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Jonas Stehl, Lutz Depenbusch,
Sebastian Vollmer

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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

Healthy diet based poverty lines

Jonas Stehl[a], Lutz Depenbusch[b], Sebastian Vollmer[a]

[a]University of Goettingen [b]Misereor

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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 around food consumption inadequate for lifelong health. We propose 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 our proposed poverty lines, 2,283 to 2,865 million people were poor in 2022, facing a shortfall of US$ 1,657 to US$ 2,370 billion per year to meet their basic needs. This is in contrast to 654 million people who are considered to live in extreme poverty according to the World Bank's conventional poverty line. Further, these poverty lines identify 286 to 868 million more people as poor compared to the Societal Poverty Line, with the majority of these individuals concentrated in South Asia and Sub-Saharan Africa.

Key words: Poverty Measurement, Nutrition, Basic Needs, Healthy Diets, Welfare

JEL Classification: I32, I14, I15, N30, E20

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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 712 million individuals were living in extreme poverty worldwide in 2022. The global income shortfall for those living on less than the IPL amounts to US$ 174 billion per year (World Bank, 2024c). 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; Moatsos, 2024), a fundamental aspect of food security as defined by the FAO (FAO, 2004). Specifically, the designated consumption 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 contemporary concepts of basic needs should encompass the affordability of healthy diets to sustain long-term health. To that end, we 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 poverty and monitoring progress in poverty elimination, as declared in the Millenium Development Goals and the Sustainable Development Goals (SDGs). It 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, Ravallion et al. (1991) compiled national poverty lines of 33 countries to conceptualize the first international poverty threshold. 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 attempted 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). Henceforth, we will refer to these lines as country-specific poverty lines (CPLs). 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][3] This approach allows to construct country-specific poverty lines that share a common interpretation of achievement (Reddy and Pogge, 2010). It 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

[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, 2010).

[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).

[3]Mahrt et al. (2022) have shown that diets based on energy only may not even be sufficient to meet immediate nutrient needs, for instance, for child development.

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, according to these estimates, 72 percent of the population was poor in China in 1990 (World Bank, 2023). Globally, more than one out of three people could not afford basic needs (World Bank, 2023). Hence, the cost of basic caloric needs as consumed through the diet of a typical low-income person 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 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.

Many people globally lack the financial means to afford sufficiently nutritious foods even in higher income countries where the international poverty line is largely irrelevant (Hirvonen et al., 2020; Menyhért, 2022). To address this issue, the World Bank Commission on Global Poverty recommended a new approach to monitor global poverty that accounts for a country's standard of living because a change in living standards is associated with a change in the evaluation of what minimum needs are (Atkinson, 2017; Ravallion, 1998). In response, Jolliffe and Prydz (2021) developed the Societal Poverty Line (SPL), building on earlier work by Atkinson and Bourguignon (2001), Chen and Ravallion (2013), and Ravallion and Chen (2011, 2013).

The SPL combines elements of both absolute and relative poverty, recognizing bare minimum needs but also the change in minimum standards and social participation with income. It considers individuals as poor if they live on less than US$1.15 (in 2017 PPPs) plus 50% of the median consumption or income in their country (Jolliffe and Prydz, 2021). Importantly, the SPL now includes a floor set at US$2.15 to ensure a minimum threshold equivalent to the IPL (Tetteh Baah et al., 2024). As noted by Jolliffe and Prydz (2021), the original intercept in the SPL equation corresponds to the cost of a "barebone basket" as calculated by Lindgren (2015) and the lowest cost of a diet providing 2,100 calories per day, with 50g (or, in some countries, 34g) of protein for Zimbabwe, the country with the lowest value, as estimated by Allen (2017). However, while these baskets meet basic survival requirements, they are insufficient to maintain long-term health and survival as other nutritional requirements are unlikely to be met. Furthermore, the authors note that the intercept of the SPL is also unlikely to be socially acceptable because it allows for almost no diversity in diets (Jolliffe and Prydz, 2021). For several of the lowest-income countries comprising more than 200 million people, the SPL remains equivalent to the US$2.15 IPL. Yet, this thresholds may be insufficient to meet basic nutritional needs, especially regarding the consumption of micronutrient-rich foods like fruits, vegetables, and animal-source products. It therefore does not correspond to the human right to food that has been defined as "quantitatively and qualitatively adequate and sufficient food [...] which ensures a physical and mental, individual and collective, fulfilling and dignified life free of fear" (Ziegler, 2008).

Hirvonen et al. (2020) assessed the affordability of the EAT-Lancet reference diet, which provides a useful measure of affordability of the food component. They show that the proportion of people unable to afford this diet exceeds the proportion of people considered poor by the IPL in all countries except Germany (where both figures are zero). In fact, the average cost of the EAT-Lancet diet (US$3.92 in 2011 PPP) is more than double the IPL at that time of US$1.90, indicating that neither the IPL nor the SPL in low-income countries may adequately capture the cost of essential dietary requirements in poverty measurements.

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 various characteristics of the food environment.

Addressing the concerns of impracticality and social acceptability, least cost diets such as those used for SOFI 2020 incorporate local preferences and tastes by restricting item selection to products actually being bought and sold on local markets (FAO et al., 2020; Herforth et al., 2020). 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, 2016). 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 food needs as defined by a healthy diet basket. 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 summed income shortfall of these people below the threshold.

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 meet 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 three different healthy-diet poverty lines (HPLs) that vary in the way non-food expenditures are taken into account but generally follow the form $poverty\,line_{c,y} = NFE_c + CoHD_{c,y} \times DSF_{c,y}$, with c corresponding to the country and y to the year. *NFE* are the non-food expenditures, *CoHD* is the expenditure on food, the cost of a healthy diet, and *DSF* a demographic scaling factor.

