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The global income gap to a healthy diet

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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 2.9 billion people were poor in 2021 and US$ 2.439 trillion per year would be needed to lift them out of poverty. 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. 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 is sufficient for survival and normal activity levels.

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 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

[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).

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 acknowledged that essential needs are not 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).

To set our poverty threshold based on nutritional standards for optimal health instead, 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 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 dietary 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 avail-

able 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 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

[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).

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 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 estimat-

[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.

[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.

ing 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]

As incomes rise, individuals tend to allocate a larger proportion of their resources to non-food goods (*see Figure A.1*). 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

[6]In cases where both WB-GCB and other data is 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 median of the same income group.

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 five distinct scenarios that vary by assumptions on food expenditure shares and non-food expenditures. In scenario 1, we use country-specific and thus varying food expenditure shares of the lowest income segment and apply the formula above. Food-expenditure shares of the poorest 20 percent within a country may understate food expenditure in extremely poor countries where a substantially higher proportion of the population is considered poor. Therefore, in scenario 2, we base our analysis on FES from income quintiles that align with the prevailing poverty rates determined by the US$ 2.15 IPL. To illustrate, in a country where 55 percent of the population lives below this poverty line, we employ the FES

[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 allocates 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.

data from the third income quintile. This approach may offer a more accurate representation of food-expenditure shares among the population residing around the current poverty threshold. Scenario 3 adopts a food expenditure share of 52 percent and no DSFs, aligning with the approach used in the FAO et al. (2020).

In our poverty approach, we base our food expenditure on the minimum financial resources that are needed for optimal nutrition instead of caloric sufficiency. The costs of essential needs for food are therefore increased compared to conventional approaches in low-income countries. The share used to determine non-food basic needs remains the same in scenarios 1 and 2, which also implies higher non-food basic needs. The following two scenarios apply food-expenditure shares to current national poverty lines to determine non-food basic needs. Subsequently, these non-food basic needs are added to the Cost of a Healthy Diet, the basic food needs.[9] In scenario 4, non-food basic needs are determined using variable food-expenditure shares of the lowest income segment. In scenario 5, a constant FES of 52 percent is applied.

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[10] 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.[11]

Under scenario 1, poverty lines begin at US$ 2.48 for the Democratic Republic of the Congo, extending up to US$ 25.34 for Norway. Norway is also the country with the highest national implicit poverty line (US$ 37.80). There are no visible differences when using FES from poverty segments based on the US$ 2.15 IPL. The lowest value changes only marginally to US$ 2.50. The spectrum of poverty lines anchored to a constant food expenditure share of 52% exhibits a relatively narrow range, spanning from US$ 3.22 (United Kingdom) to US$ 11.62 (Jamaica). When utilizing non-food expenditures of national implicit poverty lines, poverty lines in richer countries increase substantially compared to the previous scenarios. Using variable FES, the highest poverty lines is at US$ 34.7. A constant FES yields a maximum poverty line of US$ 20.12, both for Norway.

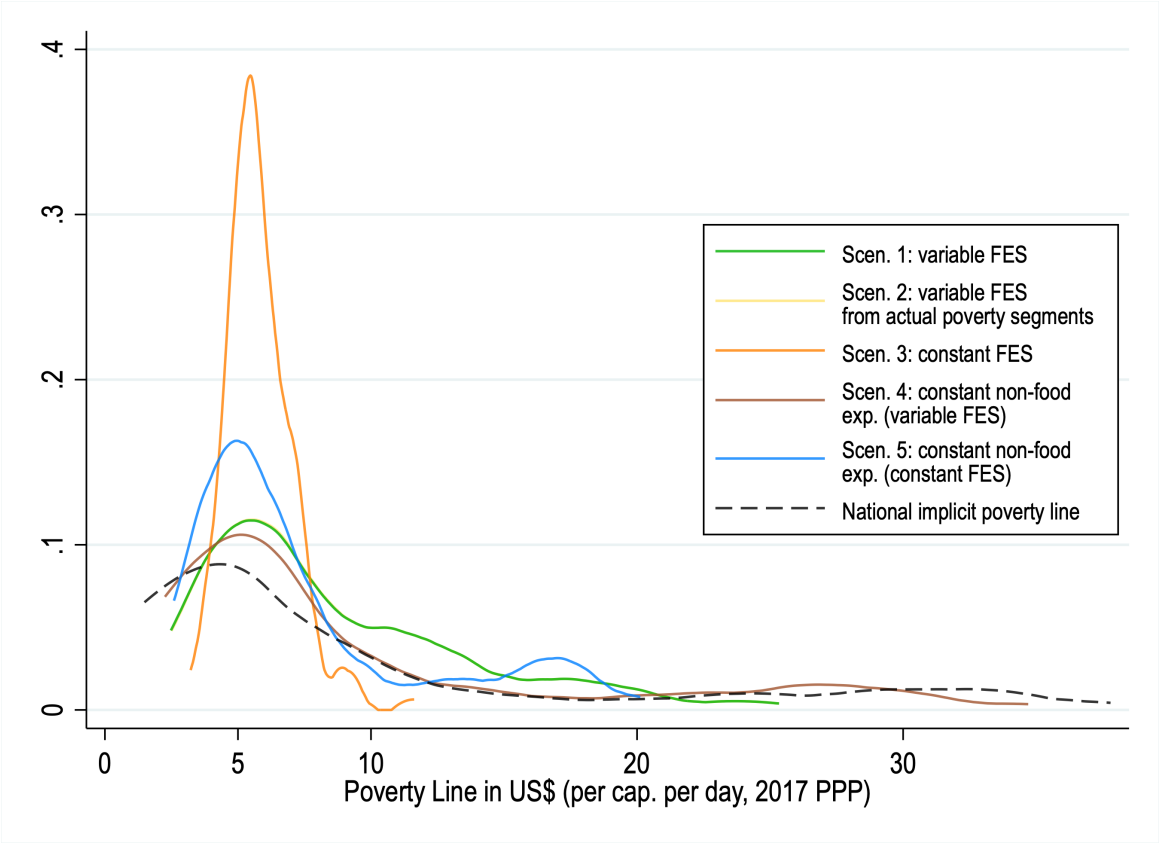
Albeit less dispersed, the distribution of scenarios with variable FES reveals a similar pattern as current national poverty lines. Particularly scenario 1 exhibits higher poverty lines among poorer countries by about US$ 2 per person per day across most of the distri-

[9] $NatPovLine \times (1 - FoodExpShare) + CoHD$

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

[11] The sample of harmonized national poverty lines used from Jolliffe et al. (2022) contains 133 countries. Poverty headcount and poverty gap based on this limited sample are provided in Table A.4 and A.5.

