furthermore, much of the LDC data is dated. Ten of the countries solely have data from 2005 or before, including populous countries such as Zambia and Venezuela. For six of these countries, FAO only has access to survey data that is older than the Chinese household survey data were at the time of the revision (Cafiero et al., 2020). The average sample size for surveys from LDCs used to calculate the CV|y is furthermore significantly smaller at 11 360 households compared to the average of 15 626 for all surveys.

Fig. 7 visualizes the level of food security in LDCs and FAO's access to household data. As shown, the countries with the highest levels of food insecurity tend to have very scarce access to household surveys. This is also evident if we look at specific examples: Out of the ten countries with the highest measured PoU in SOFI (FAO et al., 2022), FAO has survey data for only Haiti, Liberia, and Rwanda with a single survey each. Only Rwanda in turn has survey data that is less than 15 years old. Haiti's data is from 1999, the same year as the survey data used for China before the revision (Cafiero et al., 2018). The legibility provided by the PoU is thus founded on much less data for the countries that have the most acute need of food security aid and intervention, providing another clear argument for greater transparency and facilitation of reproduction of research results.

5. Discussion

The PoU has for a long time been one of the most prominent global development indicators. In the coming section, we discuss what kind of legibility it has offered modern societies. This discussion takes the historical account of its technical development outlined in the previous section as its starting point.

5.1. The right narrative

The significant revisions of the PoU in recent decades question the integrity of the model's estimates. For the dramatic MDG reversal of hunger estimates, part of the explanation could be that the PoU has become a crucial advocacy tool. This makes it important for the indicator to support the right story at the right time.

In the turmoil of the food price and financial crisis, the important and opportune story was one of record hunger that urgently needed to be

[4] In its own metadata, FAO only marks whether estimates are produced by itself, official sources, other international actors, are not available or have not been published (FAOSTAT, 2022).

[5] This excludes FIES surveys, which are used to estimate CV|y if the preferred household survey data on food consumption, income or expenditure is not available.

addressed and relieved. At the end of the MDG-era it was one of global progress led on by the UN and the international community. The trend of increasing hunger was at the time not in line with the World Bank's poverty indicator which declined during the MDG period (Pogge, 2016). As the sun set on the MDGs and it was time to judge what progress had been made, the very recent narrative of crises and a decades-long consistent rise in undernutrition was entirely discarded by technical adjustments. They brought the hunger and poverty-estimates into line and bolstered a narrative of global progress in the era of the MDGs. According to Pogge (2016), this alignment was a key move in legitimizing broad UN development efforts as well as a neoliberal political order by changing the PoU's lens to harmonize hunger trends with poverty numbers. Access to new survey data from China in 2020 meanwhile enabled FAO to provide verification of the Chinese government's narratives of social progress under authoritarian rule. The year after the revision, President Xi Jinping publicly announced that extreme poverty had been eradicated in China, with implicit backing from UN statistics (BBC, 2021).

The three greatest shifts in PoU estimates have since the start of SOFI occurred in the wake of significant data updates and methodological tweaks. The provision of Chinese survey data was the main factor in the most dramatic revision of SOFI estimates to date, driving a global reduction of the number of undernourished by over 16 percent (FAO et al., 2019; FAO et al., 2020). The dramatic increases in projections of SOFI (FAO and WFP, 2009) to over 1 billion undernourished on a backdrop of the financial and food price crisis was fueled by an ad hoc integration of projections from USDA-modelling, causing almost 10 percent increase in the number of undernourished from SOFI (FAO, 2008b). The COVID 19-projections meanwhile pioneered greater use of FIES-estimates in calculating the PoU in SOFI (FAO et al., 2021), recording an increase of the number of undernourished of 12 percent from SOFI (FAO et al., 2020).

Increase in hunger during a pandemic is expected, but the methodological changes needed to capture these developments highlights the struggle of the PoU to detect the big crises of the global food system. One of the causes of its inability to capture ongoing crises is the lack of incorporation of price data in the PoU's estimates (FAO et al., 2012). It remains to be seen whether the PoU will manage to represent the effects of the spiking food price inflation and turmoil in world markets following Russia's invasion of Ukraine in 2022.

5.2. A productivist lens

The PoU was important for opening up a frontier of *global legibility* for hunger. The emergence of this particular mode of legibility has not just been important for states, but crucial for civil society and international organizations. It highlights how probabilistic modeling enabled new kinds of legibility, beyond the administrative counting, maps, registries, city planning and scientific practices described by Scott (1998). Global legibility for instance remains highly dependent on probabilistic sampling, as surveying the entire global population is unrealistic.

The PoU operates at a high level of abstraction, yielding only national, regional, and global estimates – the actual hungry person is replaced by undernourished populations and national averages. It says little about who the hungry are or where they are located. Due to this inability to disaggregate, the PoU can do little to guide policy at the national or local level. As a result it has done much less to enhance legibility of food insecurity for national or local decisionmakers than for agencies with global mandates and responsibilities. Its impact rather came through legitimizing communication efforts and advocacy measures. The PoU produced scientifically credible estimates and stylized facts about the problem of hunger, such as a substantial part of the world population being undernourished and most of them living in developing countries.

The indicator was from its inception a part of a productivist paradigm for agricultural development and food security. On the eve of the Green Revolution, Sukhatme (1961) provided a range of estimates of how much production would need to increase to offset or improve upon the food security situation following projected population growth. He concluded that food supplies needed to double by 1980 and triple by 2000 to support even a moderate improvement in nutrition. The PoU and the associated reports thus provided an important scientific and political legitimation of the productivist paradigm that characterized much of agricultural development in the 20th century.