2.2 Healthy diets

We use Cost of a Healthy Diet (CoHD) data provided by the World Bank's Food Prices for Nutrition data (World Bank, 2024a). 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 SOFI 2020 (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 (*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.[4] 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.

[4]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).

2.3 Demographic scaling factors

The Cost of Healthy Diet 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., 2024). 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.

To account for variations in physical composition and nutrient needs across countries, we employ demographic scaling factors (DSFs). These factors are derived using sex and age-disaggregated population information from the United Nations Population Division's World Population Prospects 2022. For energy requirements, we follow the approach proposed by Headey et al. (2024) using data on energy requirements from FAO (2004) and Willett et al. (2019), depicted in Table A.2.

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 in this year. 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.

2.4 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, 2024c). 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.

In their annual update in March 2024, for the first time, the World Bank provided global income distributions for post-COVID years 2020, 2021, and 2022.[5] It is important to note that survey coverage during the post-2019 period is still limited in Sub-Saharan Africa and the Middle East and North Africa. Therefore, these numbers should be interpreted with some caution (World Bank, 2024b).

2.5 Non-food expenses

To determine healthy-diet poverty lines, 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. These expenditures tend to be more diverse, with prices for these items exhibiting greater variability and more difficult accessibility, making them more challenging to ascertain than food prices. There are two main approaches to calculating non-food expenditures: applying food-expenditure shares (FES) to income or food-expenditure data or developing a minimum non-food needs basket and calculate its costs. For our calculations, we use actual FES of the poorest income segment in each country, assuming that this population group spends its income to meet minimum food and non-food needs.

FAO et al. (2023) 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

[5]These numbers align well with the nowcasts by Mahler et al. (2022) used in a previous version of this paper (World Bank, 2024b).

in non-food costs between countries (Headey et al., 2024). 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. (2024) 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.

To estimate households' shares of income spent on food, the SOFI-2023 makes use of national accounts expenditure data from the World Bank's International Comparison Program (FAO et al., 2022, 2023). 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.[6] 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 spent 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. (2024) for more countries and more recent ICP data. Although this marks progress, expenses for basic health care or education are not considered which does not align with our understanding of basic

[6]For instance, South Africa reports national accounts food expenditure shares of 16.5 percent. However, in reality, poor households spend almost a third of their consumption on food.

needs. While their estimations of costs for fuel, lighting, and clothing vary with the climate, values for housing ($3m^2$ per capita) and soap (25g per capita per week) are fixed. In reality, the evaluation of those needs may also vary across countries.

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 133 countries. This information is sourced from reports and studies that rely on nationally representative surveys, or alternatively, we calculate it using available micro data (*Table A.3*). Most of the data is obtained from national statistics offices.[7] We utilize the most recently available data point for all years in our analysis. Nationally representative household surveys, which are used for the calculation of food-expenditure shares, are not conducted annually. Consequently, comprehensive FES information is not obtainable for each year. However, the fluctuations in food-expenditure shares have been quite modest. As an illustrative example, among the 22 countries with FES data derived from EUROSTAT Household Budget Surveys in both 2015 and 2020, the FES exhibited changes of no more than 5 percentage points. For 12 of these countries, the FES remained stable with changes of less than 1 percentage point. Therefore, we anticipate that the alterations in FES between 2017 and 2022 are also relatively slight.

As incomes rise, individuals tend to allocate a larger proportion of their resources to non-food goods (*Figure A.1*). In high-income countries, the poorest income quintile spends an average of 22 percent of their income on food. In upper-middle income countries, the poorest segment already devotes 44 percent of their income to food, while in lower-middle income countries, this figure rises to 56 percent, and in low-income countries, it reaches as high as 61.4 percent, almost the same as calculated for the FAO et al. (2020).[8]

Food-expenditure shares of the poorest 20 percent within a country may understate minimum food needs in extremely poor countries, where a substantially higher proportion of the population is considered poor, and overstate minimum food needs in rich countries, where a

[7] In cases where both WB-GCB and other data is missing, we approximated it by using the median 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. Of those countries included in the final analyses ($n = 145$), 20 of the food-expenditure shares are from the WB-GCB and 13 are proxied.

[8] The highest food expenditure shares are observed in Somalia (79.5%), Sao Tome and Principe (78.42%) and the Democratic Republic of the Congo (76.41%). The smallest proportion of income that the poorest quintile allocates on food is observed in Norway (11.4%) and the Netherlands (11.8%).

lower proportion is considered poor. However, food-expenditure shares in extremely poor countries do not necessarily decrease with higher-income quintiles. Households tend to allocated a similar proportion of their income on food and non-food needs as their poorer counterparts (*Figure A.1*). This implies that our proposed HPLs would only change marginally if we based the selection of the income quintile on other income or poverty measures. For simplicity, we therefore use FES of the poorest income segments.

2.6 Setting the parameters for different poverty approaches

We develop three distinct HPL variants that vary by how non-food expenditures are taken into account. For healthy-diet poverty line variant 1 (HPL 1) we apply the following formula:

$$HPL\,1_{c,y} = \frac{CoHD_{c,y}}{FES_c} \times DSF_{c,y}. \tag{1}$$

This variant assumes that households continue allocating the same proportion of their income to food if they can afford both a healthy diet and other essential needs, as the poorest income quintile currently does. However, this assumption may not always hold. The equation only provides an exact estimate if the poorest 20% under-consume non-food needs to the same extent as food needs. Yet it provides a reasonable and practical approximation. In the case of absolute national poverty lines, non-food needs are typically determined by averaging the non-food spending of households near the food poverty line, meaning that non-food expenditures are also tied to the assessment of food poverty. The food component typically reflects the cost of meeting caloric requirements where the cost of a calorie reflects the diet of the typical low-income person in that country. This is then scaled to a predefined threshold of calories that varies from country to country. If countries were to adopt healthy diets as the food poverty threshold, they would add the non-food spending of households around that line to calculate minimum non-food needs. Consequently, absolute national poverty lines, similar to Equation (1), overestimate or underestimate poverty depending on whether households near the food poverty line are just above or below a hypothetical non-food poverty line.

