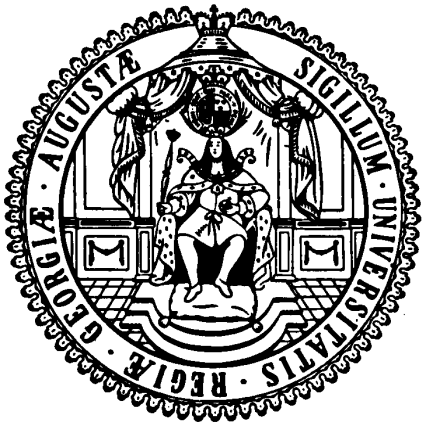
Courant Research Centre

'Poverty, Equity and Growth in Developing and Transition Countries: Statistical Methods and Empirical Analysis'

Georg-August-Universität Göttingen
(founded in 1737)



Discussion Papers

No. 293

The global income gap to a healthy diet

Jonas Stehl, Lutz Depenbusch and Sebastian Vollmer

September 2023

Platz der Göttinger Sieben 5 · 37073 Goettingen · Germany
Phone: +49-(0)551-3921660 · Fax: +49-(0)551-3914059

Email: crc-peg@uni-goettingen.de Web: http://www.uni-goettingen.de/crc-peg

The global income gap to a healthy diet

Jonas Stehl[1], Lutz Depenbusch[2], Sebastian Vollmer[1]

[1] University of Göttingen [2] Misereor

September 2023

Abstract

Access to a healthy diet is a fundamental human right, yet a significant portion of the global population faces barriers to realizing this right. Conventional poverty metrics are designed to adequately capture caloric needs but they are inadequate for capturing other essential nutritional requirements. We propose national poverty lines based on the cost of a healthy diet and explore their key metrics such as headcount ratios and the poverty gap. According to these poverty lines 2.8 billion people were poor in 2021 and US$ 2.546 trillion per year would be needed to lift them out of poverty. Applying specifications aligned with FAO reports these numbers rise to 3 billion people and US$ 2,995 trillion per year. This is in contrast to 648 million people who are considered to live in extreme poverty according to the World Bank's conventional poverty lines.

Key words: Poverty, Welfare, Healthy diets
JEL Classification: I14, I15, I32, N30

1 Introduction

In September 2022, the World Bank updated their international poverty line (IPL) to US$ 2.15 per person per day, following the release of the new 2017 Purchasing Power Parities (PPPs). Based on these revised estimates, about 648 million individuals were living in extreme poverty worldwide in 2019. To elevate all people globally out of extreme poverty, about US$ 432.7 million would be required. These key metrics of global poverty have been extensively examined. However, recent studies have pointed out the limitations of these poverty benchmarks in encompassing the means necessary for individuals to live an active and healthy life (Allen, 2017; Herforth et al., 2020; Mahrt et al., 2022), a fundamental aspect of food security as defined by the FAO (FAO, 1996). Specifically, the designated income threshold does not allow the affordability of nutritious foods and adequate micronutrient intake, which are essential for preventing deaths and diseases, as well as promoting physical and mental well-being (Willett et al., 2019). We argue that the contemporary concept of basic needs should encompass the affordability of healthy diets to sustain long-term health and introduce novel nutrition-sensitive national poverty lines and examine both the population living below these thresholds and the severity of poverty associated with them.

The international poverty line has played a pivotal role in assessing the prevalence of extreme absolute income poverty and monitoring progress in poverty elimination, as declared in the Millenium Development Goals and the Sustainable Development Goals (SDGs), and has shaped discussions in both academic and policy circles to alleviate global poverty. The IPL is derived from the national poverty lines of the poorest countries (Ferreira et al., 2016; Ravallion et al., 2009). In 1990, a group of researchers jointly with the World Bank determined the national poverty thresholds for several of the world's most impoverished countries. These benchmarks were then converted into a uniform currency using 1985 PPP exchange rates (Ravallion et al., 1991). Six of these severely impoverished countries had a poverty threshold of around US$ 1 per person per day. This finding served as the basis for the establishment of the initial IPL set at one dollar per day (Ravallion et al., 1991). In 2008, the US$ 1.25 poverty line was calculated by taking the mean of PPP-adjusted national poverty lines of 15 of the poorest countries (Ravallion et al., 2009). In 2015, these 15 poverty lines were updated from 2005 PPPs to 2011 PPPs yielding a value of US$ 1.88 which resulted in the US$ 1.90 poverty line (Ferreira et al., 2016). Following the release of 2017 PPPs in 2020, the IPL was updated to US$ 2.15 (Jolliffe et al., 2022). Thereby, multiple adjustments suggested by Jolliffe and Prydz (2016) were made that were to harmonize national poverty lines and to ensure consistency. Developed by national statistics offices, national poverty lines often exhibit variations in several key aspects such as differences in the application of adult equivalents and per capita calculations and the use of outdated or more recent Consumer Price Indices (Jolliffe and Prydz, 2016). To make these adjustments, the harmonized poverty lines approach matches national poverty rates with income/consumption distributions (Jolliffe et al., 2022). Further, the sample of countries was increased from 15 to 28

(all low-income countries (LICs) with available data) and the IPL was calculated using the median instead of the mean to prevent the lines from being overly influenced by outliers (Jolliffe et al., 2022).[1]

Although the poverty line has been adapted to new PPPs and has been subject to several other changes, the approach of measuring poverty has remained largely the same. By relying on national poverty lines, the international poverty line depends on countries' own judgments of what is considered poor. In developing countries, the predominant methods used to assess poverty are the food-energy-intake method and the cost-of-basic needs (CBN) method (Ravallion, 2010). The food-energy-intake method concentrates solely on one aspect, specifically the nutritional status, gauged through food-energy intake in relation to established caloric norms. Its objective is to identify the expenditure or income level at which food-energy intake barely meets predetermined requirements for sustaining good health and normal activity levels (Ravallion, 2010).

The CBN method defines a consumption bundle deemed adequate for basic consumption needs and subsequently calculates its cost.[2] This approach traces back to Rowntree's pioneering study in 1901, which investigated poverty in York, England (Rowntree, 1901). Rowntree established a poverty line as a minimum weekly sum required 'to obtain the minimum necessaries for the maintenance of merely physical efficiency.' His poverty line incorporated necessities such as food (in calories), shelter, clothing, light, and fuel. Thus, in contrast to the food-energy-intake method, non-food items are also included to ensure basic non-nutritional functions. This approach was later refined and became the primary method for calculating national poverty in low- and middle-income countries (Ravallion, 2010).

In the 1990s, when the CBN approach gained uptake, global hunger was widespread, which made it essential to focus on achieving physiological survival requirements. For instance, in China 72 percent of the population were in 1990 according to these estimates (World Bank, 2023). Globally, more than one out of three people could not afford basic caloric needs (World Bank, 2023). Hence, the cost of basic caloric needs was a fitting target during that time albeit it is not sustainable in the long-term. Over the years, there has been a substantial reduction in poverty and hunger levels, with a significant decrease of almost 30 percentage points since 1990 (World Bank, 2023). However, a large proportion of the global population remains deficient in essential macro- and micronutrients, particularly children. More than two billion people globally are affected by micronutrient deficiencies, also known as hidden hunger (HLPE, 2017; Institute of Medicine (US), 1998; Swinburn et al., 2019). Progress in the reduction of hidden hunger has been comparatively

[1] The previously used 15-country approach has been criticized due to its sensitivity to small changes in the data (Deaton, 2010; Klasen et al., 2016; Reddy and Pogge, 2009).

[2] The poverty line is typically calculated by computing the expenditure needed by individuals in the lower-income bracket to meet pre-determined daily calorie intake and, subsequently, incorporating an allowance for non-food expenditure which is determined based on either the average non-food expenditure of households whose food expenses match the food poverty line or those whose overall expenses align with the food poverty line (Klasen et al., 2016).

low over the past decades (Gödecke et al., 2018). In addition, the Sustainable Development Goal "Zero Hunger" encompasses access to nutritious food for all and the elimination of all forms of malnutrition by 2030. Together with the emergence of overweight and obesity in low- and middle-income countries, this sets a 'new nutrition reality' as Popkin et al. (2020) describe it, which has shaped our understanding of basic needs.

Townsend (1979) early recognized that essential needs are not necessarily fixed and should be continuously adjusted and expanded in response to evolving societal dynamics. We concur with this view and argue that poverty estimates need to evolve to reflect changing standards of minimum needs. Many people globally lack the financial means to afford sufficiently nutritious foods. In addition to meeting energy needs, poverty lines should also ensure the fulfillment of nutritional requirements and recommendations regarding the intake of proteins, vitamins, and minerals, to prevent diet-related diseases such as anemia. Suboptimal diets represent the leading risk factor in the global burden of disease (Afshin et al., 2019; Murray et al., 2020). Healthy diets play a crucial role in mitigating various forms of malnutrition (Arimond and Ruel, 2004; Hawkes et al., 2020; Headey et al., 2018) and safeguarding individuals against non-communicable diseases such as diabetes, heart disease, stroke, and cancer (Afshin et al., 2019; Willett et al., 2019). Intake of nutritious foods is not only important for the prevention of deaths and diseases but also promotes physical and mental well-being, and contributes to optimal growth and development of children (Willett et al., 2019).

In our approach, we deviate from the traditional cost of basic needs method, and instead, we set our poverty threshold based on nutritional standards for optimal health. To achieve this, we need to identify the most cost-effective combination of food items that simultaneously meets nutrient requirements. The concept of least-cost diets can be traced back to Stigler (1945) who sought to determine a cost-minimizing food bundle to satisfy specific nutritional needs in the United States. However, Stigler acknowledged that these diets were not socially acceptable, even for the most impoverished Americans, a finding later supported by Smith (1959). Nutritionists ascertained that least-cost diets often lack diversity (Masters et al., 2018). As a result of Stigler's and Smith's conclusions, the least-cost approach lost favor in the literature until 2017 when Allen (2017) employed linear programming to compute country-specific least-cost diets while maintaining globally fixed nutrient requirements. These diets are valued based on local prices, and he also incorporates expenditures on a fixed set of non-food items, including housing costs. However, Allen's linear programming solutions also indicate limited variation compared to actual consumption patterns, being high in grains and fats and low in animal-source foods, fruits, and vegetables, aligning with the findings of Stigler and Smith (Ravallion, 2020). Least-cost nutrient-adequate diets may also face social acceptability challenges in countries today, as consumption is influenced by various factors, such as social roles and local communities.

Addressing the concerns of impracticality and social acceptability, the FAO et al. (2020) incorporates local preferences and tastes through the utilization of national food-based di-

etary guidelines (FBDGs) (Herforth et al., 2020). As the choice of products is limited to those in local consumption baskets, there is a second mechanism making sure the product choice is realistic. This allows the estimation of poverty lines that account for local prices and availability, and capture individual preferences and aspects of consumption that are pertinent to social inclusion (Ravallion, 1998, 2015). This approach has revived the applicability of least-cost diets. Consideration of national nutrition authorities' recommendations for estimating least-cost diets has been undertaken globally Herforth et al. (2020), as well as in specific regions such as for South Asia (Dizon et al., 2019), Myanmar (Mahrt et al., 2019), and India (Raghunathan et al., 2021). This approach ensures that the least-cost diets align with local contexts and preferences, making them a more relevant and feasible yardstick for minimal realistic diet costs.

In this paper, we aim to develop nutrition-sensitive poverty lines that build on the CBN approach but incorporate a modern understanding of essential needs that is replacing caloric sufficiency with healthy diets. According to these lines, individuals not classified as poor can access and afford locally available and preferred food options, enabling the fulfillment of nutritional needs and dietary recommendations for an active and healthy life. These poverty lines encompass essential aspects of global poverty welfare measures, specifically focusing on nutritional status and social inclusion, aligning with the principles emphasized by Ravallion (2020). Further, we explore key metrics of these poverty lines such as the number of people deemed poor, and the income needed to lift all people globally above these poverty thresholds.

2 Concept and data

2.1 Method

We build on the CBN approach but define our poverty threshold at a level above which individuals have sufficient financial means to nourish themselves healthily and to satisfy other non-food essential needs. In addition to that, we take differences in nutritional requirements by different populations into account by applying demographic scaling factors. Given a household budget constraint, we calculate the nutrition-sensitive poverty lines as follows:

$$poverty\,line_{c,y} = \frac{CoHD_{c,y}}{FES_c} \times DSF_c \tag{1}$$

with c corresponding to the country and y to the year. *CoHD* is the expenditure on food, the cost of a healthy diet, *FES* is the food expenditure share, and *DSF* a demographic scaling factor.

2.2 Healthy diets

We use Cost of a Healthy Diet (CoHD) from the FAOSTAT Cost and Affordability of a Healthy Diet indicators. These data indicate the costs of the least expensive locally available foods to meet the requirements for a healthy diet, as defined in local FBDGs and were introduced in the FAO et al. (2020).

A healthy diet complies with the nutritional requirements outlined in dietary guidelines, encompassing sufficient variety and quantity across and within food groups to achieve adequate nutrient intake. To construct a Healthy Diet Basket (HDB) that reflects diet recommendations for people around the globe, Herforth et al. (2022) quantified ten national FBDGs from diverse world regions (*see Table A.1*). The final food group quantities in the HDB are the median amounts of each food group across the ten FBDGs scaled to meet the dietary energy intake target of an adult woman of 2330 kcal per day from locally available items from six food groups: starchy staples, animal source foods, legumes nuts and seeds, fruits, vegetables, and oils (Herforth et al., 2022).

The cost of a healthy diet is calculated using retail food consumer prices from the World Bank's International Comparison Program (ICP) to identify the most affordable items available in each country that concurrently meet the HDB quantities of each food group. For each country, 11 least-cost food items are selected into the basket.[3] To calculate the cost of each food item, the cost per quantity containing the required energy content for the item's food group is divided by the number of items in the group. Consumers can substitute food items for more cost-efficient items within the food group while keeping energy balance: $Cost = \sum_{m=1}^{6} min \sum \{\sum_{n=1}^{N} p_{m,n} q_{m,n}\}$, where m is the food group, n the food item within the food group, p the price of food item n in food group m, and q the energy content of each food group within the Healthy Diet Basket divided by the number of food items within this food group m (Herforth et al., 2022).

One substantial benefit of utilizing CoHD data lies in the avoidance of establishing a universally comparable food basket, which would prove unrealistic in many countries. Instead, we leverage country-specific food baskets that are both realistic and globally comparable.