Figure 1: Density of Poverty Lines

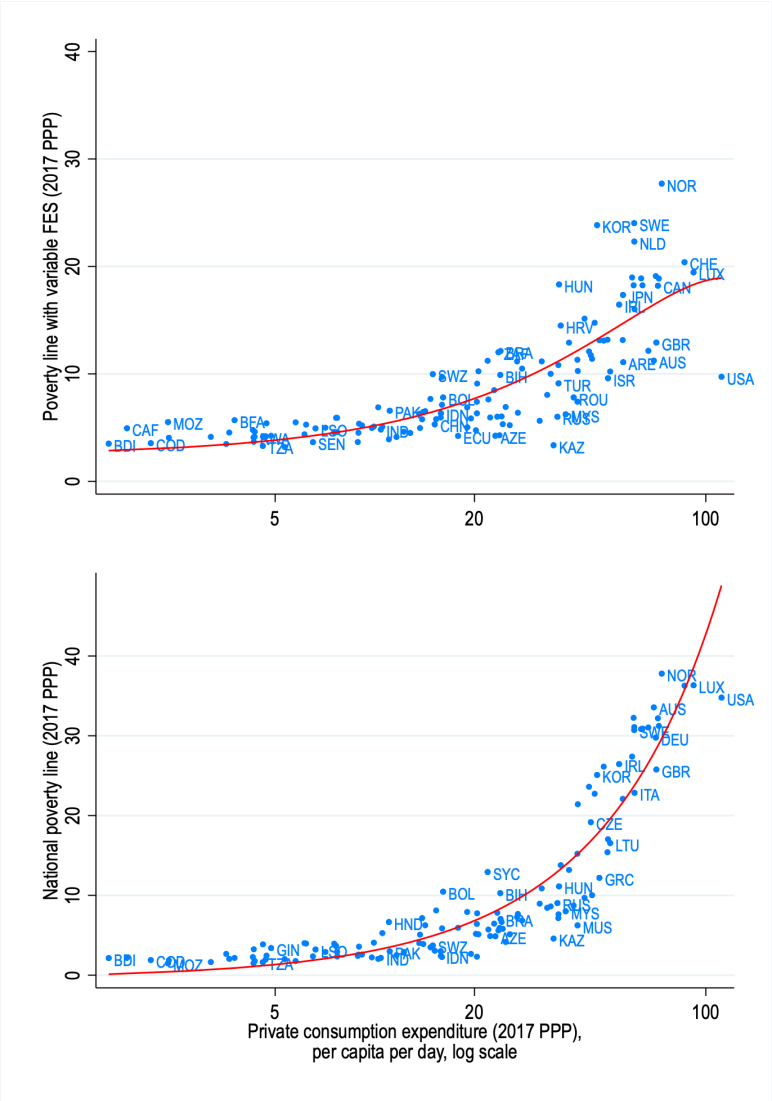


bution, however, with considerably lower maximum values. When using constant non-food expenditures, the distribution aligns with scenario 1 among countries with lower poverty lines but aligns with the national implicit poverty lines for higher values as of about US$ 9. Particularly notable is the concentration of poverty lines with constant FES values ranging from US$ 4 to 8. 63 percent of all poverty lines are within ± US$ 1 of the median of scenario 3. For comparison, only 20 and 16.5 percent of poverty lines are ± US$ 1 of the median of scenario 1 and 4, respectively. Constant non-food expenditures with constant FES exhibits a high density around US$ 5, though considerably less than in scenario 3, and a small bump among its highest values around US$ 18.

Henceforth, we will continue discussing results based on scenario 1 which incorporates variable FES and accounts for demographic composition adjustments as in Equation (1). 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).

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.

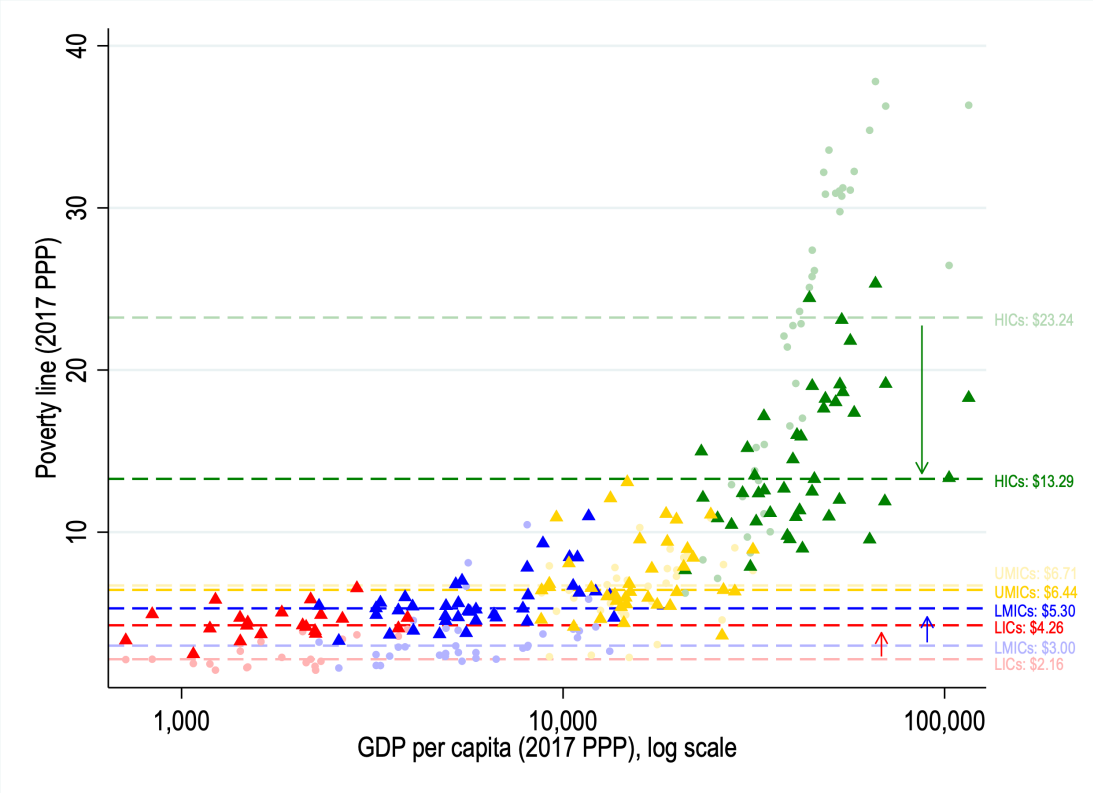
At lower levels of consumption, this relationship appears relatively flat. However, when using the full sample of poverty lines from 2017 to 2021 and limiting the sample to the poorest quartile in each year, the correlation is positive and significant and similar in size for both the harmonized national 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 though with a greater constant. 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.

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: 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.

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$ 4.26, about doubling the current International Poverty Line. Even in lower-middle income countries, the international poverty threshold would experience a nearly twofold increase, reaching US$ 5.30 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.

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.

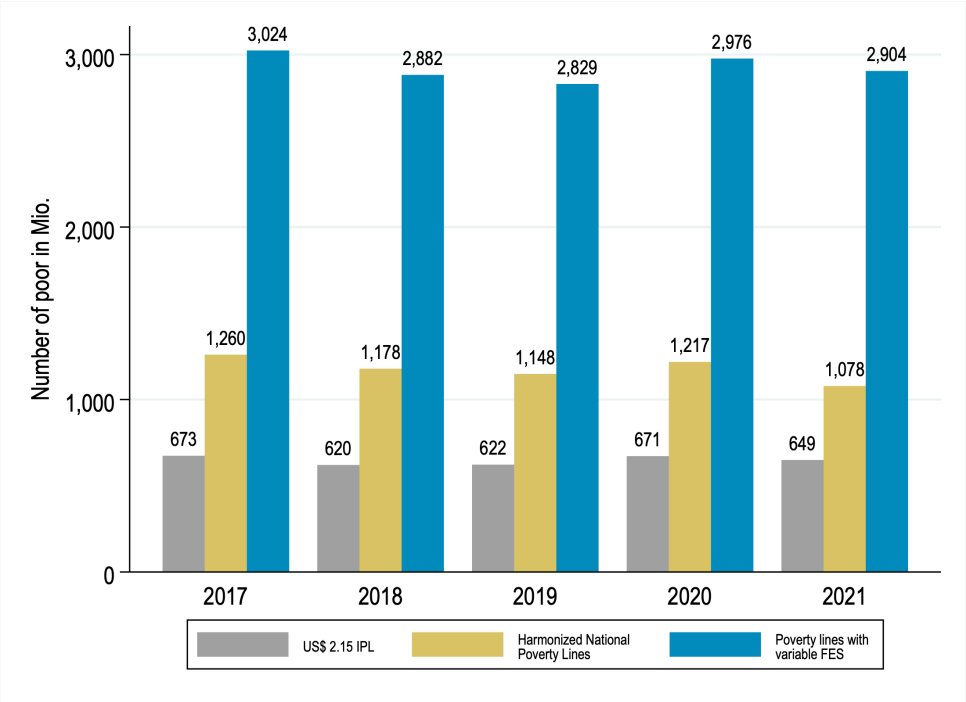
When using national poverty lines with variable food-expenditure shares, the number of individuals living in poverty is approximately four to five times larger than the current poverty estimates and 2.5 times larger than estimates based on harmonized national poverty lines. In 2017, these estimates indicate 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 42.61 percent.[12] 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). In general, all approaches to measuring poverty exhibit a similar global trend over time. In 2021, the global poverty estimates stand at 2.9 billion while the poverty rate stands at 39.41 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 and East Asia and Pacific are following a similar pattern over time with a consistent decline until 2019 and an abrupt change in 2020 which, however, should be interpreted with caution. In contrast, sub-Saharan Africa experienced a continuous increase in