If the poorest 20% have already met more than their minimal non-food needs, Equation (1) will overestimate poverty. This is likely for many countries, especially high-income ones, where

individuals around the 20th income percentile are more likely to have fulfilled their basic non-food needs compared to low-income countries. In extremely poor countries, those around the 20th percentile may spend less than the minimum required on non-food items because their priority is meeting food needs. As illustrated in Figure A.1, the FES in extremely poor countries remains relatively constant across income quintiles one to three, suggesting that individuals allocate a consistent proportion of their income to food and non-food needs as their income rises. This consistency implies that poverty estimates using this equation are likely accurate for poorer countries. In richer countries, however, is likely to be overestimated, when applying a strict understanding of basic needs. Nonetheless, higher non-food needs can also be viewed as reflecting the costs of social inclusion and participation, similar to the SPL.

A second assumption is that each country's non-food minimum needs are tied to the CoHD, with minimum non-food costs fluctuating in line with the country's food prices for the least expensive items that add up to CoHD. This would imply that non-food costs vary proportionally with the CoHD such that a country's food CPI mirrors its overall CPI. While this is plausible—given that retail prices are influenced by factors like rent, labor, and energy costs—food prices tend to be more volatile and may experience significantly greater fluctuations.

Healthy-diet poverty line variants 2 (HPL 2) and 3 (HPL 3) consider non-food expenditures in different ways. HPL 3 follows a more national perspective on global poverty measurement, as suggested by some scholars (Deaton, 2010; Greenstein et al., 2014). This approach assumes that basic non-food expenditures are assessed best by each national statistics office and, thus, the national country-specific poverty lines (CPLs). For absolute poverty lines, this is typically done by using actual food expenditure shares of households around the food poverty line which in turn vary by country. Therefore, non-food expenditures in CPLs also depend on the definition of being food poor because households around lower FPLs will most likely also spend less on non-food items. For instance, if a country uses 3000kcal per adult equivalent (as Uganda) and a rather diverse diet, the food poverty line may be higher compared to a country that assumes less kilo calories and a less diverse diet, although they would have been the same if both countries had made the same assumptions. Therefore, both food and non-food costs and, thus, the absolute national poverty lines, depend on each country's definition of food poverty. Further, non-food expenditures in absolute CPLs are implicitly based on the assumption that

households that just meet their food needs (according to which ever definition) also just meet their non-food needs.

HPL variants 2 and 3 are calculated as follows:

$$HPL\,2_{c,y} = SPL_{c,y} \times (1 - FES_c) + CoHD_{c,y} \times DSF_{c,y}. \tag{2}$$

$$HPL\,3_{c,y} = CPL_{c,y} \times (1 - FES_c) + CoHD_{c,y} \times DSF_{c,y}. \tag{3}$$

HPL 2 takes non-food expenditures from the SPL. Thus, for countries where $US\$1.15 + 0.5 \times median\,income > US\$2.15$, this value will be multiplied with non-food expenditure shares of the poorest income segment of a country. Non-food minimum needs will solely depend on a country's median income and on the proportion the poor of a country spend on food. Therefore, these are independent of a country's judgement of minimum food or non-food needs and calculated in a harmonized manner which allow better international comparability. For countries where the SPL equals the IPL, non-food expenditures eventually also depend on the median CPL of LICs, and, thus, the judgement of minimum food needs in LICs. In this case, however, SPLs are typically larger than CPLs, leading to on average slightly increased non-food expenditures in HPL 2 compared to HPL 3 for lower income countries.

3 Results

3.1 A comparison of poverty lines

Figure 1 presents poverty lines of all HPL variants, SPLs, and CPLs[9] plotted against logarithmized median consumption expenditure as a measure of economic welfare for 145 countries, around 94% of the global population.

[9]Harmonized national poverty lines are obtained from the World Bank. Since not all countries provide national poverty lines in each year, we used the resulting headcount ratios to obtain interpolated values between years with available lines and carried headcount ratios further for the most recent values available. We then used the PIP Stata command to obtain poverty lines from these headcount ratios. This implicitly assumes that the proportion of poor did not change since then. However, given that poverty rates decrease in most countries, this may slightly overestimate poverty if the country had developed a CPL for that year.

All poverty lines demonstrate a discernible trend where poverty lines tend to increase as median 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 2022 and limiting the sample to the poorest quartile in each year, the correlation is positive and significant for all but HPL 1 (*Table A.4*). The slope of HPL 2 and 3 is around a third to half the magnitude of the CPLs for the poorest quartile. 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).