2.3 Income distributions

We obtain data on incomes and income distributions from the Poverty and Inequality Platform (PIP) of the World Bank using the pip Stata command (Castañeda, 2023; World Bank, 2023). This data is derived from country-level household survey data collected by the National Statistics Offices. In some countries, income is used to determine household economic status, while in others, consumption expenditure is used. To ensure comparability across

[3]Two for starchy staples, three for vegetables, two for fruits, two for animal source foods, one for legumes, nuts and seeds, and one for oils and fats. The selection of 11 items is in accordance with the recommendations of FBDGs (Herforth et al., 2020).

countries and time periods, the data was deflated using Consumer Price Indices and adjusted for PPPs.

The World Bank released in their 2023 annual PIP update the poverty data for 2020 and 2021 only for countries with available survey data. These countries are exclusively in Europe & Central Asia, Latin America & Caribbean, or other HICs. No data is available for countries in East Asia and Pacific, Middle East and North Africa, South Asia, and sub-Saharan Africa. Due to the COVID-19 pandemic, it is difficult to predict actual values as poverty would be substantially understated. We utilize estimates for the remaining countries, which were used in Mahler et al. (2022) and provided to us by the World Bank.[4] Given that the poverty data for countries without survey data is based on the three poverty lines (US$ 2.15, US$ 3.65, US$ 6.85), we inter- and extrapolate poverty gaps for the nutrition-sensitive poverty lines. We must stress that these figures are subject to a comparatively high degree of uncertainty, especially since these estimates are made for predominantly lower-income countries where prices, incomes, and thus poverty are often subject to large fluctuations.

2.4 Non-food expenses

To determine a nutrition-sensitive poverty line, we consider both food and non-food expenditures. Besides spending on food, households also allocate a portion of their income or expenditure towards non-food items such as housing, education, health, transportation, and clothing. FAO (2022) assumes 52 percent as the proportion of expenditure allocated to food, based on the average percentage of income spent on food in LICs. Thus, if a healthy diet costs US$ 3.00, the per capita income of a household needs to be at least US$ 5.77 to afford a healthy diet while also addressing non-food needs.

However, there is substantial variation in non-food costs between countries (Headey et al., 2023). They increase with rising incomes and are additionally affected by other factors such as expenditure on warm clothes and heating in colder climates (Allen, 2017). Headey et al. (2023) show that non-food costs decrease as diet costs increase, on average. Neglecting this heterogeneity in food expenditure shares would considerably affect estimates of the global income gap to a healthy diet. The upper bound estimates of the FAO (2022) are derived from the average expenditure share within each country income group (14% for HICs, 27% for UMICs, 38% for LMICs, 52% for LICs). To estimate households' shares of income spent on food, the FAO (2022) makes use of national accounts expenditure data from the World Bank's International Comparison Program.

However, we are particularly interested in the food expenditure shares of the poorest income segments to accurately reflect non-food expenditure on other essential goods. For this reason, national accounts data is not suitable as it does not adequately represent the

[4] In future updates, the global income gap will be revised using publicly available poverty data, which is expected to become available for a greater number of countries in the coming years with increasing availability of household surveys and thus a lower degree of uncertainty after the COVID-19 pandemic.

expenditure of households around the poverty line.[5] Especially in high-income countries (HICs), where households around the poverty line only represent a fraction of the population, ICP food expenditure shares will underestimate the true food expenditure shares of these households. Ideally, one would identify the minimum non-food budget by estimating the share of household expenditure spend on non-food items for households near the poverty line (Ravallion, 2010). However, this is hardly feasible due to its requirement of household consumption survey data for a wide range of countries. For this reason, the FAO et al. (2020) used food expenditure data of the bottom consumer segment (below US$ 2.97 per capita a day using 2010 PPP conversion factors) from the World Bank's Global Consumption Database (WB-GCB) (World Bank, 2010). The average FES among low-income countries was estimated at 63 percent. This approach was discontinued as this database is not regularly updated and the most recent data originates from household surveys between 2000 and 2010 (Herforth et al., 2022).

Hence, we confront a trade-off between using data that represents the food consumption expenditures of the entire population and relying on outdated data that may not accurately capture current food expenditure shares. To address this, Allen (2017) developed an approach that estimates non-food expenditures based on the minimum costs of housing, fuel, lighting, clothing, and soap. This approach was further expanded by Headey et al. (2023) for more countries and more recent ICP data. However, these estimations do not consider expenses for basic health care or education and therefore do not align with our understanding of basic needs.

An alternative approach to estimating the costs of daily basic needs has been proposed by van de Ven et al. (2021). Their methodology takes into account various expenses, including food expenditures, non-food expenditures, and unforeseen costs. Specifically, the food costs encompass the expenses associated with a low-cost nutritious diet as well as miscellaneous food costs. The non-food costs cover housing expenses (including owner-occupied housing and other non-food utilities, maintenance, and taxes), basic healthcare and education, and an additional allocation for other goods and services such as clothing, footwear, household equipment, transportation, and communication (van de Ven et al., 2021).

In our approach, we use actual expenditure data instead of estimating non-food expenditure. We augment and update the WB-GCB data by obtaining food expenditure information of the poorest income segment of 107 countries. This information is sourced from reports and studies that rely on nationally representative surveys, or alternatively, we calculate it using the available data ourselves. Most of the data is obtained from national statistics offices.[6]

[5] For instance, South Africa reports national accounts food expenditure shares of 16.5 percent. However, in reality, poor households spend close to 40 percent of their consumption on food.

[6] In cases where both WB-GCB and other data was missing, we approximated it by using the average food expenditure shares within the corresponding World Bank region and income group. If no comparison data was available, we used the mean of the same income group.

As incomes rise, individuals tend to allocate a larger proportion of their resources to non-food goods. In high-income countries, the poorest income quintile spends an average of 21 percent of their income on food. In upper-middle income countries, the poorest segment already devotes 47 percent of their income to food, while in lower-middle income countries, this figure rises to 57 percent, and in low-income countries, it reaches as high as 63 percent, the same as calculated for the FAO et al. (2020).[7]

2.5 Demographic scaling factors

To consider differences in physical composition and nutrient requirements between countries, we use demographic scaling factors (DSFs) developed by Headey et al. (2023).[8] The CoHD data is based on the caloric needs of a 30-year-old neither pregnant nor lactating physically active woman (Herforth et al., 2020). However, energy requirements vary by age and sex. While the sex-structure of different countries only varies marginally, demographic differences are considerable. Energy needs of young children are lower which means that diet costs are over-estimated for relatively younger populations (Boom et al., 2015; Headey et al., 2023). Indeed, cost and affordability of meeting nutrient requirements vary sizably when considering variations by age, sex, and reproductive status (Bai et al., 2022). Boom et al. (2015) observed that, on average, the food poverty lines calculated on a per-capita basis are approximately 70 percent of the value of the equivalent line adjusted using adult equivalents.

The total energy requirement in each country is determined by summing the average human energy requirements for seven sex-specific age categories and multiplying them by the corresponding population. The average energy requirement of a country is obtained by dividing the total requirement by its population. To provide a relatable comparison, the average energy requirement is divided by 2,500 kcal, the average energy needs of a 30-year-old woman weighing 60 kg. On average, the global energy requirement is approximately 7 percent lower than the estimated energy needs of a 30-year-old woman. Notably, some populous and low-income countries, such as Nigeria (0.88) and Ethiopia (0.89), have relatively low scaling factors leading to lower diet costs.

2.6 Setting the parameters for different poverty approaches

We develop four distinct scenarios that vary by assumptions on food expenditure shares and demographic scaling factors to get lower and upper bound estimates of the global income gap. Scenario 1 adopts a food expenditure share of 52 percent and no DSFs, aligning with the approach used in the FAO et al. (2020). In scenario 2, we use country-specific food

[7] The highest food expenditure shares are observed in Honduras (79 percent) and Sao Tome and Principe (78 percent). The smallest proportion of income that the poorest quintile spends on food is observed in Norway (11.4 percent) and the Netherlands (11.8 percent).

[8] We approximate them for 14 missing countries by averaging DSFs of the respective world region and income group.

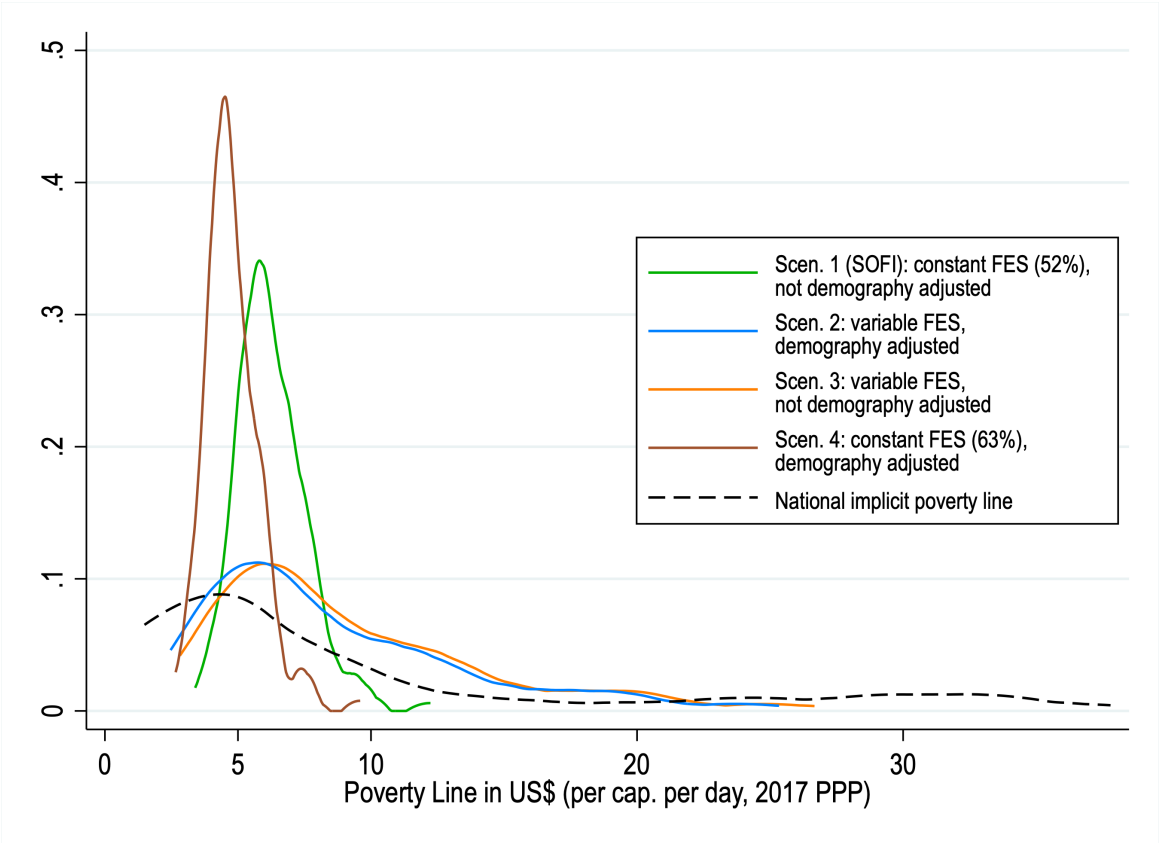
expenditure shares and apply the formula above. Scenario 3, the upper bound, corresponds to scenario 2 but excludes adjustments for demographic scaling factors. Scenario 4 utilizes 63 percent as the proportion of consumption spent on food, which is the average of all LICs, and applies DSFs. This represents the lower bound scenario.

3 Results

3.1 A comparison of poverty lines

Figure 1 presents the distribution of nutrition-sensitive poverty lines of all four scenarios in 2021, along with the harmonized national poverty lines[9] that serve as basis for the US$ 2.15 international poverty threshold. All data is expressed in US$ in 2017 PPPs. For our analysis, we use a sample of poverty lines from 139 countries.[10]

Figure 1: Density of Poverty Lines



The spectrum of poverty lines anchored to constant food expenditure shares (scenarios 1 and 4) exhibits a relatively narrow range, spanning from US$ 3.39 and US$ 2.66 (United Kingdom) to US$ 12.24 and US$ 9.59 (Jamaica). Conversely, poverty lines based on variable

[9]For a few countries, the harmonized national poverty lines, developed by Jolliffe et al. (2022), date back to the early 2000s.

[10]The sample of harmonized national poverty lines used from Jolliffe et al. (2022) contains 133 countries.

food expenditure shares present a notably broader range. Under the demographic adjustment scenario, poverty lines begin at US$ 2.47 for the Democratic Republic of the Congo, extending up to US$ 26.67 for Norway. The highest threshold of the harmonized original national poverty lines is at US$ 37.80 also pertaining to Norway.