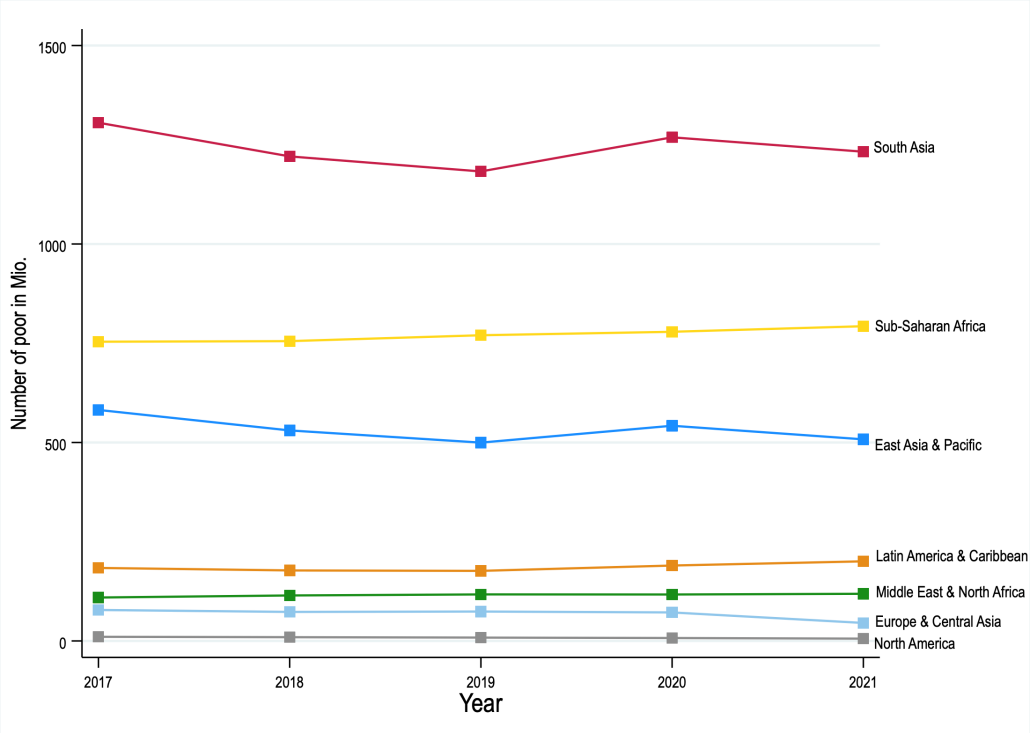
[12]Note that this rate is estimate for based on the poverty and population of 139 countries. Some of the countries for which no data is available such as Afghanistan, Somalia, South Sudan, or Venezuela may experience relatively high poverty rates.

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 1 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. Numbers are limited to 133 countries for which data is available in all scenarios are provided in Table A.4.

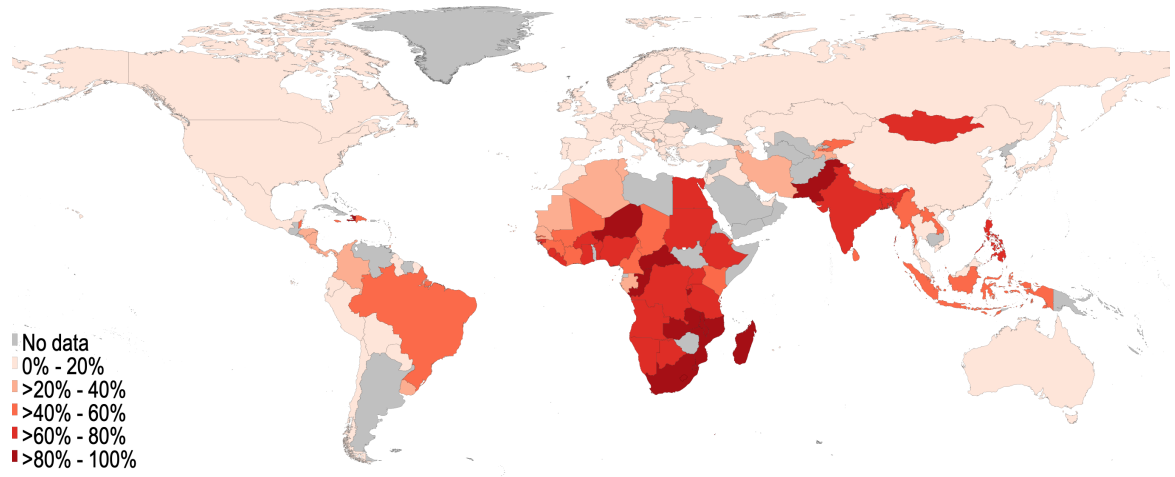
Figure 5: Number of poor by World Region



poverty rates (*see Table A.4*).[13] 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 may experience a marginal increase in the number of poor.

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 South Africa (100%), Eswatini (94%), Madagascar (94%), and Malawi (91%). Outside Africa, only Haiti (82%) and Pakistan (80%) exhibit poverty rates of 80 percent or more. 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 (30%), 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 South Africa (+ 94.7 p.p.), Pakistan (+ 77.4 p.p.), and Mongolia (+ 74.5 percentage points).

Figure 6: Poverty Headcount Ratio in 2021



3.4 Global, regional, and temporal trends in poverty severity

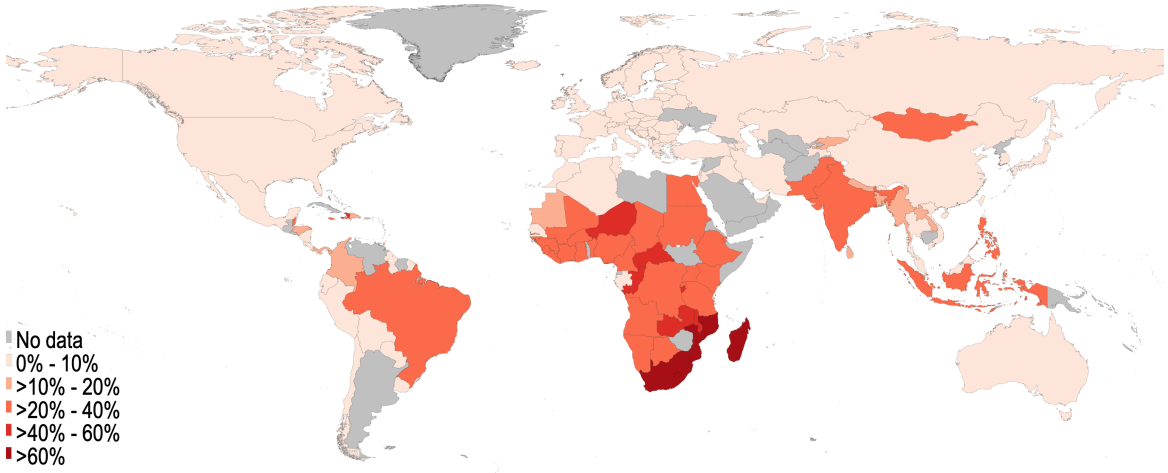
The Poverty Gap Index (PGI) is a measure of intensity or depth of poverty and goes beyond a simple headcount of the poor. It not only identifies who is living in poverty but also quantifies how far below the specified poverty line the income or consumption of a population falls.[14] As depicted in Figure 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 (0.65), South Africa (0.62), Mozambique (0.62), and Eswa-

[13] Note that Table A.4 provides numbers limited to 133 countries for which data is available in all scenarios, whereas Figure 4 provides estimates for 139 countries.

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

tini (0.61) exhibit a substantial PGI, indicating that, on average, the income or consumption of individuals in these countries is 61 to 65 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 Haiti being the exception, experiencing an income deficit of 44 percent. The greatest change in the PGI between the US$ 2.15 IPL and the proposed national poverty lines is observed in South Africa (+ 60.6 percentage points), Eswatini (+ 49.9 p.p.), and Haiti (+ 34.7 p.p.).