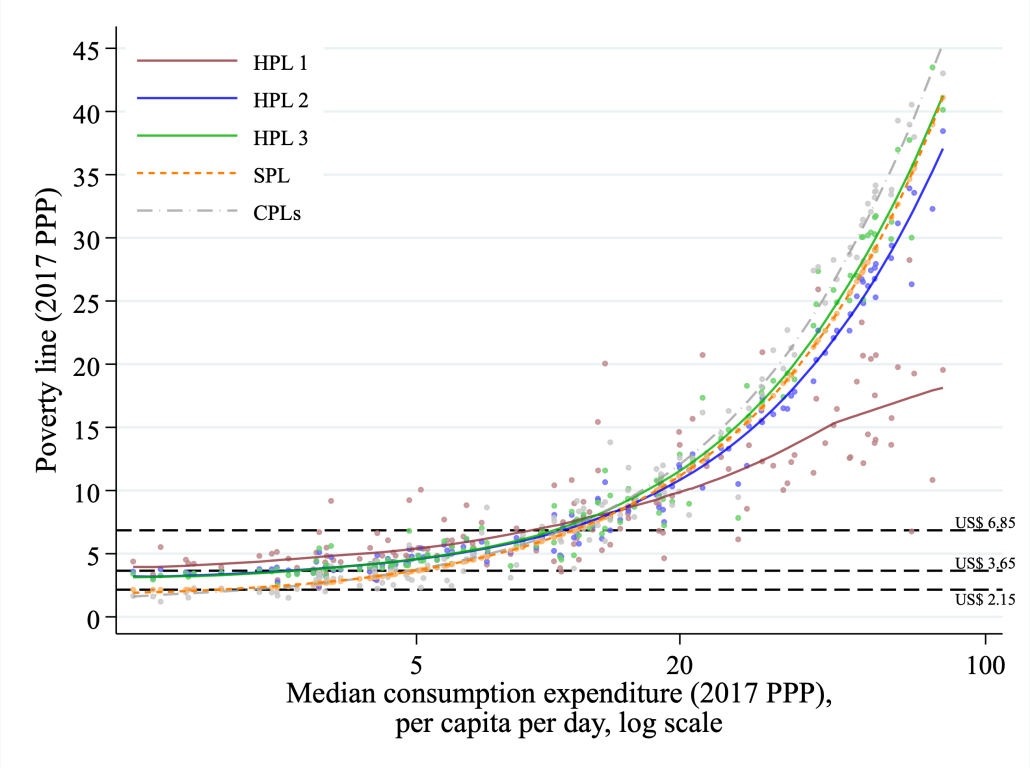

Figure 1: Poverty lines and consumption expenditure

Note: The graph displays 2022 poverty lines from three proposed healthy-diet poverty line (HPL) variants, alongside national poverty lines (CPLs) from Jolliffe et al. (2022) and the Societal Poverty Lines (SPLs) from Jolliffe and Prydz (2021) plotted against median private consumption expenditure per capita per day in 2022 (logarithmic scale). The lines depict a fitted lowess (locally weighted scatterplot smoothing) regression line for all 145 countries. All data is expressed in 2017 PPPs.

The smaller the slope coefficient, the greater the constant. When looking at the full sample in Table A.4, we find the greatest intercept for HPL 1 which is a mean consumption expenditure of US$ 4.4 or a median consumption expenditure of US$ 4.6 in the linear-linear model. In

contrast, HPL 2 has an intercept of US$ 2.2, HPL 3 of US$ 1.7, and the CPLs only of US$ 0.7 using median consumption expenditure as suggested as the preferable indicator by Jolliffe and Prydz (2021). This suggests higher poverty lines for the poorest countries in HPL 1, but also in HPL 2 and 3 compared to national poverty lines but also the SPL as seen in Figure 1. In fact, all countries have poverty lines above the US$ 2.15 IPL in all HPL variants. At the same time, Sudan, Sao Tome and Principe, Tanzania, Guinea, Dem. Rep. of the Congo, and Chad are all among the ten countries with the lowest HPLs in all variants The country with the lowest HPL 1 is Sudan at US$ 2.28 in 2017 PPPs. Sudan also has the lowest poverty line in HPL 2 with US$ 2.42, while Tanzania with US$ 2.53 represents the country with the lowest line in HPL 3. Conversely, thirteen countries have CPLs below US$ 2.15 in 2022 with China having the lowest value at US$ 1.00, a poverty line from 2020. Seven countries take the floor of the SPL at the value of the IPL at US$ 2.15 in 2022.

As consumption levels increase, the gradient becomes markedly steeper for HPL 2 and 3 and reaches a slope close to that of the CPLs (*Table A.4*). In the lowess fit regression in Figure 1 these two HPLs seemingly mirror each other until daily consumption levels of around US$ 20 when CPLs start exceeding the SPLs and, thus, the non-food expenditure parts taken from these lines in HPL 2 and 3. This is because many high-income countries set their national poverty lines at higher values such as 60% of the median income. In all these variants Luxembourg has the highest poverty line at US$ 38.45 for HPL 2, US$ 40.13 for HPL 3, US$ 41.10 for the SPL, and a CPL of US$ 43.01. In general, HPL 2 and 3 show a strong correlation with the CPLs and the SPL (*Figure A.2*). A linear fit of HPL 3 and the SPL even evolves as a 45-degree line. The greatest R-squared in the linear-linear model has HPL 2 for both mean and median consumption expenditure, while HPL 3 and the CPLs are similar in magnitude (*Table A.4*).

HPL variant 1 has considerably lower poverty lines than all other variants at the upper consumption expenditure distribution starting to fall below these lines at consumption levels of around US$ 25 (*Figure 1*). Here, the country with the highest HPL in 2022 is Norway at US$ 28.24.

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, one of the reasons for the development of the Societal

Poverty Lines by Jolliffe and Prydz (2021). 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).

Table A.5 provides an overview for each income group, year and variant. Remember that global poverty lines are developed using the median of national poverty lines within a World Bank income group. As suggested by Figure 1, HPL 1 yields a notably higher IPL for LICs in 2017 (US$ 4.17), almost twice the magnitude of the CPLs, and the lowest IPL for HICs (US$ 12.77), around half the magnitude of CPLs. If an international poverty line was developed based on the framework of our new national poverty lines, it would be positioned at approximately US$ 4.22, about doubling the current International Poverty Line.

For LMICs, the median is still greater than that calculated for CPLs, while the values for UMICs align very closely. Overall, poverty measurement for UMICs aligns very closely across all approaches with a variation of no greater than US$ 0.38 in 2017 (*Table A.5*). Hypothetical IPLs of HPL 2 and 3 also align closely across other income groups. Changes over years are small, in particular for HPL 1 and 2. CPLs and HPL 3, where non-food expenditures are calculated from CPLs, are subject to slightly more changes which may also be the result of how we account for the non-availability of annual national poverty lines.

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

Figure 2 contrasts current global poverty estimates based on the US$ 2.15 IPL or the Societal Poverty Line with poverty estimates based on national poverty lines and healthy diet poverty lines proposed in this paper.