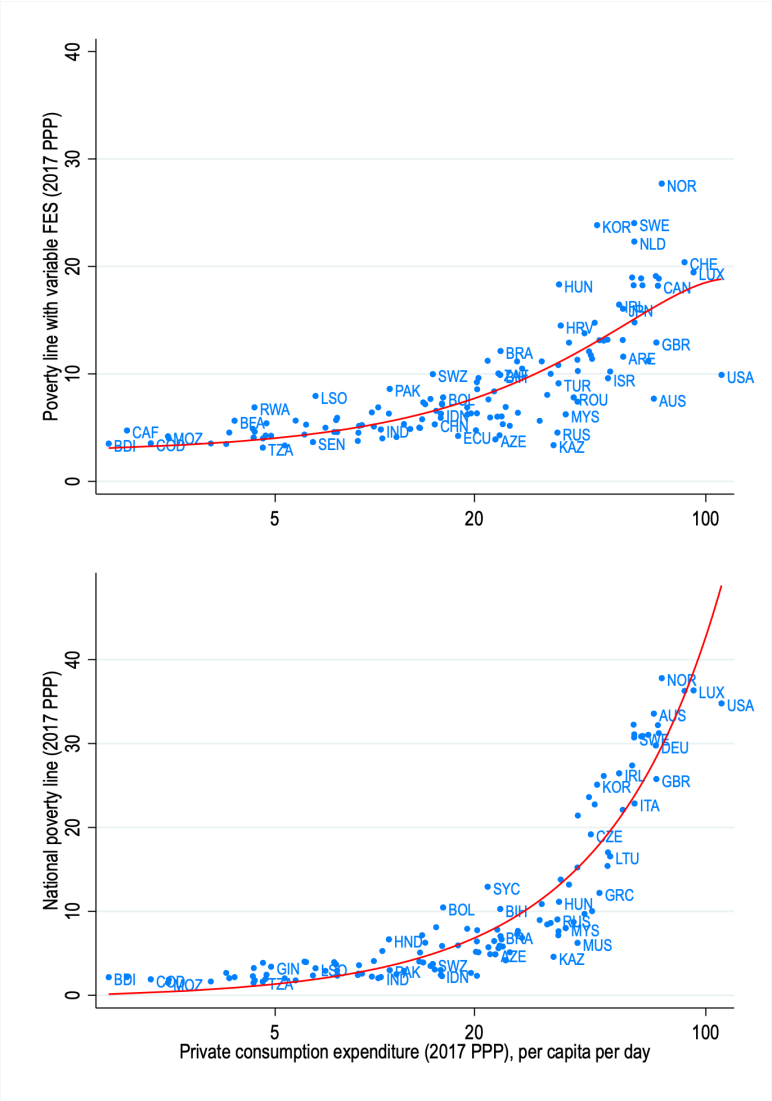
The distribution of scenarios without demography adjustments exhibit a slight shift towards higher poverty lines in comparison to their adjusted counterparts, although the overall distributional pattern remains largely the same. Particularly notable is the concentration of poverty lines with constant FES values ranging from US$ 3.5 to 7. 61 percent of all poverty lines are within ± US$ 1 of the median of scenario 1 and 70 percent are within ± US$ 1 of the median of scenario 4. On the other hand, poverty lines utilizing variable FES values display a greater dispersion, resembling the patterns observed in national implicit harmonized poverty lines. However, scenarios 2 and 3 are shifted to the right by approximately US$ 2 per person per day across most of the distribution, with lower maximum values (US$ 26.67 as opposed to US$ 37.80). For comparison, only 22 and 19 percent of poverty lines are ± US$ 1 of the median of scenario 2 and 3, respectively.

Henceforth, we will continue discussing results based on scenario 2 which incorporates variable FES and accounts for demographic composition adjustments. In section 3.5, we will delve into a comprehensive discussion of the implications arising from differing assumptions made on the parameters in the remaining scenarios.

Figure 2 illustrates the relationship between poverty lines with variables FES (upper graph), harmonized national poverty lines (lower graph), and per capita private consumption expenditure per day (on a logarithmic scale) as a measure of economic welfare in each country. Both graphs demonstrate a discernible trend where poverty lines tend to increase as mean consumption expenditure rises, indicative of a so-called 'relativist gradient' (Ravallion, 2010).

At lower levels of consumption, this relationship appears relatively flat. However, when using the full sample of poverty lines from 2017 to 2021 and limiting the sample to the poorest quartile in each year, the correlation is positive and significant and similar in size for both the harmonized national poverty lines and the poverty lines with varying FES (*see Table A.2*). Our proposed poverty lines seem to behave in a similar way as conventional national poverty lines among the poorest countries. This suggests an economic gradient in the national poverty lines which corresponds to the finding of Jolliffe and Prydz (2016) which stands in contrast with those by Ravallion et al. (1991) and Ravallion et al. (2009). As consumption levels increase, the gradient becomes markedly steeper. The 'relativist gradient' is far more pronounced for the original national poverty lines with multiple countries exhibiting poverty lines in the range of US$ 35 to 40 (*see Table A.2*). This is the result of countries with higher incomes often applying relative poverty lines. In contrast, nutrition-sensitive poverty lines tend to be lower, peaking around US$ 20 to 25. Nonetheless, both specifications indicate increasing poverty lines with increasing mean private consumption among all consumption segments.

Figure 2: Poverty lines and consumption expenditure



Note: Poverty lines with variable food expenditure shares (N = 132) in the upper graph and harmonized national poverty lines (N = 128) in the lower graph are plotted against private consumption expenditure per capita per day in 2017 (logarithmic scale). The red line depicts a quadratic fit of the data points. All data is expressed in 2017 PPPs.

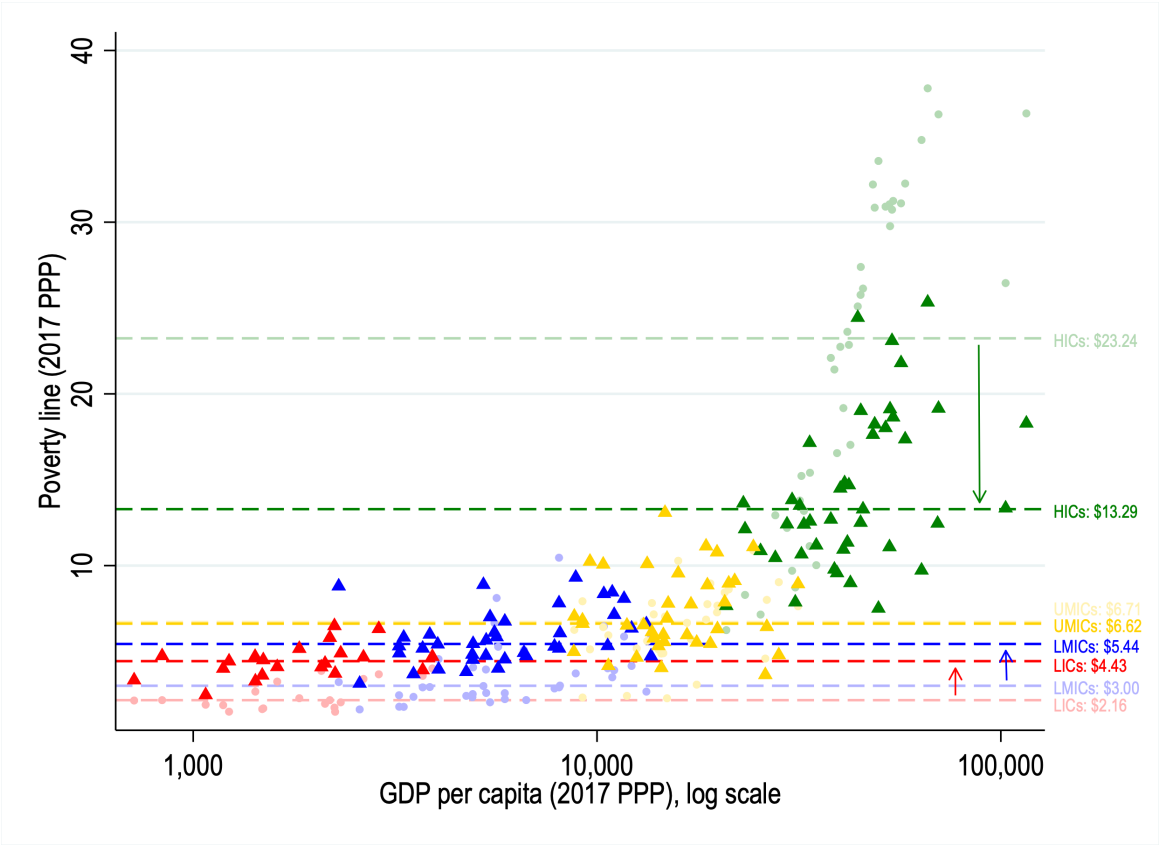
3.2 International poverty lines

In this paper, we develop poverty lines that are designed to be used as national lines for poverty measurement. In fact, one of the advantages of these lines is that they are calculated in an internationally comparable manner. However, it may be of interest to study how international poverty lines would look like if calculated in the same way as the US$ 2.15 IPL and IPLs of higher income groups (US$ 3.65, US$ 6.85, US$ 24.35).

Figure 3 provides a comparative view of global poverty lines based on established harmonized national poverty lines as in Jolliffe et al. (2022), depicted in shallow circles, and based on poverty lines with variable FES depicted in triangles. Global poverty lines are developed using the median of national poverty lines within a World Bank income group.

What emerges prominently is that poverty lines with variable FES tend to be notably higher for countries with lower incomes. If an international poverty line was developed based on the framework of our new national poverty lines, it would be positioned at approximately US$ 4.43, more than doubling the current International Poverty Line. Even in lower-middle income countries, the international poverty threshold would experience a nearly twofold increase, reaching US$ 5.44 compared to US$ 3.00 in this sample. While the poverty line for upper-middle income countries remains around a similar threshold, high-income countries would see a reduction by approximately US$ 10 to US$ 13.29. This adjustment would imply a convergence among poverty lines as depicted in Figure 1.

Figure 3: International Poverty Lines

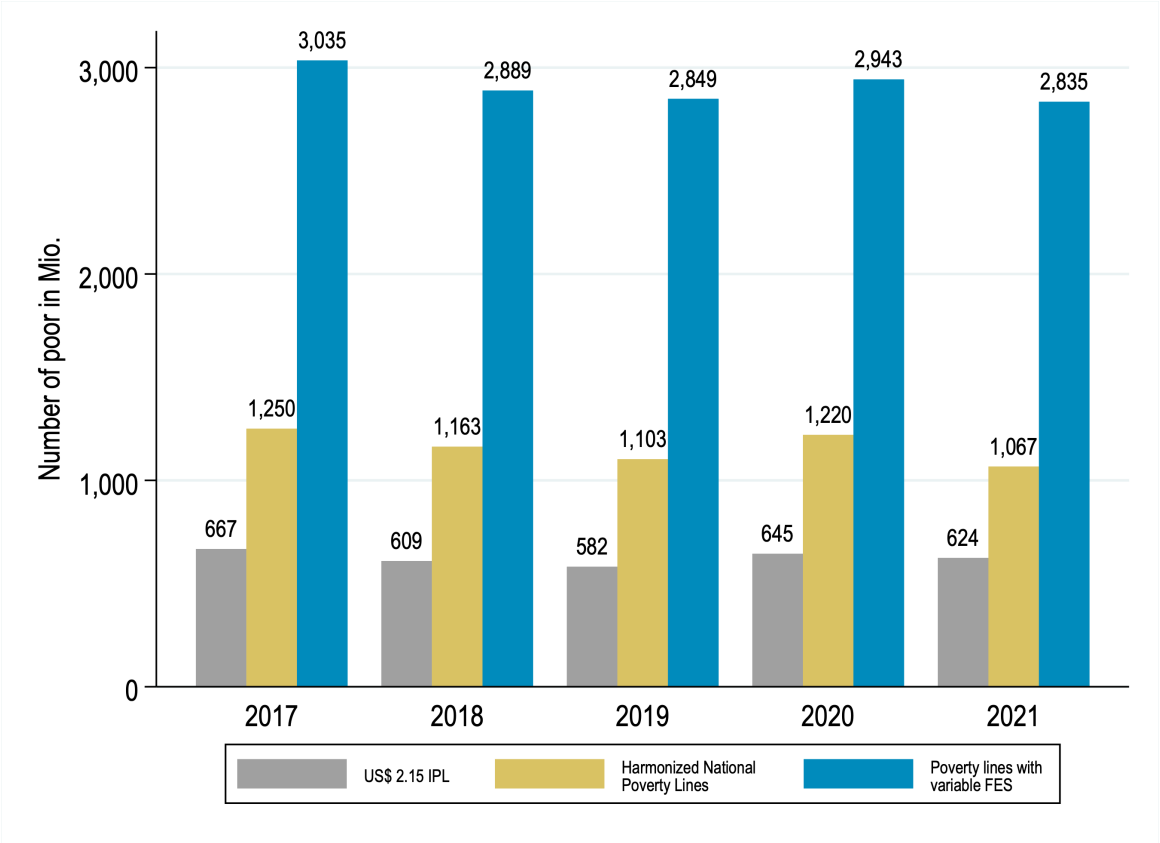


Note: This figure depicts the relationship between poverty lines with variable food-expenditure shares (in triangles) and harmonized national poverty lines (in shallow circles) and GDP per capita. The horizontal lines denote the median values of World Bank income groups in 2021 which are used to develop international poverty lines. The values from original national poverty lines may deviate from the official global poverty lines as we utilize income classifications from 2021 instead of the year the survey was conducted, and restrict our analysis to countries with available CoHD data to ensure that changes in the international poverty lines are not contingent on the inclusion or exclusion of countries. This narrows the sample of harmonized national poverty lines from 157 to 133 countries.

3.3 Global, regional, and temporal trends in the poverty headcount

Figure 4 contrasts current poverty estimates based on the US$ 2.15 IPL with poverty estimates based on national poverty lines and those calculated using the national poverty lines with variable FES presented in this paper.

Figure 4: Number of poor by Poverty Approach



Note: This figure shows the global estimates in the number of poor people according to the US$ 2.15 international poverty lines, national poverty lines, and the scenario 2 nutrition-sensitive national poverty lines. Note that for national poverty lines data is missing for six countries: Belize, Guyana, Iran, Japan, Trinidad and Tobago, United Arab Emirates.

When using national poverty lines with variable food-expenditure shares, the number of individuals living in poverty is approximately four to five times larger than the current poverty estimates and 2.5 times larger than estimates based on harmonized national poverty lines. In 2017, these estimates indicate that over 3 billion people were living in poverty. In other words, more than 3 billion people across the globe were not able to afford healthy diets and other non-food necessities. This corresponds to a global poverty rate of 42.78 percent.[11] This stands in contrast to a global poverty rate of 9.82 percent based on the US$ 2.15 IPL. To get a similar global poverty rate using the conventional approach, a poverty threshold of US$ 5.60 would need to be applied (World Bank, 2023).

[11] Note that this rate is estimate for based on the poverty and population of 139 countries. Some of the countries for which no data is available such as Afghanistan, Somalia, South Sudan, or Venezuela may experience relatively high poverty rates.

In general, all approaches to measuring poverty exhibit a similar global trend over time. Following a slight reduction until 2019, the number or poor began to rise again, surpassing 2018 levels as the COVID-19 pandemic hit. In 2021, the global poverty estimates stand at 2.8 billion while the poverty rate stands at 38.46 percent.

Figure 5 plots the development of poverty based on poverty lines with variables FES across all world regions over time. South Asia stands out as the region with the highest number of individuals living in poverty, followed by sub-Saharan Africa and East Asia and Pacific. Other world regions exhibit comparatively lower poverty levels.

South Asia consistently witnessed a decline in poverty throughout the period, including during the times of the pandemic. In stark contrast, sub-Saharan Africa experienced a continuous increase in poverty rates (*see Table A.4*). While there is not abrupt change in 2020 for both regions, East Asia and Pacific experienced an increase of approximately 78 million people living in poverty between 2019 and 2020. All other world regions did not experience substantial trends within this period. However, it may be worth noting that poverty in Europe and Central Asia seemed to decrease, whereas Latin America and the Caribbean and Middle East and North Africa faced an increase in the number of people living in poverty over time.