Figure 7: Poverty Gap Index in 2021

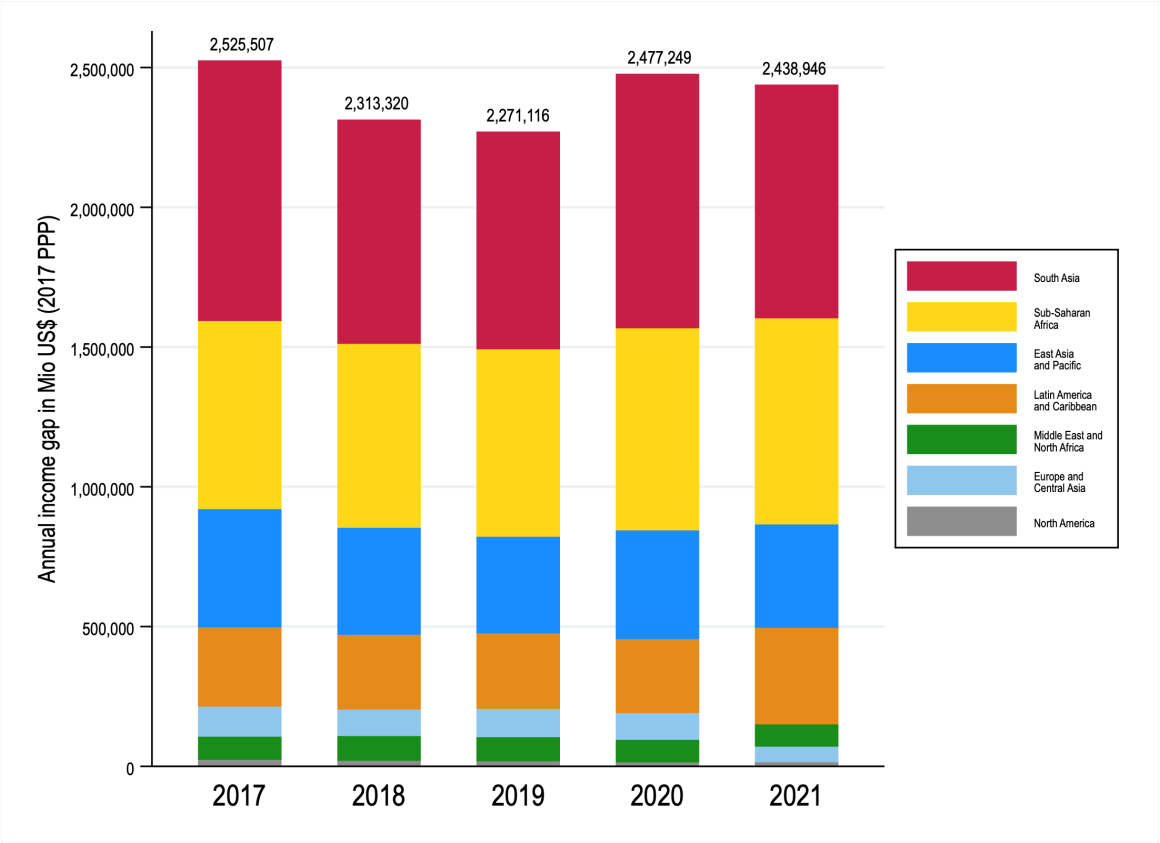


The absolute income shortfall over the entire population of a country indicates the amount of money required to lift all its inhabitants out of poverty. Figure 8 shows the annual global income gap from 2017 to 2021, with contributions from each world region delineated. In 2017, the estimated annual income needed to ensure that all people around the globe can nourish themselves healthily and meet other essential needs is estimated at US$ 2.526 trillion.[15] While there was a slight reduction in 2018 and 2019, the income gap surged by approximately 9 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$ 836 billion in 2021) contributes the largest proportion to the income gap, followed by sub-Saharan Africa (US$ 737 billion), East Asia and Pacific (US$ 370 billion) and Latin America and the Caribbean (US$ 345 billion). Notably, as depicted in Figure A.6, the annual income deficit in East Asia and the Pacific exceeded that of Latin America and the Caribbean by US$ 125 billion in 2020. However, in 2021, this gap had shrunk to only US$ 25 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

[15]This number is based on 139 countries, whereas Table A.5 provides estimations for 133 countries to make the scenarios directly comparable.

Figure 8: Annual Income Gap with Regional Composition



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.

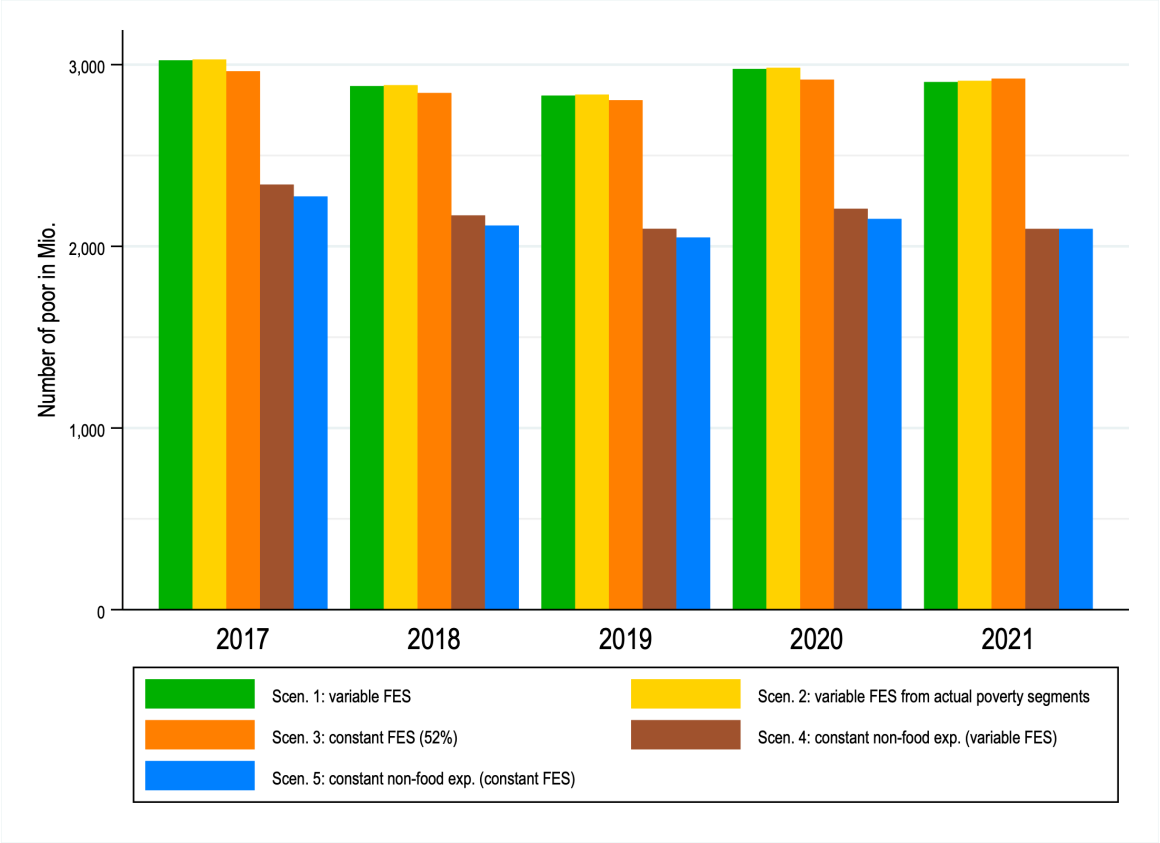
The numbers presented above result in a daily income deficit of approximately US$ 7 billion in 2017 as illustrated in Figure A.5. Notably, this gap is more than 16 times greater than the income shortfall when utilizing the US$ 2.15 IPL. This striking contrast underscores that the disparity between the 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.

3.5 Sensitivity analysis

The numbers provided in the previous sections are based on scenario 1, 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 four alternative scenarios that deviate in their assumptions regarding the utilization of variable and constant FES and how non-food expenditures are taken into account. In this section, we investigate disparities in their relation with income, poverty headcounts, and poverty severity between these scenarios.

For 133 countries, Table A.4 and A.5 in the appendix illustrate the number of people classified as poor and the annual income gap to lift the poor above the corresponding poverty thresholds for the US$ 2.15 IPL, the national poverty lines, and the five distinct scenarios that are based on the Cost of Healthy Diets. The global numbers are illustrated graphically for the five scenarios in Figure 9 and A.4.