It is striking that HPLs result in 3.5 to 4.5 times more people living in poverty in 2022 compared to the US$ 2.15 IPL. HPL 2 as a medium variant indicates that in 2022 over 2.5 billion people were living in poverty. In other words, more than 2.5 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 34.11 percent (*Figure A.3*).[10] This stands in contrast to a global poverty rate of 8.73 percent based on the US$ 2.15 IPL. HPL 1 represents an upper bound with

[10]Note that this rate is estimated based on the poverty and population of 145 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.

2.865 billion poor in 2022 and HPL 3 represents a lower bound with 2.283 billion people living in poverty.

When comparing the number of poor based on the HPLs with the SPL, the gap is substantially smaller but still sizable. In 2022, 562 million more are poor according to HPL 2 than measured by the SPLs. The global poverty rate is around 7.5 percentage points larger (*Figure A.3*).

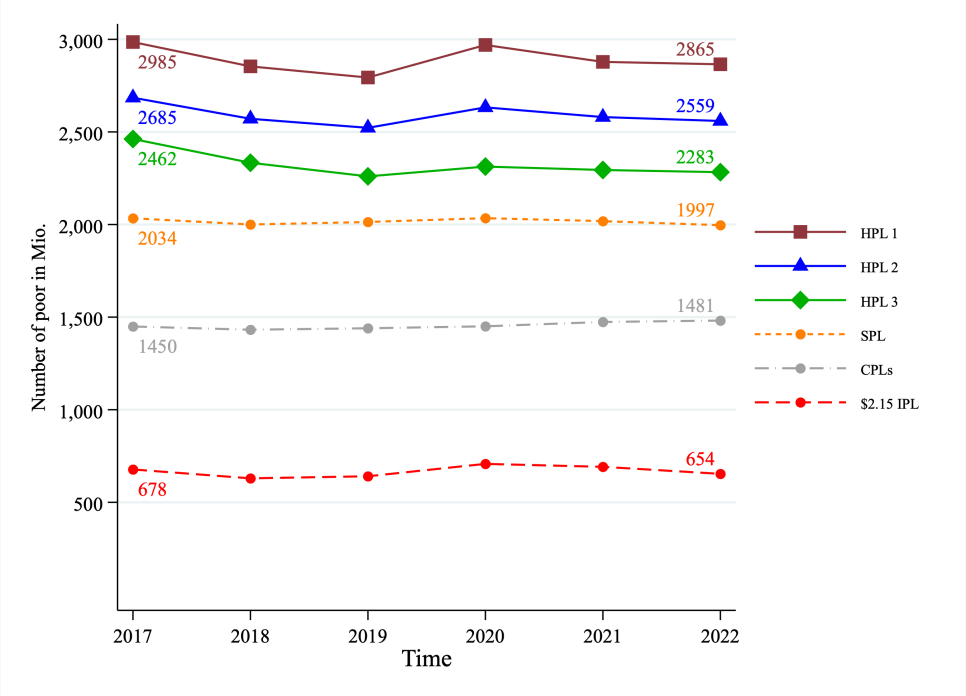

Figure 2: Number of poor by poverty approach

Note: This figure shows global estimates ($n = 145$) in the number of poor people according to our three proposed healthy-diet based poverty lines (HPL), the US$ 2.15 International Poverty Line (IPL), country-specific harmonized poverty lines (CPLs), and the Societal Poverty Line (SPL). For six countries without CPLs, we imputed the headcount ratios. Global poverty numbers for a restricted sample of $n = 139$ is available in the appendix (*Figure A.4*)

In general, all proposed approaches to measuring poverty exhibit a similar global trend over time. Between 2017 and 2022 global poverty counts have experienced a decrease of 120 (HPL 1) to 179 (HPL 3) million poor, resulting in lower poverty rates by 3-4 p.p. Most of this variation comes from South Asia (*Figure A.6*). The reduction in the number of poor according to the SPL and the US$ 2.15 IPL is comparatively small with 37 and 24 million fewer poor, resulting in lower poverty rates by 1-2 p.p. The time trend of the CPLs should be interpreted with caution given that some of the national poverty lines may be dated and headcount ratios have reduced since then and we imputed headcount ratios for six countries. Using the restricted

sample without imputed countries shows a slightly larger reduction for CPLs and HPL 3, where non-food expenditures are based on CPLs (*Figure A.4*). This suggests that imputations may have led to slight overestimations for these two variants.

In addition, it should be noted that HPL variants are adjusted for differences in dietary requirements based on the age- and sex-structures of a country, while conventional approaches are expressed in per-capita values. Figure A.5 shows that disregarding these differences increases the global number of poor by 154 mio. (HPL 3) to 215 mio. (HPL 1).