Figure 5: Number of poor by World Region

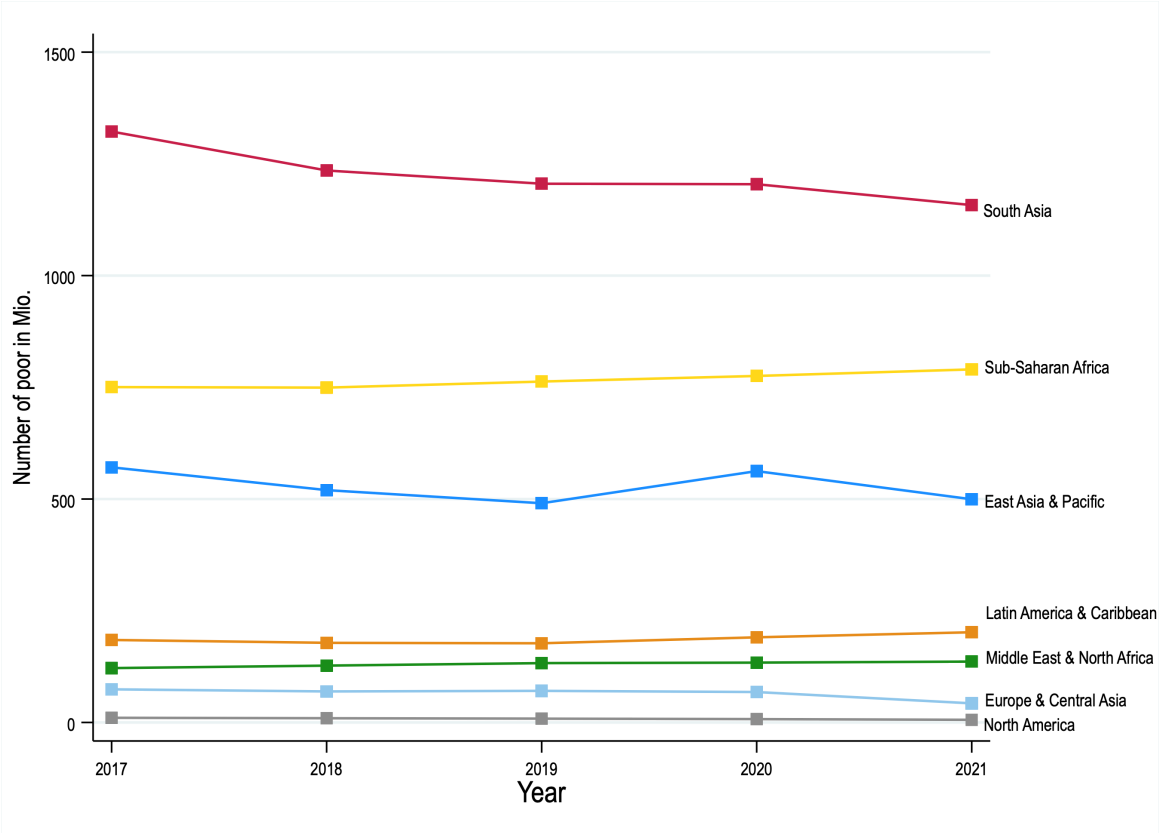
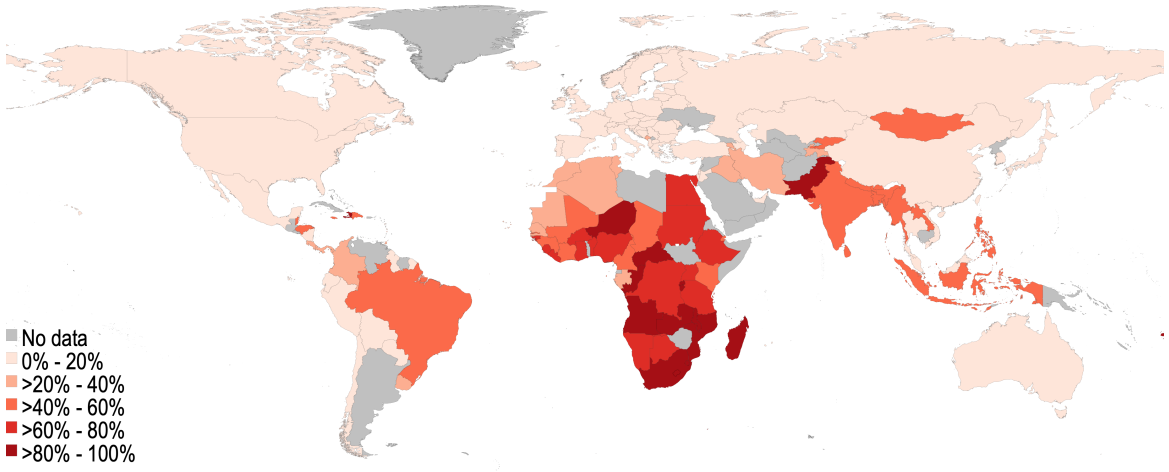


Figure 6 depicts the poverty headcount ratios for all countries with available data in 2021. The headcount ratio indicates the percentage of the population living in poverty. Across Africa, nearly all countries display headcount ratios exceeding 40 percent. Particularly high poverty headcounts in Africa are observed in Lesotho (99%), Eswatini (93%), Madagascar (93%), and South Africa (90%). Globally, these figures are only surpassed by Pakistan (100%) and Fiji (99%). In North America, all headcount ratios are below 20 percent, which is also seen in Europe and Central Asia, with exceptions in Montenegro (21%), Tajikistan (27%), Armenia (29%), and Kyrgyzstan (45%). The greatest changes in the headcount ratios between the US$ 2.15 IPL and our proposed national poverty lines are observed for Fiji (+ 97.6 percentage points), Pakistan (+ 95.5 p.p.), and South Africa (+ 85 p.p.).

Figure 6: Headcount Ratio in 2021

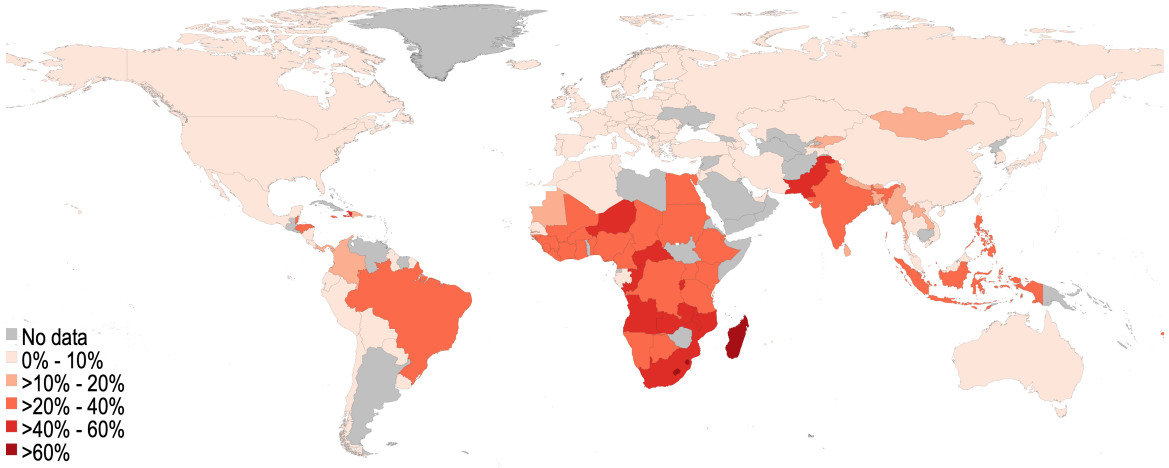


3.4 Global, regional, and temporal trends in poverty severity

The Poverty Gap Index (PGI) is a measure of intensity or depth of poverty and goes beyond a simple headcount of the poor. It not only identifies who is living in poverty but also quantifies how far below the specified poverty line the income or consumption of a population falls.[12] As depicted in Figure 7, the PGI reveals a comparable global pattern with that of the headcount ratio, with pronounced poverty intensity prevalent in sub-Saharan Africa and South Asia. Notably, Madagascar, Eswatini, and Lesotho exhibit a substantial PGI of 0.61, indicating that, on average, the income or consumption of individuals in these countries is 61 percent below the variable FES poverty lines. Among the top ten countries with the highest PGIs, all but one are situated in sub-Saharan Africa, with Pakistan being the exception, experiencing an income deficit of 53 percent. The greatest change in the PGI between the US$ 2.15 IPL and the proposed national poverty lines is observed in Pakistan (+ 52.4 percentage points), Eswatini (+ 49.9 p.p.), and Lesotho (+ 48.5 p.p.).

[12]The Poverty Gap Index is calculated as the sum of income/consumption shortfalls of those who are considered poor, divided by the total population: $PGI = (1/N) \times \sum(Poverty\ Line - Income\ of\ the\ Poor)$

Figure 7: Poverty Gap Index in 2021

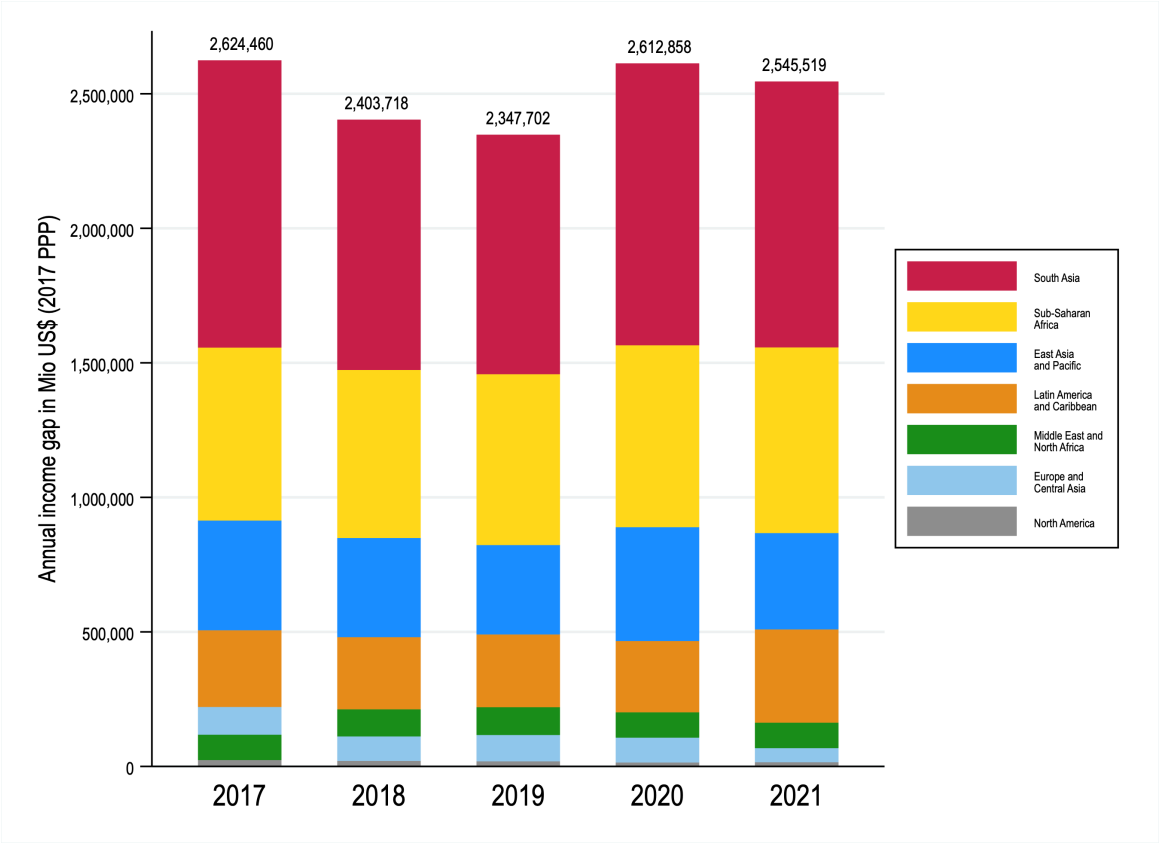


The absolute income shortfall over the entire population of a country indicates the amount of money required to lift all its inhabitants out of poverty. Figure 8 shows the annual global income gap from 2017 to 2021, with contributions from each world region delineated. In 2017, the estimated annual income needed to ensure that all people around the globe can nourish themselves healthily and meet other essential needs is estimated at US$ 2.6 trillion. While there was a slight reduction in 2018 and 2019, the income gap surged by approximately 11 percent in 2020. This increase can be attributed in particular to rising food costs resulting from disruptions in the food supply chain and the absence of incomes due to the impact of COVID-19 and measures put in place to contain it (Laborde et al., 2020; Mahler et al., 2022).

As for the headcount ratios, South Asia (US$ 988 billion in 2021) contributes the largest proportion to the income gap, followed by sub-Saharan Africa (US$ 690 billion), East Asia and Pacific (US$ 358 billion) and Latin America and the Caribbean (US$ 347 billion). Notably, as depicted in Figure A.7, the annual income deficit in East Asia and the Pacific exceeded that of Latin America and the Caribbean by US$ 158 billion in 2020. However, in 2021, this gap had shrunk to only US$ 12 billion, owing to both an upward trend in Latin America and a downward trend in East Asia. This abrupt change between 2020 and 2021 in Latin America was not visible in Figure 5 when looking and the number of poor only suggesting that those who were already poor fell more behind leading to an increase in inequality within these countries. In general, poverty severity underlies larger fluctuations than poverty headcounts.

The numbers presented above result in a daily income deficit of approximately US$ 7 billion as illustrated in Figure A.5. Notably, this gap is nearly 17 times greater than the income shortfall when utilizing the US$ 2.15 IPL. This striking contrast underscores that the disparity between the established IPL and the national poverty lines with variable FES becomes considerably more pronounced when assessing poverty severity, as opposed to a simple headcount of individuals living in poverty.

Figure 8: Annual Income Gap with Regional Composition



3.5 Sensitivity analysis

The numbers provided in the previous sections are based on scenario 2, which incorporates variable food-expenditure shares and accounts for differences in the demographic composition of countries. As explained in detail in Section 2.6, we have developed three alternative scenarios that deviate in their assumptions regarding the utilization of variable and constant FES and adjustments for demographic composition. In this section, we investigate disparities in their relation with income, poverty headcounts, and poverty severity between these scenarios.