Figure 9: Number of Poor by Scenario

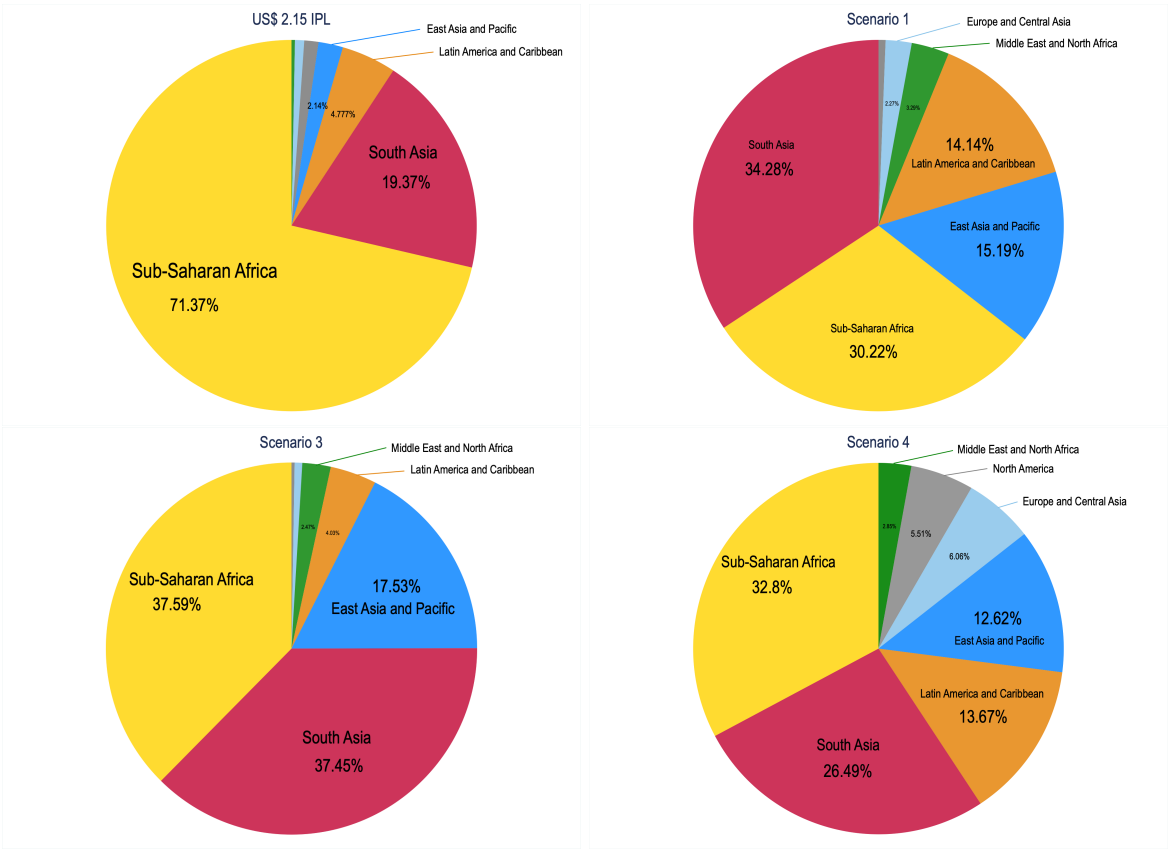


The number of poor people in 2021 thereby fluctuates within a range spanning from 2.01 billion to 2.9 billion, contingent upon the specific scenario (*see Table A.4*). Notably, scenarios 1 to 3 produce very similar global figures. The variation in the number of individuals living in poverty across these scenarios does not exceed US$ 56 million at any point during the observation period (*see Table A.5*). Similarly, the disparity in the poverty gap is limited to no more than US$ 50 billion among these scenarios. In scenarios 4 and 5, which consider non-food expenditures from national poverty lines, the number of people in poverty is somewhat lower by approximately 600 to 800 million individuals. In 2021, both of these scenarios estimate a total of 2.096 billion individuals living in poverty (*see Table A.4*). The resources required to raise all those in poverty above the poverty threshold in scenario 5 are roughly 50 percent of the amount needed in scenario 3, totaling US$ 1.166 trillion in 2021. Scenario 4 provides similar but slightly higher estimates for each year (*see Table A.5*).

Albeit the global figures of scenarios 1 to 3 and 4 to 5 align relatively closely, there are considerable regional differences. Figure A.3 and 10 provide a detailed breakdown of the regional distribution global poverty headcount and poverty gap in 2021. Notably, when we

base poverty assessment on access to healthy diets rather than caloric sufficiency, South Asia emerges as the region with the highest number of impoverished individuals, whereas, by the current IPL, three out of five poor people are located in sub-Saharan Africa. Nevertheless, there are no substantial discrepancies across scenarios in the regional distribution of the global number of poor (*see Table A.4*).

Figure 10: Proportion of Annual Gap by World Region



Regional poverty severity patterns exhibit variations across scenarios. Based on the US$ 2.15 IPL, 71% of the income gap is concentrated within sub-Saharan African countries. Scenarios 1 and 2 demonstrate minor disparities in both the poverty headcount and poverty gap. Scenario 2 records consistently higher numbers only within sub-Saharan Africa, although these variations are negligible. When constant FES are used in instead of variable FES, the proportion of Latin America and the Caribbean substantially decreases. In Scenario 1, it would take approximately US$ 345 billion to lift all the population in that region out of poverty, whereas this figure drastically decreases to about US$ 100 billion in Scenario 3. Similarly, North America, Europe, and Central Asia exhibit considerably reduced figures compared to scenarios 1 and 2. This occurs because there is no correlation between these poverty lines and mean private consumption expenditure, and thus no economic/relativist gradient for national poverty lines with constant FES (*see Figure A.2*).[16] Table A.3 indicates that the median national poverty lines among high-income countries in scenario 3 is even

[16]Poverty lines with constant FES are densely concentrated around their median value (*see Figure 1*).

below those of upper-middle-income countries. In low-income countries, however, poor households often spend more than 52% of their income on food (*see Figure A.1*), leading to a lower poverty gap in South Asia and sub-Saharan Africa in Scenarios 1 and 2 in comparison to Scenario 3.

In scenarios 4 and 5, high-income countries emerge as even more substantial contributors to the global income gap when compared to scenarios 1 and 2. According to scenario 4, two out of every five US dollars needed to alleviate poverty lie outside of sub-Saharan Africa and South Asia. This arises because non-food expenditures are based on national poverty lines, which in wealthier countries are often calculated at 50% of the median income. This introduces a more pronounced relativist gradient, as illustrated in Figure 1. In richer regions, scenarios 4 and 5 may even register a higher number of poor individuals compared to the first two scenarios, while in poorer regions, these scenarios indicate considerably fewer people living in poverty. These disparities are even more pronounced for the poverty gap (*see Table A.5*).

In summary, poverty lines derived from both constant and variable food-expenditure shares yield comparable global estimates. While the regional composition of the global 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. When non-food expenditures from national poverty lines are incorporated, the global count of individuals in poverty significantly decreases, and effectively halving the income gap. This reduction is primarily driven by lower-income nations due to a more pronounced relativist gradient, resulting in a relatively higher proportion of wealthier countries.

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 focuses 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 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 the potential concern that 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. In addition, 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 2.9 billion people were living in poverty in 2021 indicating a poverty rate of 39 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$ 2.4 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 1.6 to 2.0 percent of the world's total annual income or 1.5 to 1.8 percent of the combined wealth of all millionaires and billionaires worldwide, depending on the scenario (Chancel et al., 2022). Despite the siz-

able 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[17] 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

[17] 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).

lifestyle. We argue that one needs to possess the capability of living a healthy life, regardless 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 median food expenditure within the 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.[18]

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 four alternative nutrition-based scenarios. Our analysis reveals that, according to our proposed measure, 2.9 billion people are classified as impoverished, with the collective income deficit amounting to US$ 2.438 trillion per year. These figures exceed those generated by the US$ 2.15 IPL by factors of

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

4.5 and 17, respectively. 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 a difficult challenge. Nevertheless, it is essential to reflect evolving nutritional concerns and expand poverty measurements to encompass those who are financially constrained in attaining recommended diets.

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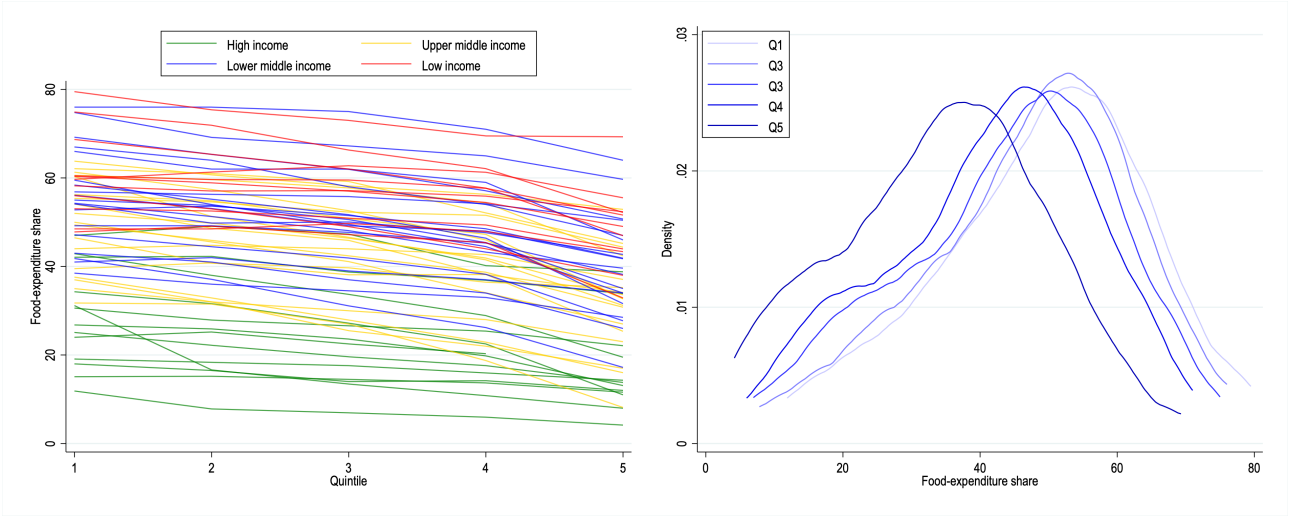
A Appendix

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: Food-expenditure shares by income quintile



Note: Graph (a) depicts food-expenditure shares across income or consumption quintiles for 83 countries for which we obtained additional data based on nationally representative surveys since 2010. High-income countries are represented in green, upper-middle income countries in yellow, lower-middle income countries in blue, and low-income countries in red. Graph (b) depicts the density of food-expenditure shares within each quintile. The intensity of the blue line increases as the income quintiles increase.