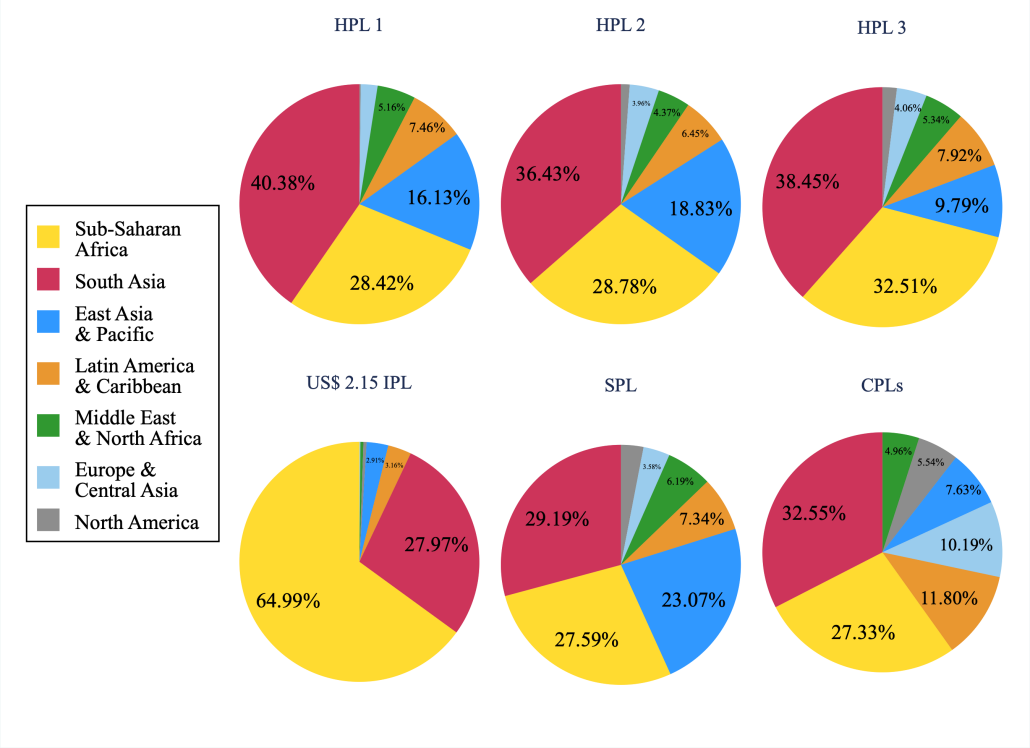

Figure 3: Proportion of global poor by world region and variant in 2022

Note: The graph shows the proportion of the global number of poor by world region according to our three proposed healthy-diet based poverty lines (HPL), the US$ 2.15 International Poverty Line (IPL), country-specific harmonized poverty lines (CPLs), and the Societal Poverty Line (SPL) in 2022.

Figure 3 plots the proportion of poor in 2022 by world region and approach to poverty measurement. While around 93% of the global poor are living in sub-Saharan Africa or South Asia according to the US$ 2.15 extreme poverty line, these two world regions only constitute between 65% (HPL 2) and 71% (HPL 3) of the global poor, when applying HPLs. With less than 60%, this proportion is even smaller when SPLs or CPLs are applied. In all of these approaches higher poverty lines are applied to richer countries, and, thus, also increase poverty

in these regions. South Asia is the region with the largest number of poor, while around two-thirds of the poor live in sub-Saharan Africa according to the US$ 2.15 IPL. Notably, East Asia and Pacific represents a relatively small share in HPL 3 and the CPLs which is largely due to a low national poverty line applied by China. In the SPL approach, this region constitutes 23%, more than in any other variant. The proportion of poor in Europe and Central Asia, the Middle East and North Africa, and Latin America and the Caribbean varies only slightly across HPL variants and the SPL approach. Europe and Central Asia and Latin America and the Caribbean contribute somewhat more to global poverty when CPLs are applied.

Figure 4, panel a) depicts the poverty headcount ratios for HPL 2 as a medium variant for all countries with available data in 2022. Headcount ratios for HPL 1 and HPL 3 are depicted in Figure A.8 and Figure A.9 in the appendix. The headcount ratio indicates the percentage of the population living in poverty.

Across Africa, almost all countries display headcount ratios exceeding 40 percent. Particularly high poverty headcounts in Africa are observed in Madagascar (92%), Mozambique (89%), Malawi (88%), and the Democratic Republic of the Congo (87%). Outside Africa, only Haiti (78%) exhibit poverty rates of 60 percent or more. While most headcount ratios in Europe and Central Asia are below 15%, there are some exceptions where almost one in three persons cannot afford basic needs (Kyrgyzstan: 37%, Tajikistan: 30%, Armenia: 30%).

Figure 4, panel b) and c) show the differences in poverty headcount ratios of medium variant HPL 2 with the SPL and the US$ 2.15 IPL. While the headcount ratio for Malaysia (– 11 p.p.) and Ecuador (– 10 p.p.) is higher when the SPL approach is used, particularly Haiti (+ 35 p.p.), Niger (+ 31 p.p.), and Pakistan (+ 30 p.p.) have an increased proportion of poor when HPL 2 is used. Compared to the extreme poverty line of US$ 2.15, headcount ratio increase severely for Pakistan (+ 52 p.p.), Egypt (+ 48 p.p), and Haiti (+ 46 p.p.). While countries with high headcount ratios do not face higher healthy diet costs, it is mainly the lack of income that drives poverty (*Figure A.7*).

HPL variant 1 has higher headcount ratios at medium poverty levels compared to other approaches (*Figure A.10*). The largest differences compared to HPL 2 emerge for Lebanon (+ 36 p.p.) and Grenada (+ 35 p.p.). In contrast, poverty headcounts of HPL 2 and 3 align very closely, with a pairwise correlation of 0.982 (*Figure A.10*). Here, the largest difference

compared to HPL 2 emerge for Lebanon (+ 23 p.p.) and China (– 16 p.p.). Comparing HPL approaches to the headcount ratios based on the SPL, they have lower values at low poverty levels, while headcount ratios are higher than those based on the SPL for higher poverty levels (*Figure A.10*).