The PoU is completely dependent on counting calories. Although food balance sheets in principle should include domestic production both inside and outside the agricultural sector (FAO, 2022), some types of food production are very difficult to register or measure. For example, subsistence farming, meat from wild animals, insects, home gardens, agroforestry, wild edible plants, and harvesting of indigenous edible plants are often overlooked (FAO, 2008a). They are, however, substantial sources of nutrients in many low and middle-income contexts, which agricultural statistics has historically been slow to adapt to (Hill, 1984). Different kinds of food plants can also be placed in a hierarchy of legibility. Rice and wheat are crops that have historically been easy for states to tax, whereas roots or tubers are less legible for the state (Scott, 2010). So are mixed crops, which are more difficult to measure than monocrops (Hill, 1984). As mentioned above, estimates of food waste at the retail levels have become integrated in the PoU. This is also the case for waste at the household level (FAO et al., 2020, p. 202). Losses during pre-harvest and harvest stages are however not included (FAO, 2008a; FAO, 2019).

The PoU is also productivist in the sense that quantified calories by construction link energy input to output, connecting the intake of food to capacity for labor (Scott-Smith, 2020). As the food security discourse evolved to become more concerned with socioeconomic access to food, FAO developed its undernourishment estimation to better account for this dimension of the phenomenon by including and refining estimates of the distribution of intake of calories in the population.

As Scott (1998, p. 12) points out, creating legibility tends to require the creation of simplified objects that replace complexity. The greater the complexity of the systems represented through numbers, the greater reduction of complexity is required to facilitate quantification. The knowledge and governance effects of measurement (Merry, 2016), are therefore made extra potent through the immense complexity of global issues. This is also the case for global measurement of hunger.

The narrow focus on caloric undernourishment thus requires a bracketing that keeps many variables in the food system out of sight. A prime example of this is the *sustainability* dimension of food security, which is becoming increasingly important in food security discourse (Westengen & Banik, 2016; HLPE-CFS, 2020). The other new food security dimension proposed by the HLPE, *agency*, is also not captured (Iversen, Westengen, & Jerven, 2023). The PoU has previously been criticized for framing food insecurity as an issue of supply and production, marginalizing complex socio-economic determinants, human development, and human rights priorities (Fukuda-Parr & Orr, 2014). Another crucial aspect of food security that disappears when using the PoU is malnutrition in terms of micronutrient deficiencies (Pogge, 2016). The quantification of global undernutrition thus provides an illustrative case: it shows that rendering society legible requires replacement of complex human beings and systems so that they will fit neatly into the idealized schemes of statistical models.

6. Conclusions

Measuring global hunger is fraught with radical uncertainty along several axes. The global legibility provided by the PoU has repeatedly been changed by technical adjustments that have shifted and inverted crucial narratives of worldwide hunger in modern times. The indicator has been unable to capture recent crises, prompting a series of extensive and at times ad hoc revisions of its own estimation technique. Trend lines have not just shifted upwards or downwards from year to year but

flipped within short time frames to underpin wildly different narratives of international hunger for the same periods of history. The data basis for its estimation is moreover highly fragmented, as is well illustrated by how the countries that suffer the highest measured undernutrition have the poorest data basis. This instability in the estimates of the PoU show the need for greater transparency and facilitation of reproduction of results. There is fortunately substantial and easily attainable potential for improving transparency by disclosing to the public more information on what data enable the PoU's estimates, further modelling details and previous time series.

The model introduced by Sukhatme (1961) was perceived as legitimate and credible due to its advanced scientific technique. Models that are mainly used for advocacy purposes, however, also need to support the right story. The estimates of the PoU have been molded by the power dynamics and political economy that its host organization is situated in, serving to justify the position and ambitions of FAO. As such, the PoU is also an indicator of the changes in the agri-food development agenda over the last 60 years, from the public sector based Green Revolution of the 60s and 70s to the rise of the neoliberal agenda in the 80s and the last decades' private sector focused New Green Revolution (Friedman & McMichael, 1989; McMichael, 2009; Sumberg & Thompson, 2012). FAO's choice of how to 'see' the world is tightly connected to and has been an efficient tool to serve its specific needs as an evolving organization.

When measuring caloric undernutrition, it is therefore worth considering exactly what aspects of food security fall outside FAO's field of vision. Two examples are the elements of democratic agency and sustainability, which are rapidly gaining importance in food policy and science (HLPE-CFS, 2020; HLPE-CFS, 2022). By serving as a legitimating tool for promoting productivism, the map provided by the PoU has shaped the terrain and contributed to make it more visible through promoting types of agricultural modernization that tends to lead to production in bigger units. These are in turn more easily measured by caloric accounting.

Indicators can also have indirect effects on governance, such as the substitution of broader political goals with an indicator that is intended to monitor its progress (Merry, 2016). The PoU risks providing perverse incentives by nudging governments toward an emphasis on the production and intake of more calories, as increasing caloric availability is likely to be perceived as a more easily attainable policy goal than reducing socioeconomic inequality. Insufficient national availability of food is generally not considered the main reason for undernutrition or famine (De Waal, 2017; Sen, 1981). The main reason for hunger is rather poverty (Svedberg, 1999).

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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