Figure A.2: Poverty Lines and Consumption Expenditure by Scenario

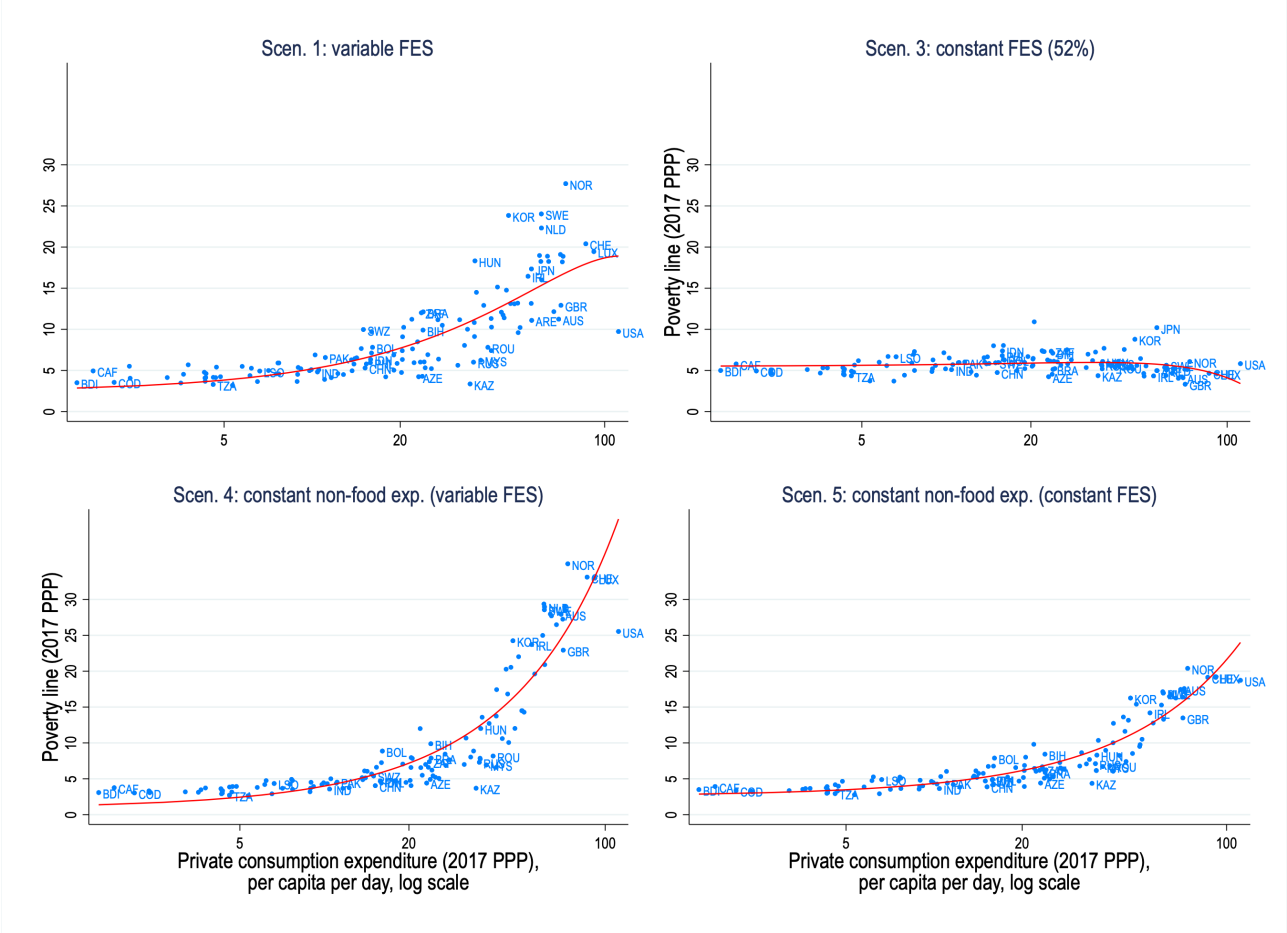


Table A.2: Regression Results

	(1) Harm. nat. povlines	(2) Poorest quartile	(3) Scen. 1 povlines	(4) Poorest quartile
Panel A: linear-linear				
Consumption exp. p.c.	0.411***	0.193***	0.185***	0.157***
	(0.000)	(0.000)	(0.000)	(0.000)
Constant	-1.269***	1.558***	3.613***	3.682***
	(0.000)	(0.000)	(0.000)	(0.000)
Panel B: log-log				
Log. consumption exp. p.c.	0.845***	0.355***	0.450***	0.183***
	(0.000)	(0.000)	(0.000)	(0.000)
Constant	-0.598***	0.343***	0.702***	1.201***
	(0.000)	(0.000)	(0.000)	(0.000)
Observations	611	160	630	160

Standard errors in parentheses

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table A.3: International Poverty Lines

Income classification	Harmonized national povlines		Scenario 1		Scenario 2		Scenario 3		Scenario 4		Scenario 5	
	Median	**N**	**Median**	**N**	**Median**	**N**	**Median**	**N**	**Median**	**N**	**Median**	**N**
High income	23.24	40	13.29	43	13.29	43	5.29	43	20.7	40	13.35	40
Upper middle income	6.71	34	6.44	37	6.44	37	6.06	37	6.75	34	6.28	34
Lower middle income	3.00	38	5.3	38	5.36	38	6.01	38	4.53	38	4.83	38
Low income	2.16	21	4.26	21	4.47	21	5.15	21	3.47	21	3.74	21
Total		133		139		139		139		133		133

Figure A.3: Proportion of Poor by World Region

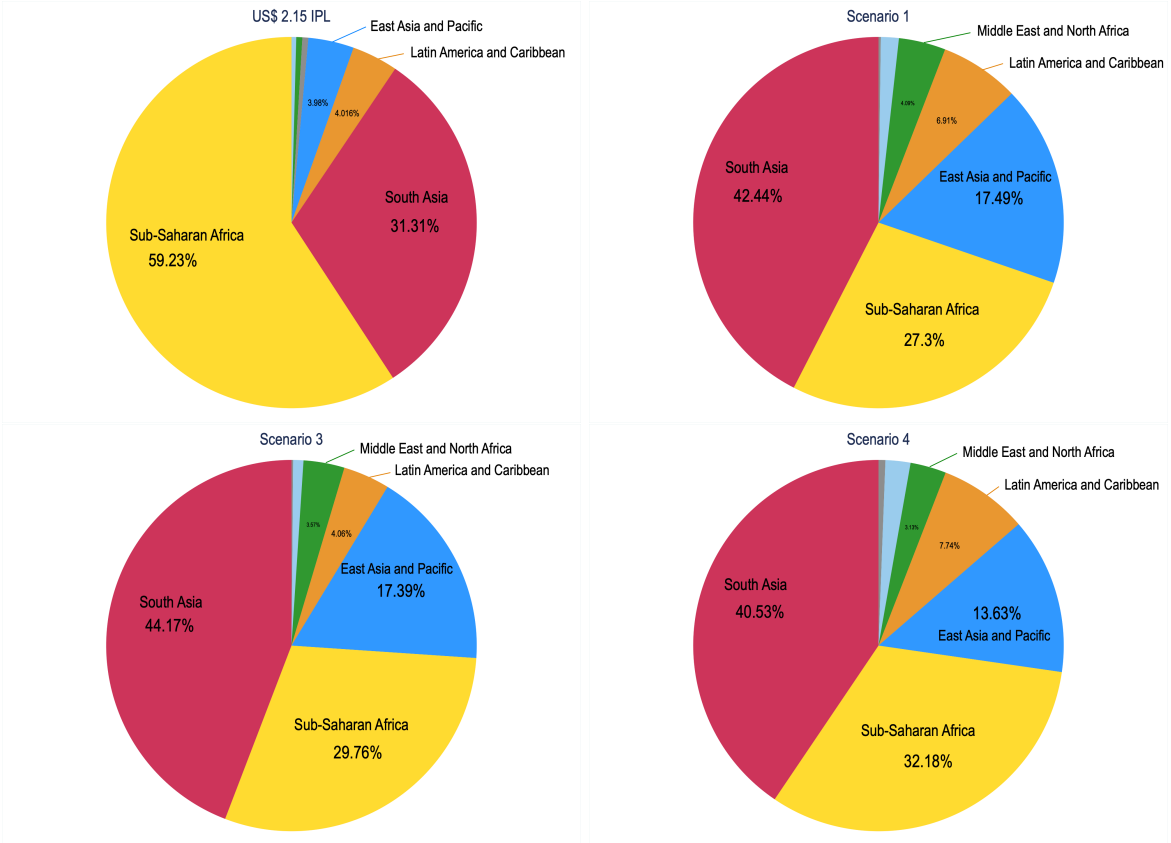


Table A.4: Number of Poor by Year, World Region and Scenario (in Mio.)