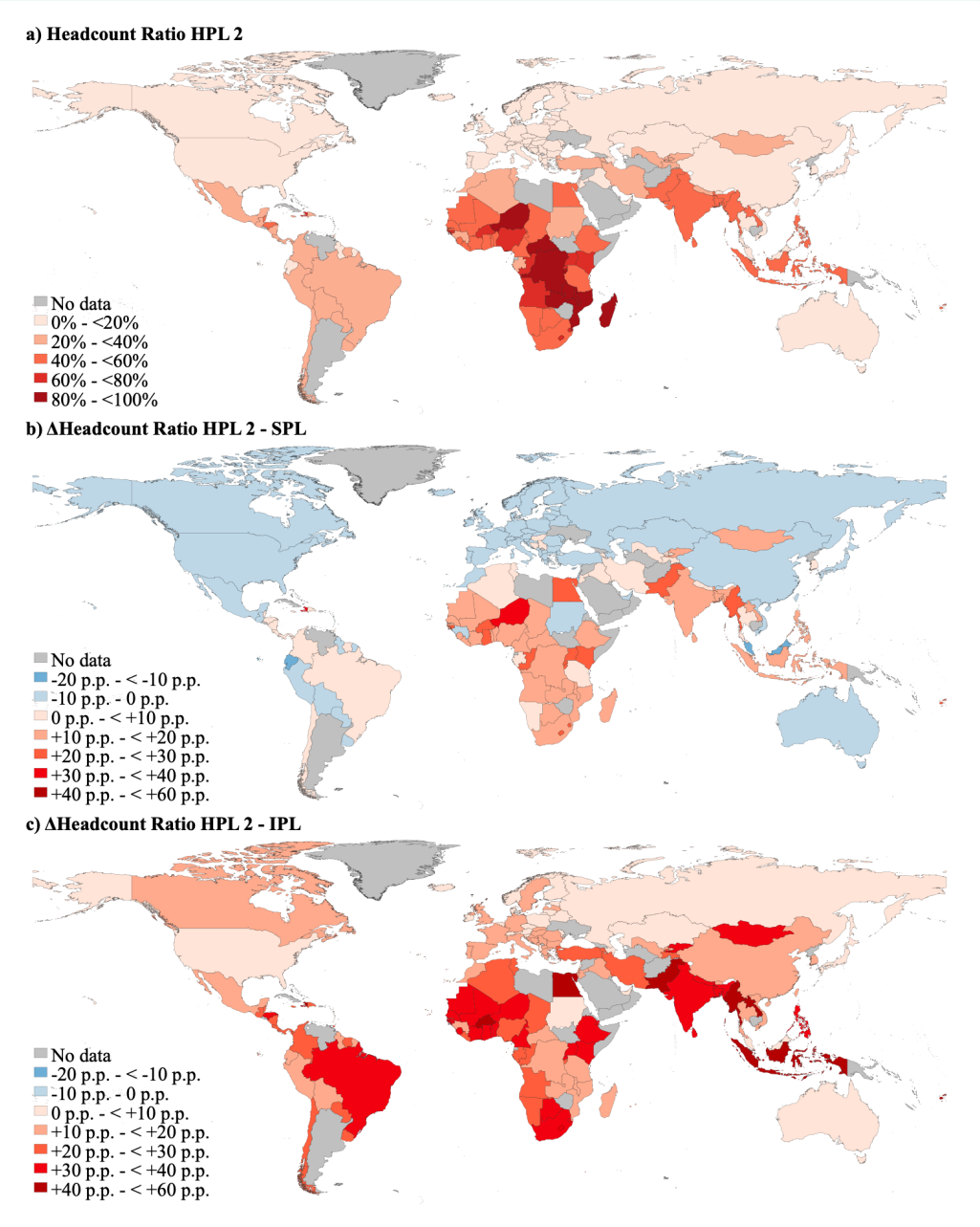

Figure 4: HPL 2 poverty headcount ratio in 2022

Note: Panel a) shows poverty headcount ratios in 2022 based on healthy diet poverty line 2 (HPL 2). Panel b) depicts the absolute difference in poverty headcount ratios between HPL 2 and the Societal Poverty Lines (SPLs). Blue shades depict countries for which the SPL headocunt ratio is higher than the HPL 2 headcount ratio. Panel c) shows the difference between HPL 2 and the US$ 2.15 IPL in 2022. The same maps for HPL 1 and 3 are provided in the appendix (*Figure A.8 and Figure A.9*)

3.3 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.[11]

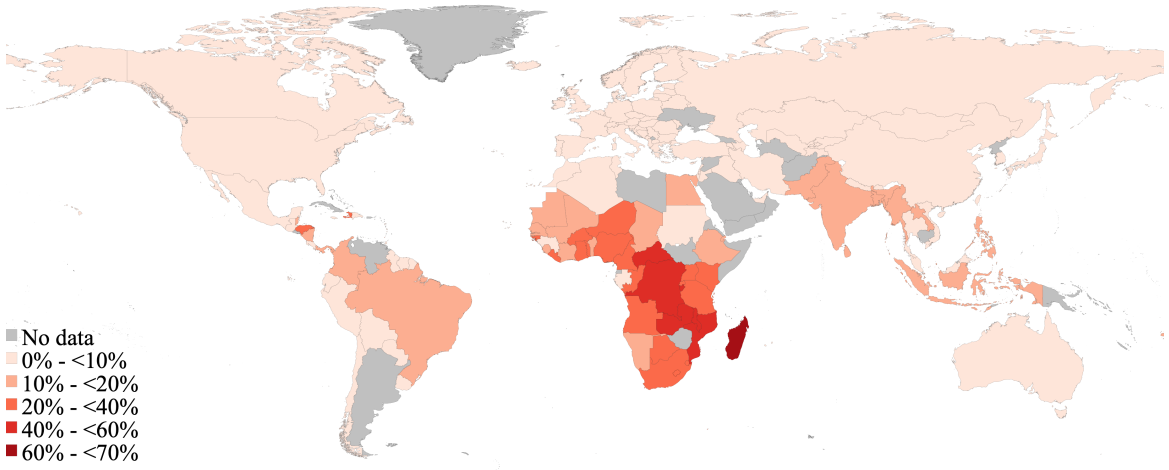

Figure 5: Poverty gap index HPL 2 in 2022

As depicted in Figure 5 for the medium variant HPL 2, 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 (0.60) and Mozambique (0.57) exhibit a substantial PGI, indicating that, on average, the income or consumption of individuals in these countries is 57 to 60 percent below the healthy diet poverty lines of variant 2. Among the top twenty-five countries with the highest PGIs, all but one are situated in sub-Saharan Africa, with Haiti being the exception, experiencing an income deficit of 39 percent. PGIs of HPL 1 and 3 provide a similar picture (*Figure A.11 and Figure A.12*). Mozambique and Madagascar represent also here the countries with the highest PGI (0.68 and 0.59 for HPL 1 and 0.67 and 0.53 for HPL 3).