Figure A.2 in the appendix and Figure 9 below illustrate the number of people classified as poor and the annual income gap to lift the poor above the corresponding poverty thresholds for the four distinct scenarios that are based on the Cost of Healthy Diets. The number of poor in 2021 fluctuates within a range spanning from 2.25 billion to 3.05 billion, contingent upon the specific scenario. Notably, scenarios 1 to 3 are no more than 218 million apart throughout each year. The scenario aligning with the SOFI approach, characterized by a constant 52% FES and devoid of demographic adjustments, exhibits 3.039 billion that could not afford a healthy diet in 2021. It closely parallels the scenario featuring variable FES and no demographic adjustments, diverging by a mere 12 million individuals in 2021. Conversely, scenario 4, which utilizes a 64% FES and accounts for demographic composi-

tion, notably deviates from the other scenarios, registering approximately 581 million fewer impoverished individuals in 2021.

The annual income missing to lift the entire global population out of poverty ranges between US$ 1.5 trillion and US$ 3.1 trillion. Using a constant food expenditure share of 52%, this income deficit amounts to US$ 2.995 trillion in 2021, surpassing scenario 2 by US$ 449 billion. Again, scenarios 1 and 3 yield comparable global figures, whereas scenario 4 presents substantially lower estimates. As seen in Figure 1, poverty lines with constant FES are densely concentrated around their median value. Figure A.1 reveals that there is also no correlation between these poverty lines and mean private consumption expenditure, hence, there is no economic/relativist gradient for national poverty lines with constant FES. Table A.3 indicates that the median national poverty lines among high-income countries in scenarios 1 and 4 are below those of upper-middle-income countries.

Figure 9: Annual Income Gap by Scenario

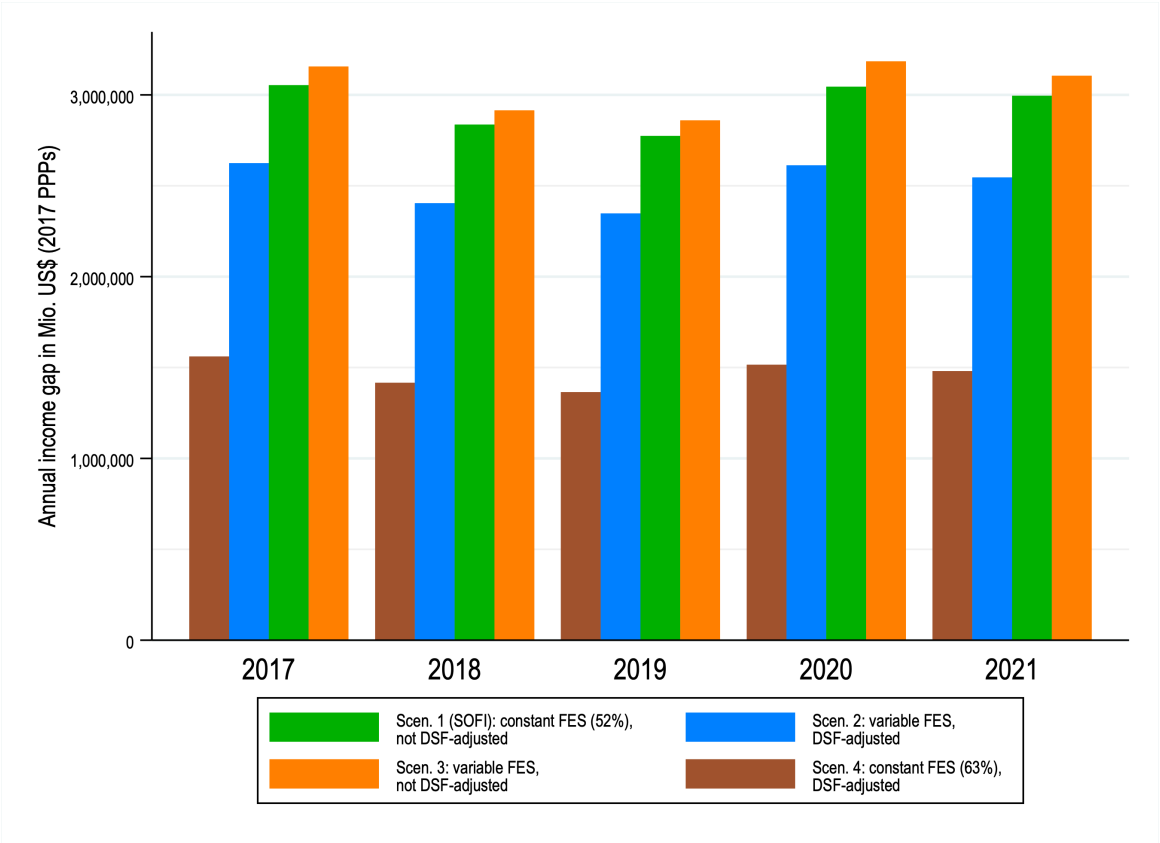


Figure A.4 shows the regional composition and temporal development of poverty under scenario 1. It becomes evident that temporally poverty estimates evolve in a similar manner and the composition of poverty is largely the same as in scenario 2. However, world regions with previously low numbers of poor have even fewer poor in this scenario. Notably, sub-Saharan Africa witnesses an increase in the number of poor compared to scenario 2. A detailed breakdown by poverty approaches, years and world regions in provided in Table A.4.

Figure A.8 and Table A.5 in the appendix depict the temporal evolution and regional composition of the annual income gap under different scenarios. Most strikingly, the income gap of sub-Saharan Africa is greater than that of South Asia in 2021 in scenario 1 by about US$ 153 billion per year. What also stands out is that the income gap for Latin America and the Caribbean is substantially lower compared to scenario 1, aligning it more closely with the Middle East and North Africa.

In conclusion, poverty lines based on constant and variable food-expenditure shares exhibit similar estimates on the global level. While the regional composition of the number of poor also remains largely similar, the income gap in sub-Saharan Africa increases substantially, whereas the gap in Latin America and the Caribbean shrinks.

4 Limitations

Our objective is to establish a globally applicable approach to measure poverty in a way that allows optimal nutrition, is straightforward to compute and can be regularly updated. However, this process requires certain assumptions to be made.

First, our analysis does not account for within-country heterogeneity or temporal variations, as we rely on single national estimates of healthy diet costs and utilize national income distributions. It is important to acknowledge that diet costs, as well as non-food expenditures, can significantly vary within a country, especially in relation to urbanization levels (Headey et al., 2019; Ravallion et al., 2007). Food prices and consumption from own production also underlies considerable seasonality (Gilbert et al., 2017). However, this issue is not specific to our approach and has been recognized also for conventional poverty estimates. For few countries, income distributions by rural-urban location are already available. Extending the CoHD data to these locations and incorporating food-expenditure shares of rural and urban households is subject to further research and would add great value to international poverty measurement.

Second, as we ultimately rely on ICP data, which focusses on items sold in multiple countries, country-specific foods that may represent a least-cost item within a food group such as teff in Ethiopia, are omitted (Headey et al., 2023).

Third, in the process of annually updating CoHD data, we rely on national-level CPI data for food and non-alcoholic beverages (FAO, 2022). However, this approach may not adequately capture item-specific fluctuations that that outpace the general food inflation rate, as seen in instances like the price spikes in oil and wheat in 2022. This issue has also been demonstrated in the context of Ethiopia (Bachewe and Headey, 2017).

Fourth, most of our food-expenditure shares used in the scenario with variable food shares are representative of the poorest income quintiles within a country. This raises two potential concerns. First, in high-income countries this may not adequately represent food expenditure patterns of households around the poverty line which would tend towards higher food expenditure share, thereby resulting in a narrower gap to attain a healthy diet.

However, this approach introduces a relative perspective that also encompasses a dimension of social inclusion, as discussed in more detail in the following section. Second, also in the poorest countries like Madagascar and Burundi, this approach may not mirror the food expenditure patterns of those near the poverty lines, since the poorest income quintile falls below the poverty threshold in these cases. Some of the food-expenditure shares that we were not able to update may also be slightly outdated.

Fifth, it is important to note that our data is limited to the period up to 2017 due to the availability of CoHD data. To gain a deeper understanding of the long-term trends in these indicators using nutrition-sensitive poverty lines, it would be beneficial to study a broader time frame.

5 Discussion

5.1 Key metrics of poverty

The affordability of adequate, let alone healthy, diets is a distant reality for many people worldwide. This new measurement of poverty indicates that 2.8 billion people were living in poverty in 2021 indicating a poverty rate of 38 percent. More than one out of three people globally were not able to afford healthy diets and other essential goods. To overcome this gap, individuals are lacking about US$ 2.5 trillion annually. Our findings underscore significant global differences in the affordability of nutritious diets. Particularly in the Global South, people face considerable financial barriers to achieving recommended nutrient intake, thereby impeding their ability to sustain long-term health and well-being. Countries in sub-Saharan Africa and South Asia are in particular need of support considering their high burden relative to their GDP. We need to transform food systems to provide equitable access to healthy and sustainable diets for everyone.

The global income gap to afford a healthy diet is substantial but manageable. To provide perspective on this figure, the income gap amounts to 1.8 to 2.2 percent of the world's total annual income or 1.6 to 1.9 percent of the combined wealth of all millionaires and billionaires worldwide, depending on the scenario (Chancel et al., 2022). Despite the sizable global income gap to a healthy diet, it is important to also consider the costs that result from suboptimal diets through factors such as healthcare costs, reduced productivity, lower educational attainment, and increased mortality rates. For instance, the global cost of diabetes, to which unhealthy diets contribute, is estimated at US$ 1.3 trillion in 2015 and may increase to US$ 2.2 trillion by 2030 (Bommer et al., 2017, 2018). It is projected that the annual health costs associated with non-communicable diseases and diet-related mortality will amount to more than US$ 1.3 trillion by 2030 and US$ 2.2 trillion by 2050, excluding the adverse impacts of undernutrition (FAO et al., 2020; Springmann, 2020). Economic losses attributable to undernutrition are estimated at US$ 3.5 trillion annually (Swinburn et al., 2019). The economic benefits of improving diets have been estimated at US$ 1 to 31

trillion[13] which may substantially exceed the annual global price of a healthy diet (Springmann et al., 2016). In conclusion, despite the substantial global income gap, the potential economic benefits resulting from ensuring affordable access to healthy diets may surpass it considerably. Consideration of cost avoidance is therefore imperative when making investments to enhance the universal affordability of a nutritious diet.

5.2 Poverty measurement

A striking disparity emerges when we compare key metrics of our poverty lines with those based on the conventional US$ 2.15 IPL and national poverty lines. The number of individuals classified as poor increases by 4.5 and 2.5 times, respectively. The income gap surges by 17 and 4 times, respectively. This highlights that neither the conventional IPL nor national poverty lines adequately capture the extent to which people worldwide struggle to afford nutritious foods. It underscores the substantial obstacles that individuals continue to face in accessing nutritious diets, even if they are not classified as extremely poor by conventional standards. It becomes clear that the current poverty line falls short in addressing the economic accessibility of obtaining nutritious food to meet the dietary requirements for a healthy and active life.

We argue that the understanding of basic needs has developed with economic progress and the reduction in global hunger rates since the development of initial national poverty lines. Standard poverty lines fall short in considering the nutritional requirements essential for individuals to lead active and healthy lives, a pivotal element of food security, and therefore substantially underestimates those who cannot afford to live and active and healthy life. Access to healthy diets is a fundamental human right, and sufficient calorie intake alone leads to poor health in the long run. Poverty lines need to be expanded to encompass economic access to healthy diets to ensure sustainable long-term health. Individuals should be classified as extremely poor if they are unable to follow recommended diets or afford the essential nutrients and food groups required for maintaining an active and healthy lifestyle. We argue that one needs to possess the capability of living a healthy life, independently of whether a healthy diet is desired or consumed at this level of income. Our measure can serve as a tool to monitor this affordability aspect of healthy diets.

The US$ 2.15 IPL represents a common global absolute poverty measure which disregards that poverty can also have relative elements (Sen, 1983). National poverty lines of richer economies are often explicitly relative (share of mean or median income) leading to a steep increase in national poverty lines with increasing GDP. The provided nutrition-sensitive national poverty lines primarily represent absolute poverty thresholds, but they do incorporate a weak relative element. This relative dimension is intertwined with the allocation of expenditure on food. When we calculate the average food expenditure within the

[13]These estimates are derived using two distinct approaches. The „cost-of-illness“ approach resulted in a calculation of US$ 1 trillion, whereas the “value-of-statistical-life” approach estimated the economic benefits of improving diets at US$ 31 trillion (Springmann et al., 2016).

poorest quintile, it is important to note that in richer countries, this average is on average based on individuals with higher incomes. Consequently, it reflects the food expenditure of those who are comfortably above the poverty line, which introduces a relative component. In richer countries, individuals near the poverty line tend to allocate a relatively larger portion of their budget to food compared to the proportion we utilize for the nutrition-sensitive poverty lines. This element leads to a shape of the presented poverty lines that aligns with the current shape of national poverty thresholds but unveil a more concentrated distribution, with elevated values for poorer countries and lower values for richer ones.[14]

6 Conclusion

In this paper, we propose a measure of poverty that is grounded in the economic costs of maintaining a healthy diet. As the world moves closer to eliminating extreme poverty, the traditional threshold of US$ 2.15 will become increasingly socially irrelevant in many parts of the world. An expansion from caloric sufficiency to affordability healthy diets enables to sustain long-term health. Our approach offers a dynamic and adaptable internationally consistent way of assessing poverty, distinct from conventional approaches that often rely on subjective country-specific judgments. We introduce these thresholds as absolute poverty lines in nations with lower incomes, while they encompass a relative dimension in wealthier countries. This leads to a denser distribution of poverty lines compared to current national poverty lines, wherein lower-income countries have higher poverty thresholds, while higher-income countries have lower.

We explore the key metrics of this poverty measure and compare them with the conventional US$ 2.15 IPL, harmonized national poverty lines, and three alternative nutrition-based scenarios. Our analysis reveals that, according to our proposed measure, 2.8 billion people are classified as impoverished, with the collective income deficit amounting to US$ 2.546 trillion per year. These figures exceed those generated by the US$ 2.15 IPL by factors of 4.5 and 17, respectively. Using parameters consistent with FAO reports, these figures increase to 3 billion individuals and a yearly total of US$ 2,995 trillion. These findings underscore the significant challenges we face in achieving universal affordability of healthy diets and other basic needs.