Year	World Region	Int. Pov. Line	Nation. Pov. Lines	Scen. 1	Scen. 2	Scen. 3	Scen. 4	Scen. 5
2017	East Asia and Pacific	37	143	582	582	544	362	350
	Europe and Central Asia	4	127	78	78	28	103	50
	Latin America and Caribbean	24	164	184	184	110	153	130
	Middle East and North Africa	3	46	109	109	97	69	62
	North America	4	88	10	10	6	52	25
	South Asia	229	293	1306	1306	1350	957	978
	Sub-Saharan Africa	372	400	754	759	828	645	679
	Total	672	1260	3007	3012	2951	2340	2275
2018	East Asia and Pacific	30	117	530	530	499	320	311
	Europe and Central Asia	3	120	73	73	24	96	46
	Latin America and Caribbean	24	162	178	178	107	149	127
	Middle East and North Africa	4	50	115	115	103	73	67
	North America	3	82	10	10	5	47	23
	South Asia	188	248	1221	1221	1275	842	864
	Sub-Saharan Africa	369	399	755	761	833	642	677
	Total	618	1178	2863	2868	2829	2170	2115
2019	East Asia and Pacific	22	92	500	500	470	284	277
	Europe and Central Asia	3	113	74	74	25	94	45
	Latin America and Caribbean	24	162	177	176	107	149	127
	Middle East and North Africa	4	47	117	117	105	69	63
	North America	3	74	9	9	5	42	21
	South Asia	192	256	1183	1183	1242	806	826
	Sub-Saharan Africa	374	404	770	776	851	653	689
	Total	620	1148	2806	2811	2783	2097	2048
2020	East Asia and Pacific	23	93	542	542	501	294	285
	Europe and Central Asia	3	114	72	72	25	93	45
	Latin America and Caribbean	22	161	190	190	107	150	127
	Middle East and North Africa	4	50	117	117	102	68	62
	North America	1	66	7	7	4	35	17
	South Asia	241	303	1269	1269	1324	905	925
	Sub-Saharan Africa	378	431	779	785	852	662	689
	Total	670	1217	2951	2957	2896	2207	2151
2021	East Asia and Pacific	26	100	508	508	508	286	282
	Europe and Central Asia	3	49	45	45	26	46	35
	Latin America and Caribbean	26	170	201	201	119	162	137
	Middle East and North Africa	3	47	119	119	104	66	60
	North America	3	16	6	6	4	13	10
	South Asia	203	257	1233	1233	1291	850	869
	Sub-Saharan Africa	384	437	793	800	870	675	702
	Total	648	1078	2881	2887	2899	2096	2096

Figure A.4: Annual Income Gap by Scenario

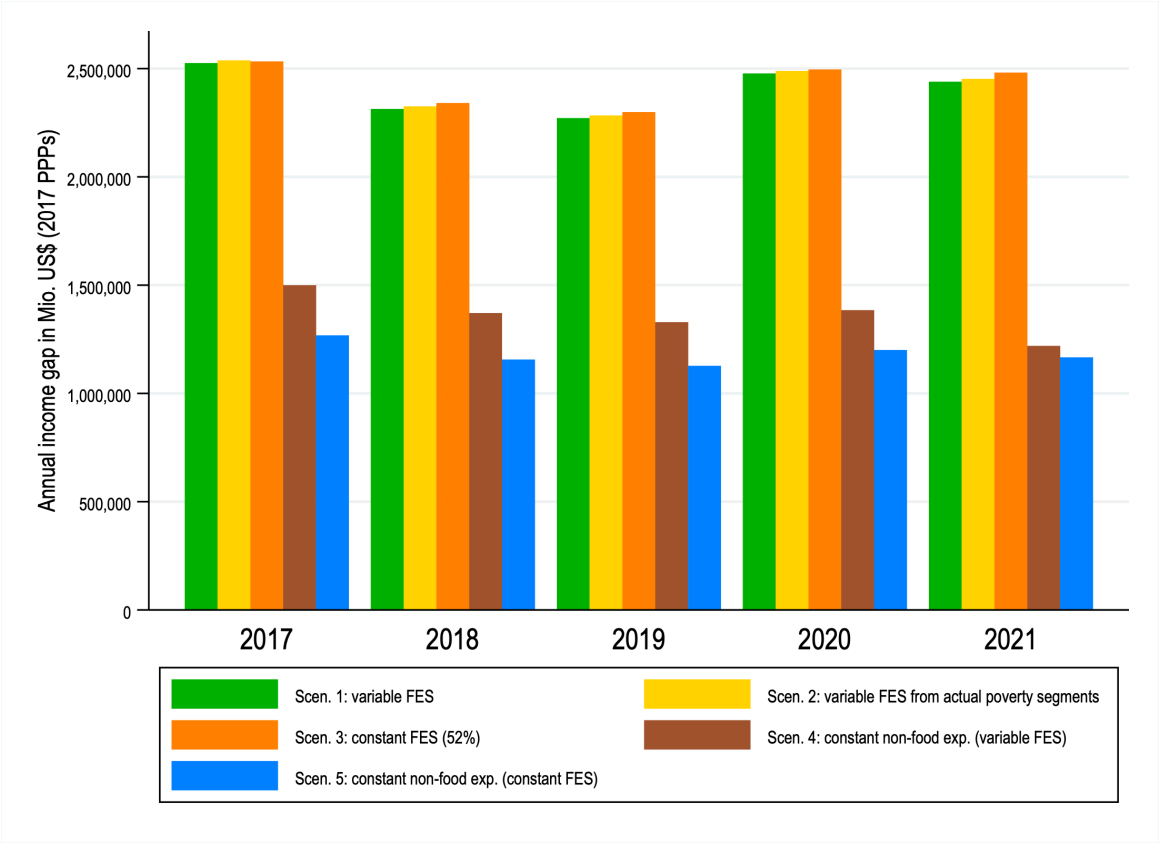


Figure A.5: Daily Income Gap (Variable FES)

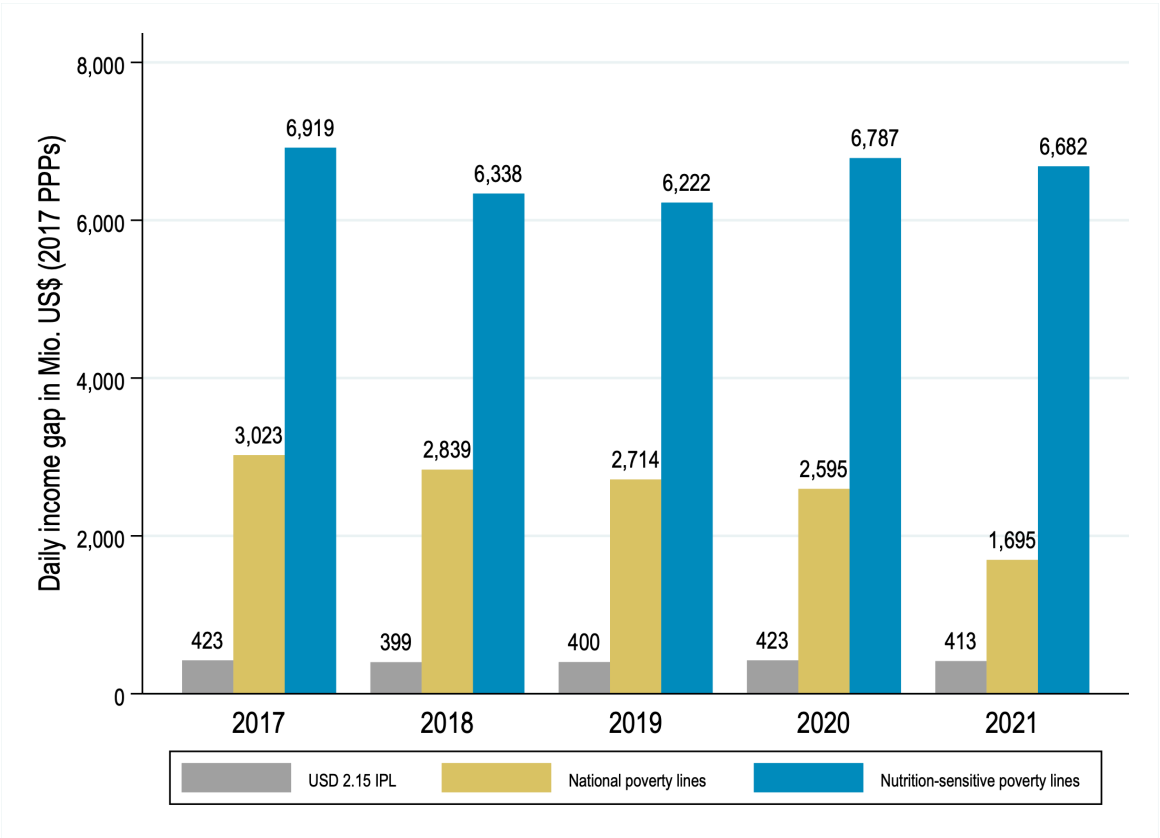


Figure A.6: Annual Gap over Time by World Region (Variable FES)

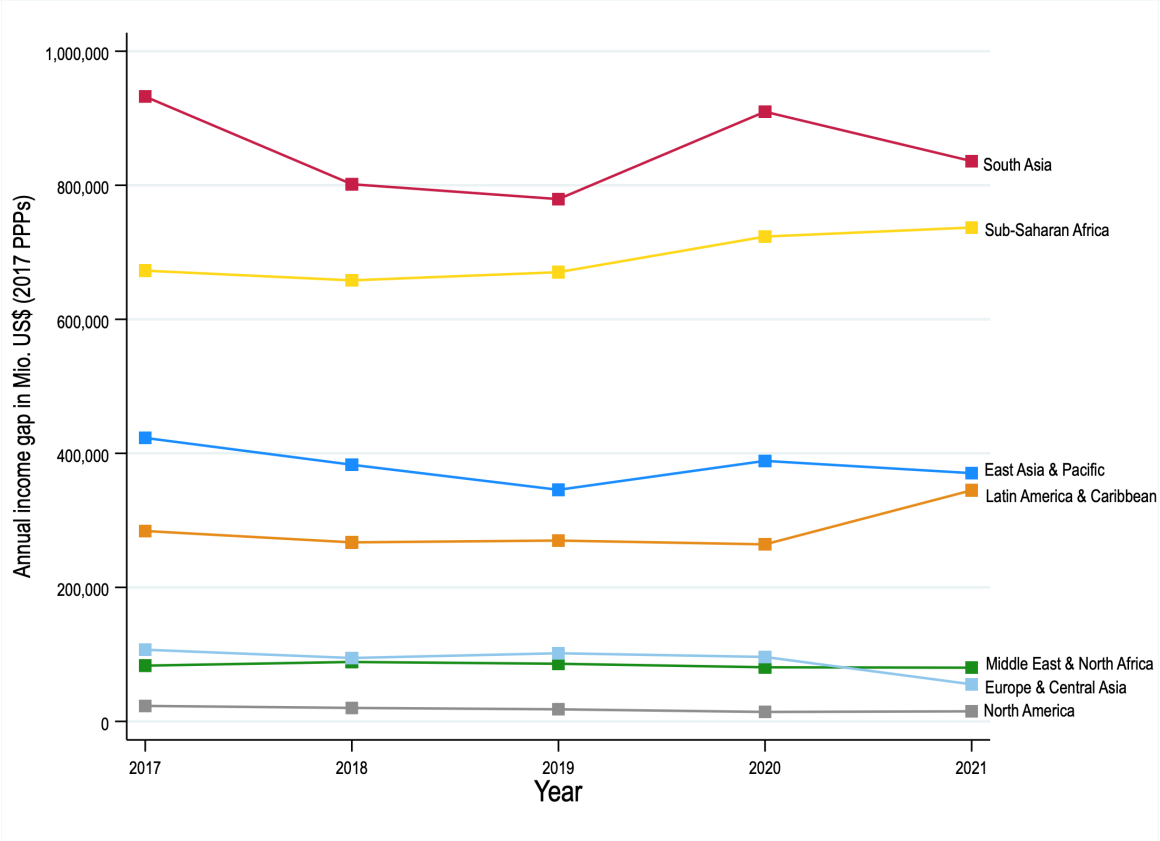


Table A.5: Annual Poverty Gap by Year, World Region and Scenario (in Mio. US$)

Year	World Region	Int. Pov. Line	Nation. Pov. Lines	Scen. 1	Scen. 2	Scen. 3	Scen. 4	Scen. 5
2017	East Asia and Pacific	5,200	80,516	423,022	423,022	439,153	195,338	176,356
	Europe and Central Asia	1,743	248,405	107,065	107,065	18,880	183,951	55,512
	Latin America and Caribbean	6,587	176,085	284,135	283,687	87,201	155,223	110,593
	Middle East and North Africa	475	21,639	83,213	83,213	59,264	35,760	28,348
	North America	2,604	392,561	23,164	23,164	9,315	172,070	72,902
	South Asia	33,685	48,366	932,301	932,301	1039266	374,650	393,347
	Sub-Saharan Africa	104,056	135,829	672,607	685,425	880,045	382,757	430,520
	Total	154,041	1,103,401	2,502,751	2,515,122	2,522,507	1,499,747	1,267,577
2018	East Asia and Pacific	4,075	73,244	383,007	383,007	406,449	174,453	157,109
	Europe and Central Asia	1,152	228,555	94,606	94,606	13,912	167,087	46,235
	Latin America and Caribbean	6,475	172,830	267,157	266,698	83,418	150,238	106,893
	Middle East and North Africa	581	23,255	88,716	88,716	63,994	38,487	30,739
	North America	2,231	360,376	20,141	20,141	7,951	156,549	66,244
	South Asia	27,680	41,542	801,598	801,598	898,810	309,656	325,671
	Sub-Saharan Africa	103,316	136,469	658,095	670,557	866,452	374,553	423,146
	Total	145,167	1,036,271	2,289,122	2,301,125	2,328,943	1,371,023	1,156,037
2019	East Asia and Pacific	2,771	66,265	345,591	345,591	372,075	152,052	135,885
	Europe and Central Asia	1,156	222,305	101,770	101,770	15,696	165,984	46,717
	Latin America and Caribbean	6,772	172,735	269,919	269,422	84,295	149,962	107,149
	Middle East and North Africa	544	21,834	86,050	86,050	63,175	34,932	27,563
	North America	2,034	325,617	18,105	18,105	7,137	139,875	59,477
	South Asia	28,193	42,745	779,334	779,334	870,008	304,146	318,708
	Sub-Saharan Africa	104,525	139,078	670,348	682,991	886,542	381,519	431,525
	Total	145,616	990,580	2,244,054	2,256,201	2,282,116	1,328,469	1,127,024
2020	East Asia and Pacific	3,124	72,398	388,770	388,770	408,366	165,944	147,677
	Europe and Central Asia	1,152	220,990	96,168	96,168	16,007	164,047	46,829
	Latin America and Caribbean	6,175	164,549	264,195	263,657	87,311	137,882	104,963
	Middle East and North Africa	502	25,339	80,803	80,803	60,702	38,042	30,716
	North America	672	272,318	14,136	14,136	3,778	117,163	47,291
	South Asia	36,733	51,158	909,778	909,778	1007300	367,383	383,694
	Sub-Saharan Africa	106,061	140,368	723,399	735,912	911,963	393,694	438,958
	Total	154,100	947,120	2,450,880	2,462,855	2,480,879	1,384,155	1,200,128
2021	East Asia and Pacific	3,223	38,056	370,416	370,416	434,934	153,815	158,119
	Europe and Central Asia	1,211	86,485	55,404	55,404	16,556	73,921	36,883
	Latin America and Caribbean	7,194	178,185	344,910	344,347	100,110	166,692	117,953
	Middle East and North Africa	455	21,338	80,151	80,151	61,299	34,804	29,172
	North America	1,870	112,463	15,056	15,056	6,683	67,137	39,044
	South Asia	29,167	40,724	836,011	836,011	929,250	322,923	338,650
	Sub-Saharan Africa	107,480	141,440	736,998	751,206	932,792	399,833	446,330
	Total	150,413	618,691	2,416,633	2,430,278	2,466,104	1,219,124	1,166,151