While considerable progress has been made in the battle against extreme poverty in recent decades, a substantial number of individuals still experience food insecurity and malnutrition. Achieving the Sustainable Development Goal of "Zero Hunger" by 2030 remains an difficult challenge. Nevertheless, it is essential to reflect evolving nutritional concerns and expand poverty measurements to encompass those who are financially constraint in attaining recommended diets.

[14] Another distinction to common weakly relative poverty lines is that the present lines do not incorporate a fixed intercept (Ravallion and Chen, 2011).

References

Afshin, A., Sur, P. J., Fay, K. A., ..., and Murray, C. J. L. (2019). Health effects of dietary risks in 195 countries, 1990–2017: a systematic analysis for the Global Burden of Disease Study 2017. *The Lancet*, 393(10184):1958–1972.

Allen, R. C. (2017). Absolute Poverty: When Necessity Displaces Desire. *American Economic Review*, 107(12):3690–3721.

Arimond, M. and Ruel, M. T. (2004). Dietary Diversity Is Associated with Child Nutritional Status: Evidence from 11 Demographic and Health Surveys. *The Journal of Nutrition*, 134(10):2579–2585.

Bachewe, F. and Headey, D. (2017). Urban Wage Behaviour and Food Price Inflation in Ethiopia. *The Journal of Development Studies*, 53(8):1207–1222.

Bai, Y., Herforth, A., and Masters, W. A. (2022). Global variation in the cost of a nutrient-adequate diet by population group: an observational study. *The Lancet Planetary Health*, 6(1):e19–e28.

Bommer, C., Heesemann, E., Sagalova, V., Manne-Goehler, J., Atun, R., Bärnighausen, T., and Vollmer, S. (2017). The global economic burden of diabetes in adults aged 20-79 years: a cost-of-illness study. *The Lancet. Diabetes & Endocrinology*, 5(6):423–430.

Bommer, C., Sagalova, V., Heesemann, E., Manne-Goehler, J., Atun, R., Bärnighausen, T., Davies, J., and Vollmer, S. (2018). Global Economic Burden of Diabetes in Adults: Projections From 2015 to 2030. *Diabetes Care*, 41(5):963–970.

Boom, B., Halsema, A., and Molini, V. (2015). Are We Confusing Poverty with Preferences?

Castañeda, R. A. (2023). PIP: Stata module to access World Bank's Global Poverty and Inequality Data. original-date: 2021-08-23T22:18:18Z.

Chancel, L., Piketty, T., Saez, E., and Zucman, G. (2022). World Inequality Report 2022. Technical report.

Deaton, A. (2010). Price Indexes, Inequality, and the Measurement of World Poverty. *American Economic Review*, 100(1):5–34.

Dizon, F., Herforth, A., and Wang, Z. (2019). The cost of a nutritious diet in Afghanistan, Bangladesh, Pakistan, and Sri Lanka. *Global Food Security*, 21:38–51.

FAO (1996). Rome Declaration on World Food Security.

FAO (2022). *The State of Food and Agriculture 2022: Leveraging agricultural automation for transforming agrifood systems*. Number 2022 in The State of Food and Agriculture (SOFA). FAO, Rome, Italy.

FAO, IFAD, UNICEF, WFP, and WHO (2020). The State of Food Security and Nutrition in the World 2020. Technical report, FAO, IFAD, UNICEF, WFP and WHO.

Ferreira, F. H. G., Chen, S., Dabalen, A., Dikhanov, Y., Hamadeh, N., Jolliffe, D., Narayan, A., Prydz, E. B., Revenga, A., Sangraula, P., Serajuddin, U., and Yoshida, N. (2016). A global count of the extreme poor in 2012: data issues, methodology and initial results. *The Journal of Economic Inequality*, 14(2):141–172.

Gilbert, C. L., Christiaensen, L., and Kaminski, J. (2017). Food price seasonality in Africa: Measurement and extent. *Food Policy*, 67:119–132.

Gödecke, T., Stein, A. J., and Qaim, M. (2018). The global burden of chronic and hidden hunger: Trends and determinants. *Global Food Security*, 17:21–29.

Hawkes, C., Ruel, M. T., Salm, L., Sinclair, B., and Branca, F. (2020). Double-duty actions: seizing programme and policy opportunities to address malnutrition in all its forms. *The Lancet*, 395(10218):142–155.

Headey, D., Hirvonen, K., and Alderman, H. (2023). Estimating the Cost and Affordability of Healthy Diets: How Much Do Methods Matter?

Headey, D., Hirvonen, K., and Hoddinott, J. (2018). Animal Sourced Foods and Child Stunting. *American Journal of Agricultural Economics*, 100(5):1302–1319. _eprint: https://onlinelibrary.wiley.com/doi/pdf/10.1093/ajae/aay053.

Headey, D., Hirvonen, K., Hoddinott, J., and Stifel, D. (2019). Rural Food Markets and Child Nutrition. *American Journal of Agricultural Economics*, 101(5):1311–1327. _eprint: https://onlinelibrary.wiley.com/doi/pdf/10.1093/ajae/aaz032.

Herforth, A., Bai, Y., Venkat, A., Mahrt, K., Ebel, A., and Masters, W. A. (2020). Cost and affordability of healthy diets across and within countries. Technical report, FAO.

Herforth, A., Venkat, A., Bai, Y., Costlow, L., Holleman, C., and Masters, W. A. (2022). Methods and options to monitor the cost and affordability of a healthy diet globally.

HLPE (2017). Nutrition and food systems. Technical Report 12, The High Level Panel of Experts on Food Security and Nutrition.

Institute of Medicine (US) (1998). *Prevention of Micronutrient Deficiencies: Tools for Policymakers and Public Health Workers*. National Academies Press (US), Washington (DC).

Jolliffe, D., Mahler, D. G., Lakner, C., Atamanov, A., and Tetteh-Baah, S. K. (2022). Assessing the Impact of the 2017 PPPs on the International Poverty Line and Global Poverty.

Jolliffe, D. and Prydz, E. B. (2016). Estimating international poverty lines from comparable national thresholds. *The Journal of Economic Inequality*, 14(2):185–198.

Klasen, S., Krivobokova, T., Greb, F., Lahoti, R., Pasaribu, S. H., and Wiesenfarth, M. (2016). International income poverty measurement: which way now? *The Journal of Economic Inequality*, 14(2):199–225.

Laborde, D., Martin, W., Swinnen, J., and Vos, R. (2020). COVID-19 risks to global food security. *Science*, 369(6503):500–502. Publisher: American Association for the Advancement of Science.

Mahler, D. G., Yonzan, N., and Lakner, C. (2022). The Impact of COVID-19 on Global Inequality and Poverty.

Mahrt, K., Herforth, A. W., Robinson, S., Arndt, C., and Headey, D. (2022). Nutrition as a Basic Need: A New Method for Utility-Consistent and Nutritionally Adequate Food Poverty Lines.

Mahrt, K., Mather, D. L., Herforth, A., and Headey, D. (2019). Household dietary patterns and the cost of a nutritious diet in Myanmar. Edition: 0.

Masters, W. A., Bai, Y., Herforth, A., Sarpong, D. B., Mishili, F., Kinabo, J., and Coates, J. C. (2018). Measuring the Affordability of Nutritious Diets in Africa: Price Indexes for Diet Diversity and the Cost of Nutrient Adequacy. *American Journal of Agricultural Economics*, 100(5):1285–1301. _eprint: https://onlinelibrary.wiley.com/doi/pdf/10.1093/ajae/aay059.

Murray, C. J. L., Aravkin, A. Y., Zheng, P., . . . , and Lim, S. S. (2020). Global burden of 87 risk factors in 204 countries and territories, 1990–2019: a systematic analysis for the Global Burden of Disease Study 2019. *The Lancet*, 396(10258):1223–1249. Publisher: Elsevier.

Popkin, B. M., Corvalan, C., and Grummer-Strawn, L. M. (2020). Dynamics of the double burden of malnutrition and the changing nutrition reality. *The Lancet*, 395(10217):65–74.

Raghunathan, K., Headey, D., and Herforth, A. (2021). Affordability of nutritious diets in rural India. *Food Policy*, 99:101982.

Ravallion, M. (1998). Poverty Lines in Theory and Practice. Working paper 133, World Bank Publications. Google-Books-ID: VdfW0Hzeqn0C.

Ravallion, M. (2010). Poverty Lines Across The World.

Ravallion, M. (2015). *The Economics of Poverty: History, Measurement, and Policy*. Oxford University Press. Google-Books-ID: GUL_CgAAQBAJ.

Ravallion, M. (2020). On Measuring Global Poverty. *Annual Review of Economics*, 12(1):167–188. _eprint: https://doi.org/10.1146/annurev-economics-081919-022924.

Ravallion, M. and Chen, S. (2011). Weakly Relative Poverty. *The Review of Economics and Statistics*, 93(4):1251–1261.

Ravallion, M., Chen, S., and Sangraula, P. (2007). New Evidence on the Urbanization of Global Poverty. *Population and Development Review*, 33(4):667–701. _eprint: https://onlinelibrary.wiley.com/doi/pdf/10.1111/j.1728-4457.2007.00193.x.

Ravallion, M., Chen, S., and Sangraula, P. (2009). Dollar a Day Revisited. *The World Bank Economic Review*, 23(2):163–184.

Ravallion, M., Datt, G., and van de Walle, D. (1991). Quantifying Absolute Poverty in the Developing World. *Review of Income and Wealth*, 37(4):345–361. _eprint: https://onlinelibrary.wiley.com/doi/pdf/10.1111/j.1475-4991.1991.tb00378.x.

Reddy, S. G. and Pogge, T. (2009). How Not to Count the Poor. Technical report.

Rowntree, B. S. (1901). *Poverty: A study of town life*. Macmillan, London.

Sen, A. (1983). Poor, Relatively Speaking. *Oxford Economic Papers*, 35(2):153–169. Publisher: Oxford University Press.

Smith, V. E. (1959). Linear Programming Models for the Determination of Palatable Human Diets. *Journal of Farm Economics*, 41(2):272–283. Publisher: [Oxford University Press, Agricultural & Applied Economics Association].

Springmann, M. (2020). Valuation of the health and climate-change benefits of healthy diets: Background paper for The State of Food Security and Nutrition in the World 2020.

Springmann, M., Godfray, H. C. J., Rayner, M., and Scarborough, P. (2016). Analysis and valuation of the health and climate change cobenefits of dietary change. *Proceedings of the National Academy of Sciences*, 113(15):4146–4151. Publisher: Proceedings of the National Academy of Sciences.

Stigler, G. J. (1945). The Cost of Subsistence. *Journal of Farm Economics*, 27(2):303–314. Publisher: [Oxford University Press, Agricultural & Applied Economics Association].

Swinburn, B. A., Kraak, V. I., Allender, S., . . . , and Dietz, W. H. (2019). The Global Syndemic of Obesity, Undernutrition, and Climate Change: The Lancet Commission report. *The Lancet*, 393(10173):791–846. Publisher: Elsevier.

Townsend, P. (1979). *Poverty in the United Kingdom: A Survey of Household Resources and Standards of Living*. University of California Press, Harmondsworth.

van de Ven, G. W. J., de Valença, A., Marinus, W., de Jager, I., Descheemaeker, K. K. E., Hekman, W., Mellisse, B. T., Baijukya, F., Omari, M., and Giller, K. E. (2021). Living income benchmarking of rural households in low-income countries. *Food Security*, 13(3):729–749.

Willett, W., Rockström, J., Loken, B., ..., and Murray, C. J. L. (2019). Food in the Anthropocene: the EAT–Lancet Commission on healthy diets from sustainable food systems. *The Lancet*, 393(10170):447–492. Publisher: Elsevier.

World Bank (2010). Global Consumption Database | Sector: Food and Beverages.

World Bank (2023). Poverty and Inequality Platform.

A Appendix

Table A.1: The Healthy Diet Basket

Food Group	kcal	grams
Starchy Staples	1,160	322
Vegetables	110	367
Fruits	160	254
Animal-source Foods	300	210
Legumes, Nuts, and Seeds	300	85
Oils and Fats	300	34

Source: Herforth et al. (2022)

Figure A.1: Poverty Lines and Consumption Expenditure by Scenario

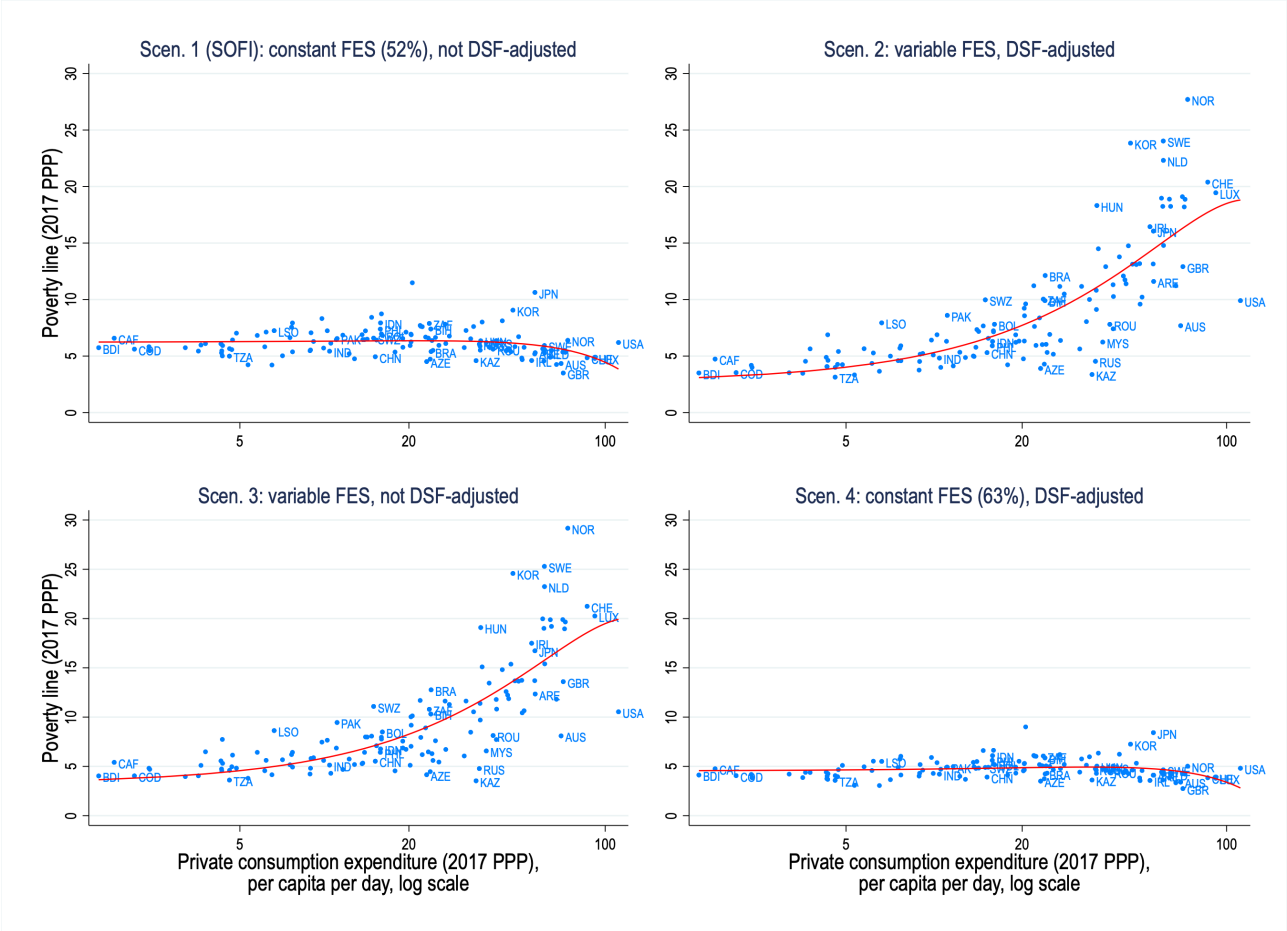


Table A.2: Regression Results

Sample	(1) Implicit nation. Pov. lines	(2) Harmon. nat. pov. lines (poorest quartile)	(3) pov. lines with variable FES	(4) Pov. lines with variable FES (poorest quartile)
Panel A: Linear-linear model				
Cons. Exp.	0.411***	0.193***	0.179***	0.198***
per Cap. per Day	(0.000)	(0.000)	(0.000)	(0.000)
Constant	-1.269***	1.558***	3.761***	3.572***
	(0.000)	(0.000)	(0.000)	(0.000)
Panel B: Log-log model				
Log. Cons. Exp.	0.845***	0.355***	0.436***	0.238***
per Cap. per Day	(0.000)	(0.000)	(0.000)	(0.000)
Constant	-0.598***	0.343***	0.747***	1.130***
	(0.000)	(0.000)	(0.000)	(0.000)
N	611	160	630	160

Table A.3: International Poverty Lines

Income classification	Harmonized national povlines		Scenario 1		Scenario 2		Scenario 3		Scenario 4	
	Median	**N**	**Median**	**N**	**Median**	**N**	**Median**	**N**	**Median**	**N**
High	23.24	40	5.51	43	13.29	43	13.84	43	4.37	43
Upper middle	6.71	34	6.44	37	6.62	37	7.36	37	5	37
Lower middle	3	38	6.7	38	5.44	38	6.01	38	4.96	38
Low	2.16	21	5.85	21	4.43	21	5	21	4.25	21
Total		133		139		139		139		139

Figure A.2: Number of Poor by Scenario

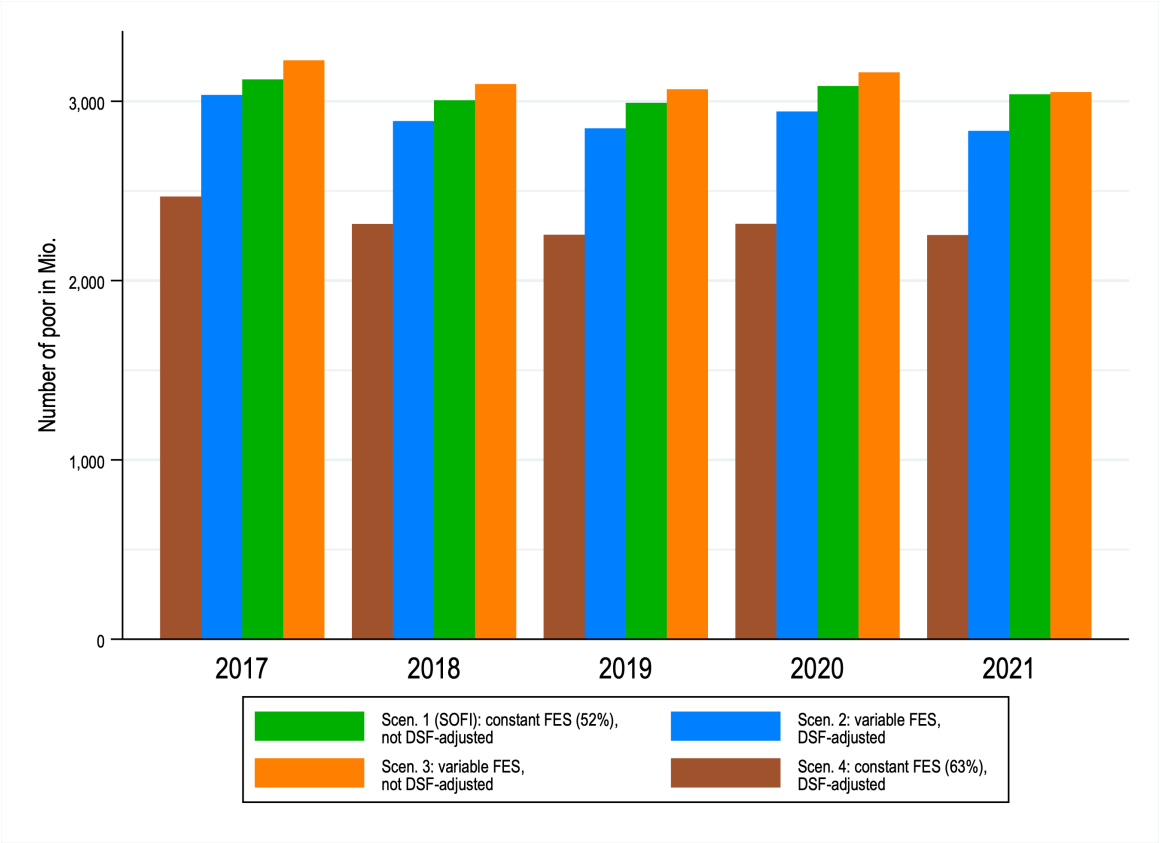


Figure A.3: Proportion of Poor by World Region

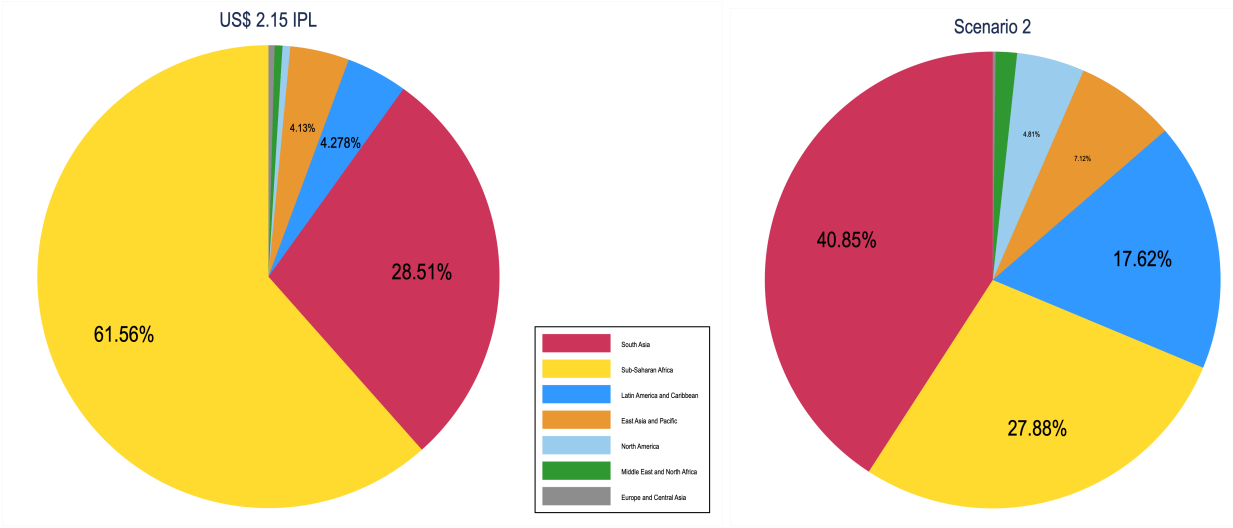


Table A.4: Number of Poor by Year, World Region and Scenario

Year	World Region	Int. Pov. Line	Nation. Pov. Lines	Scen. 1	Scen. 2	Scen. 3	Scen. 4
2017	East Asia and Pacific	37	143	588	571	619	393
	Europe and Central Asia	4	127	32	74	82	18
	Latin America and Caribbean	24	164	121	185	198	82
	Middle East and North Africa	3	44	111	122	140	64
	North America	4	88	7	10	12	6
	South Asia	226	288	1399	1322	1375	1154
	Sub-Saharan Africa	369	397	864	751	803	751
	Total	667	1250	3122	3035	3228	2468
2018	East Asia and Pacific	30	117	541	520	567	357
	Europe and Central Asia	3	120	27	69	78	14
	Latin America and Caribbean	24	162	117	178	192	79
	Middle East and North Africa	4	49	117	127	145	69
	North America	3	82	6	10	11	5
	South Asia	182	240	1330	1235	1298	1042
	Sub-Saharan Africa	365	394	868	749	804	749
	Total	609	1163	3005	2889	3096	2316
2019	East Asia and Pacific	22	92	514	491	539	327
	Europe and Central Asia	3	113	29	71	78	16
	Latin America and Caribbean	24	162	117	177	190	79
	Middle East and North Africa	4	46	122	133	152	70
	North America	3	75	5	9	10	4
	South Asia	158	218	1318	1206	1278	996
	Sub-Saharan Africa	368	397	887	763	820	764
	Total	582	1103	2991	2849	3067	2256
2020	East Asia and Pacific	27	119	604	563	616	377
	Europe and Central Asia	3	113	28	68	76	16
	Latin America and Caribbean	22	161	119	191	205	80
	Middle East and North Africa	4	50	122	134	157	67
	North America	1	67	4	8	9	4
	South Asia	210	280	1295	1204	1263	1010
	Sub-Saharan Africa	378	431	913	775	835	763
	Total	645	1220	3085	2943	3161	2316
2021	East Asia and Pacific	26	100	562	500	550	346
	Europe and Central Asia	3	49	29	43	47	17
	Latin America and Caribbean	27	171	130	202	217	90
	Middle East and North Africa	3	47	124	136	159	69
	North America	3	16	4	6	6	4
	South Asia	178	245	1255	1158	1220	952
	Sub-Saharan Africa	384	437	934	790	852	777
	Total	624	1067	3039	2835	3051	2254

Figure A.4: Number of Poor (Constant FES)

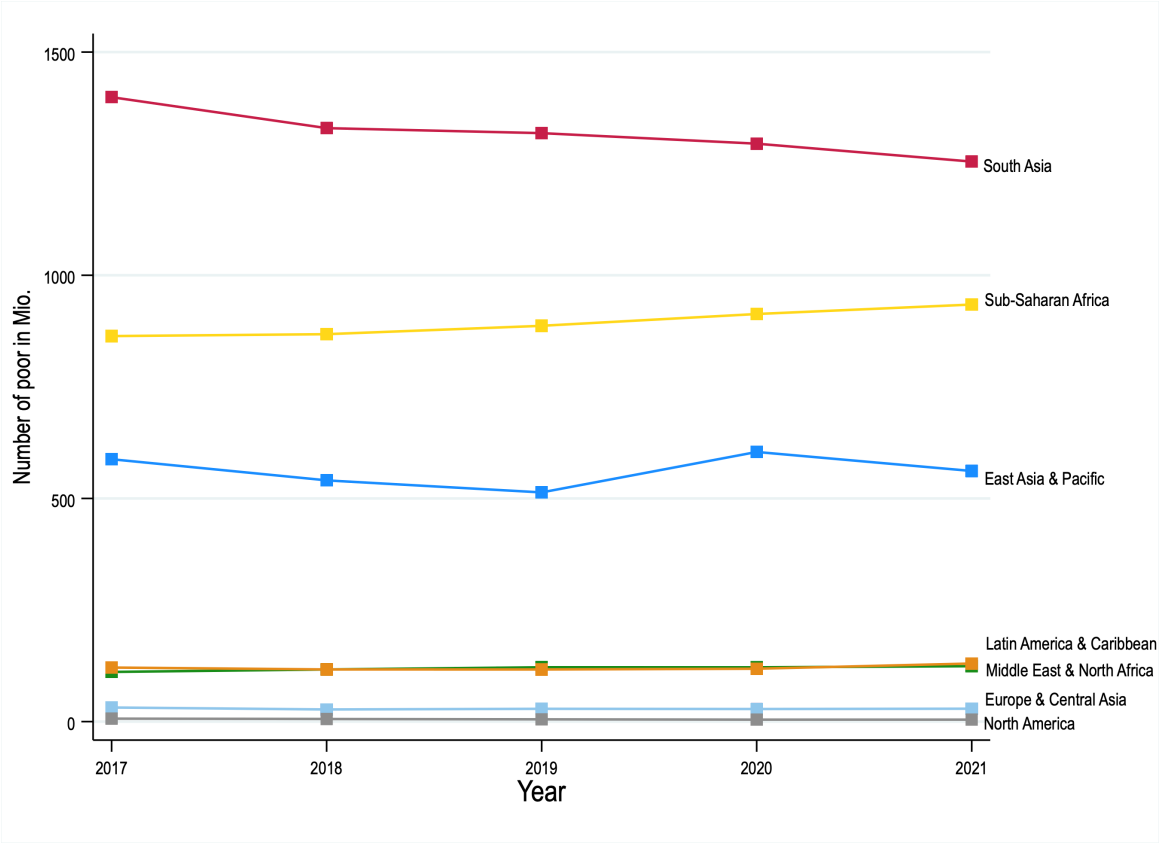


Figure A.5: Daily Income Gap (Variable FES)

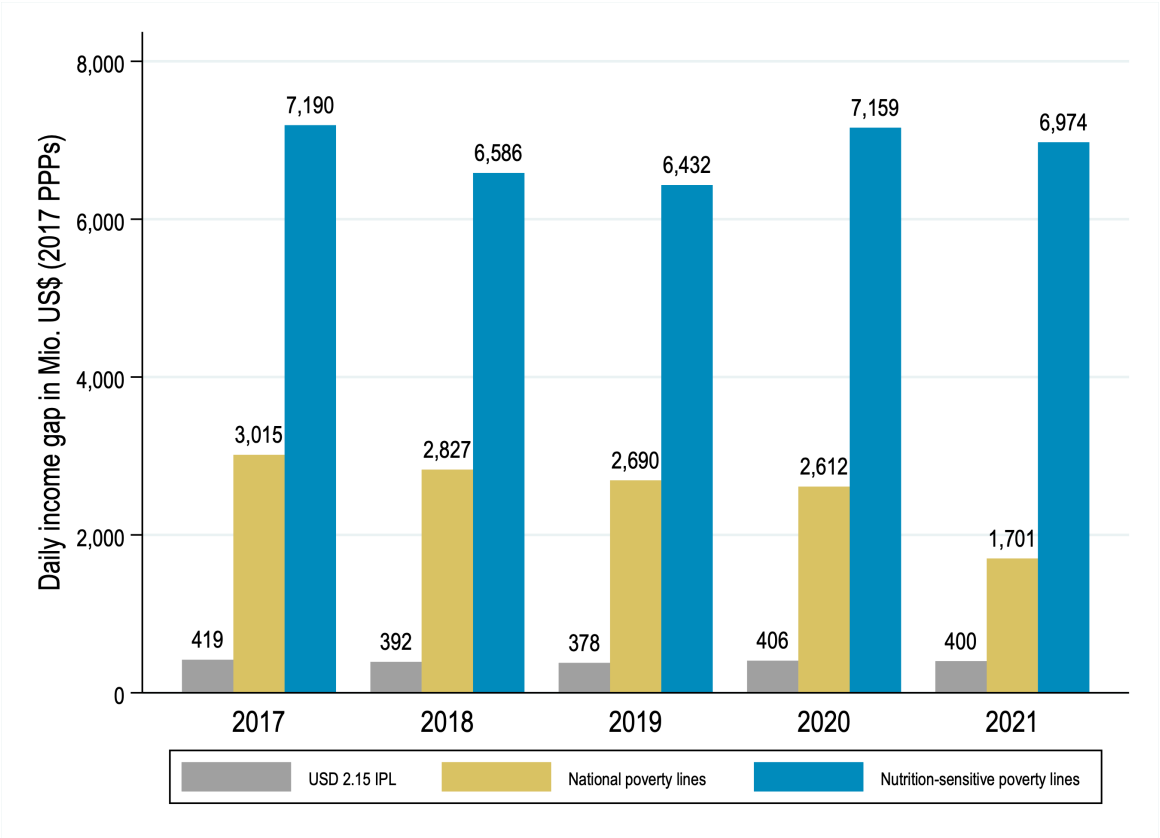


Figure A.6: Proportion of Annual Gap by World Region

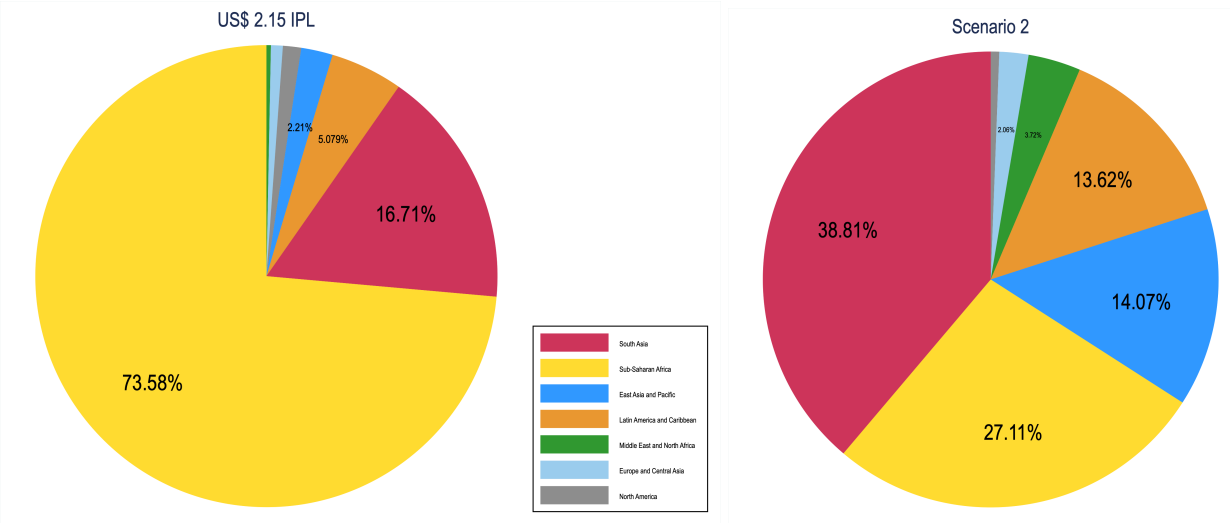


Figure A.7: Annual Gap over Time by World Region (Variable FES)

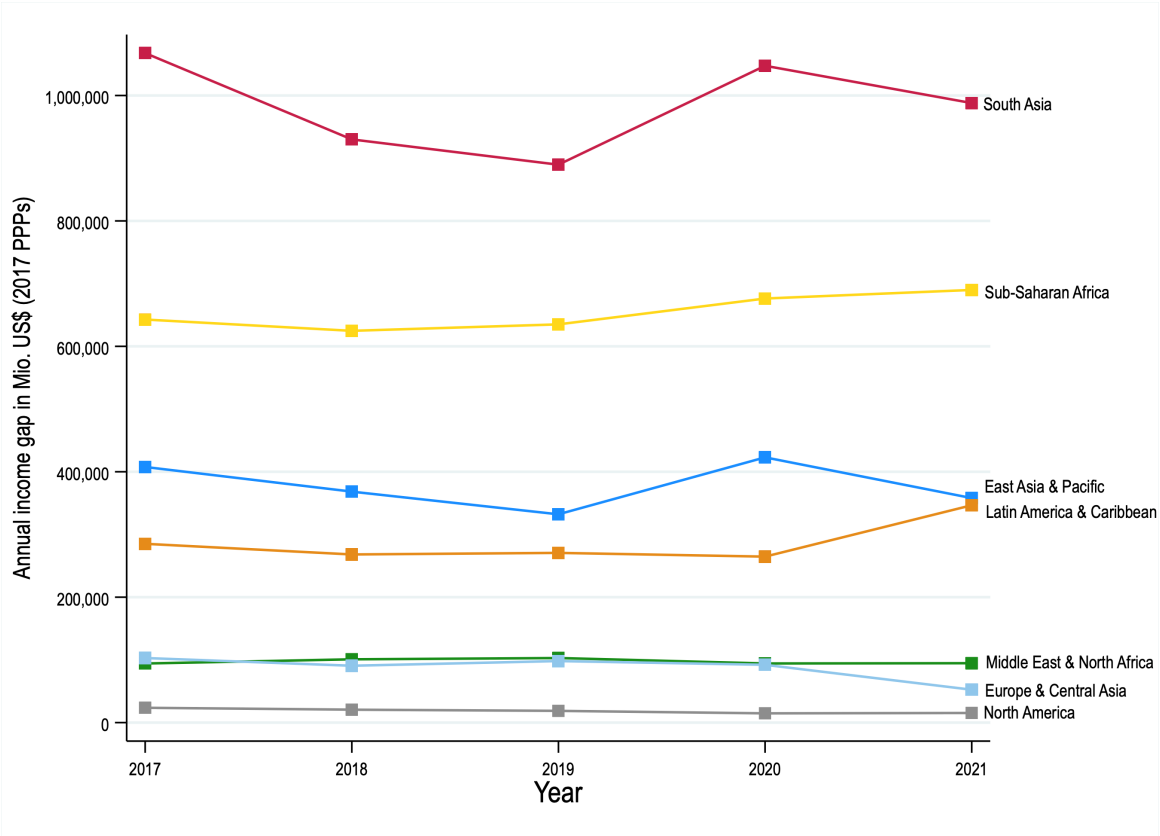


Figure A.8: Annual Gap over Time by World Region (Constant FES)

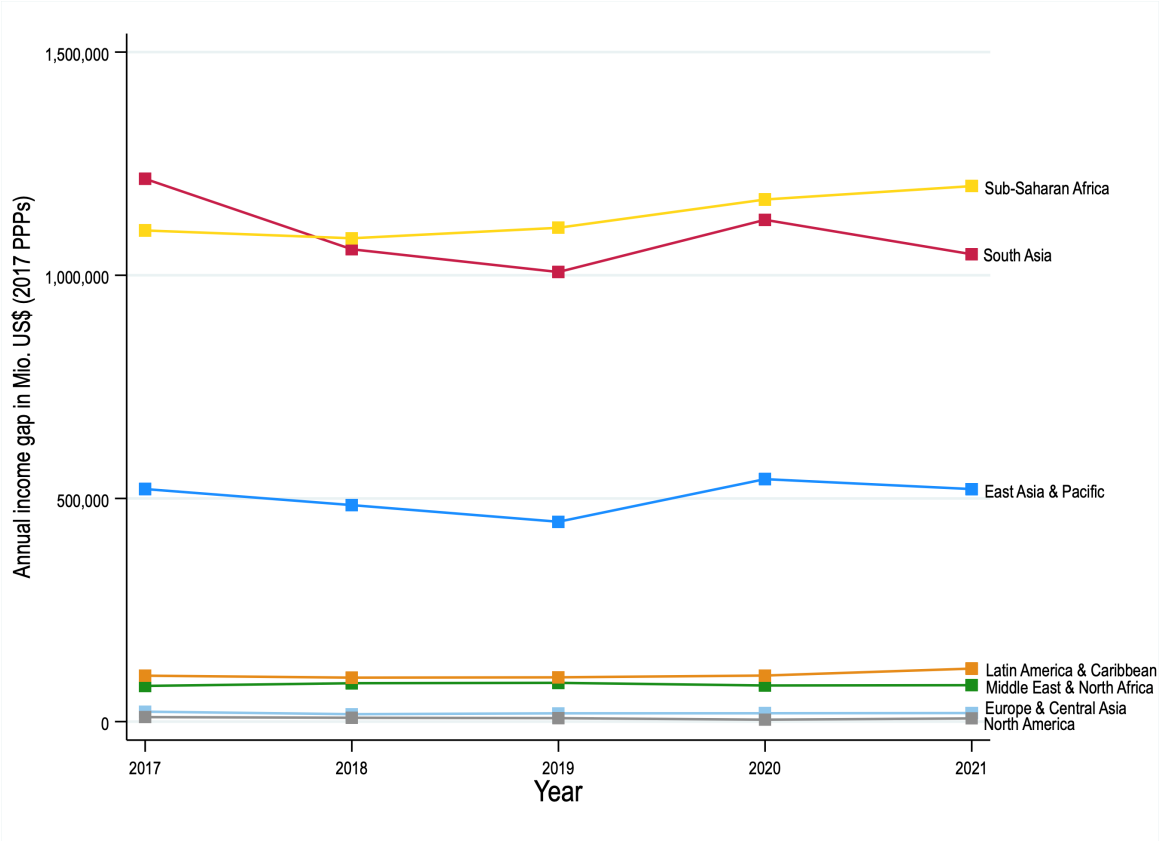


Table A.5: Annual Poverty Gap by Year, World Region and Scenario (in Mio. US$)

Year	World Region	Int. Pov. Line	Nation. Pov. Lines	Scen. 1	Scen. 2	Scen. 3	Scen. 4
2017	East Asia and Pacific	5200	80516	521120	407705	483593	250493
	Europe and Central Asia	1752	248491	22339	103029	119483	10674
	Latin America and Caribbean	6587	176085	102993	285199	324407	52818
	Middle East and North Africa	458	20403	80008	94302	125873	28024
	North America	2604	392561	10160	23745	26426	7140
	South Asia	33079	47102	1216069	1067662	1260136	610957
	Sub-Saharan Africa	103229	135244	1100426	642818	816167	600766
	Total	152909	1100402	3053114	2624460	3156086	1560871
2018	East Asia and Pacific	4075	73244	485095	368371	440216	230245
	Europe and Central Asia	1152	228561	16644	90692	106406	7245
	Latin America and Caribbean	6475	172826	98563	268166	305382	50557
	Middle East and North Africa	566	22064	86108	100997	133993	31025
	North America	2231	360376	8695	20662	22969	6091
	South Asia	26728	39475	1058267	930056	1109475	504595
	Sub-Saharan Africa	101863	135209	1082866	624774	796186	586155
	Total	143091	1031755	2836239	2403718	2914627	1415912
2019	East Asia and Pacific	2771	66266	447774	332186	400803	206081
	Europe and Central Asia	1151	222261	18592	98205	114860	8202
	Latin America and Caribbean	6771	172712	99307	270693	307814	51419
	Middle East and North Africa	538	20855	86897	103068	137899	30338
	North America	2034	327230	7829	18766	20822	5515
	South Asia	22200	35308	1007202	889712	1067012	465576
	Sub-Saharan Africa	102586	137388	1106445	635073	810231	597675
	Total	138052	982020	2774045	2347702	2859441	1364806
2020	East Asia and Pacific	3533	79354	543323	423062	499200	255564
	Europe and Central Asia	1145	220862	18799	92210	107870	8425
	Latin America and Caribbean	6173	164428	103257	264726	305500	53117
	Middle East and North Africa	502	25339	80965	94320	122782	30567
	North America	672	274246	4382	14798	16815	2441
	South Asia	30027	48915	1124247	1047461	1266630	549196
	Sub-Saharan Africa	106061	140368	1169772	676282	865819	615919
	Total	148114	953512	3044745	2612858	3184616	1515228
2021	East Asia and Pacific	3223	38056	520995	358107	427019	245322
	Europe and Central Asia	1211	86485	19301	52519	58983	9229
	Latin America and Caribbean	7418	178946	118848	346680	392320	63032
	Middle East and North Africa	455	21338	81712	94791	123304	31033
	North America	1870	112463	7261	15413	16861	5183
	South Asia	24414	42004	1047059	987991	1202130	496884
	Sub-Saharan Africa	107480	141440	1199779	690018	884436	629534
	Total	146071	620732	2994954	2545519	3105053	1480218