The absolute income shortfall over the entire population of a country indicates the amount of money individuals are missing to be able to afford a healthy diet and other basic needs. If money could be transferred to the poor without any costs and without any targeting errors in identifying who the poor are and how poor they are, then the total amount needed to be transferred would be the amount of the income gap. Figure 6 shows the annual global income

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

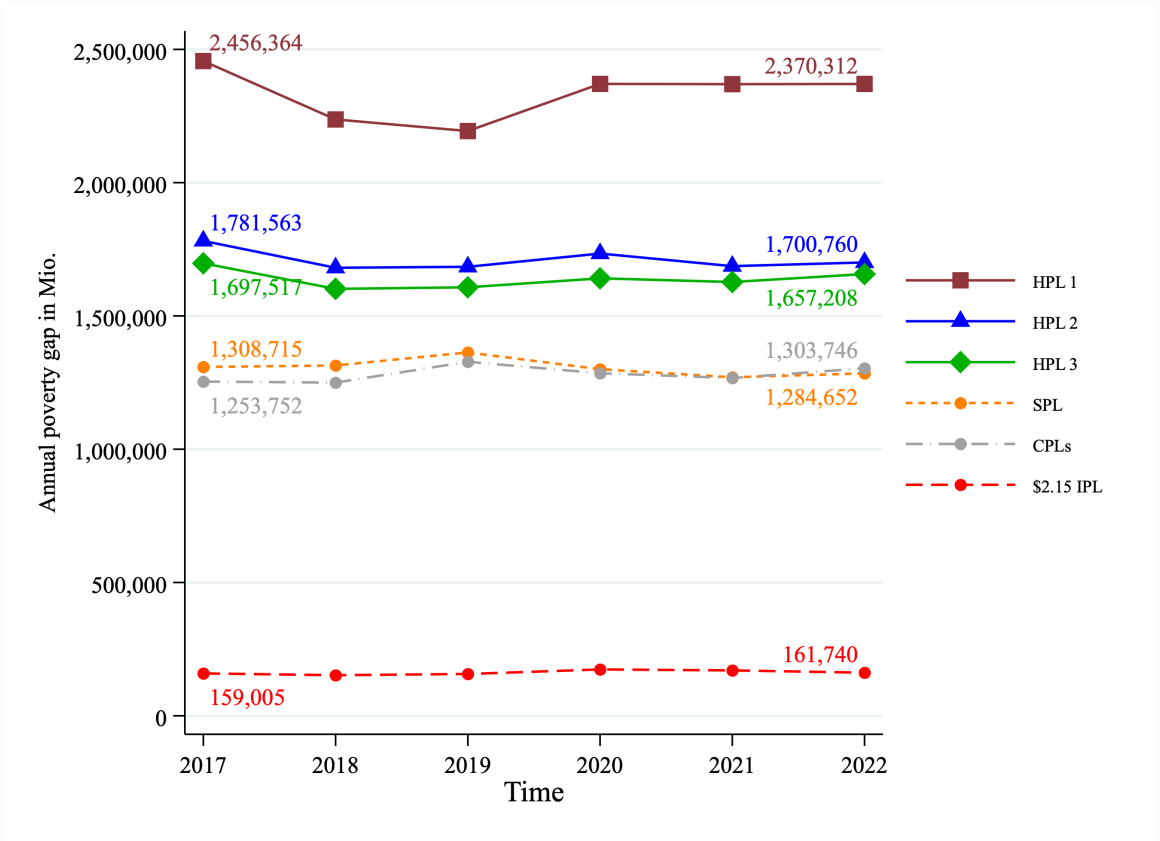

Figure 6: Annual income gap

Note: This figure shows global annual income gaps according to our three proposed healthy-diet based poverty lines (HPL), the US$ 2.15 International Poverty Line (IPL), country-specific harmonized poverty lines (CPLs), and the Societal Poverty Line (SPL) in 2017 Purchasing Power Parities. For six countries without CPLs, we imputed the headcount ratios.

gap from 2017 to 2022 for each poverty approach. In 2022, the estimated annual income people around the globe are lacking is estimated at US$ 2,370 trillion for HPL 1, that is US$ 6.5 billion per day (*Figure A.13*). HPL 2 and 3 amount to a similar estimate of around US$ 1,700 trillion per year (or US$ 4.6 billion per day), analogically the poverty gap based on CPLs and SPLs at around US$ 1,300 trillion. Thus, the income gap for our proposed poverty lines is ten to fifteen times higher than the extreme poverty line of US$2.15 and around a third to almost twice as high as based on the SPL, depending on the variant. Over time, there is little change, only HPL 1 indicates a reduction of almost ten percent between 2017 and 2019 (*Figure 6*).

As for the headcounts, South Asia contributes the largest proportion to the income gap for HPL 1 (US$ 756 billion) and 2 (US$ 439 billion), followed by sub-Saharan Africa with around a quarter of the total gap in all three HPL approaches (*Figure 7*). This stands in stark contrast to the three other approaches. While sub-Saharan Africa and South Asia constitute around

93% of the income gap based on the US$ 2.15 IPL, these two regions amount to only 28% when SPLs are applied and 20% when CPLs are applied. According to these two approaches North America and Europe and Central Asia constitute a much larger proportion and, in the case of the SPL, East Asia and Pacific is the largest contributor to the global income gap with around US$ 286 billion per year, largely driven by China. For both of these approaches, the Unites States has the greatest income deficit in 2022 with around US$ 214 billion based on the SPL. This deficit shrinks to US$ 84 billion per year when HPL 2 is applied.

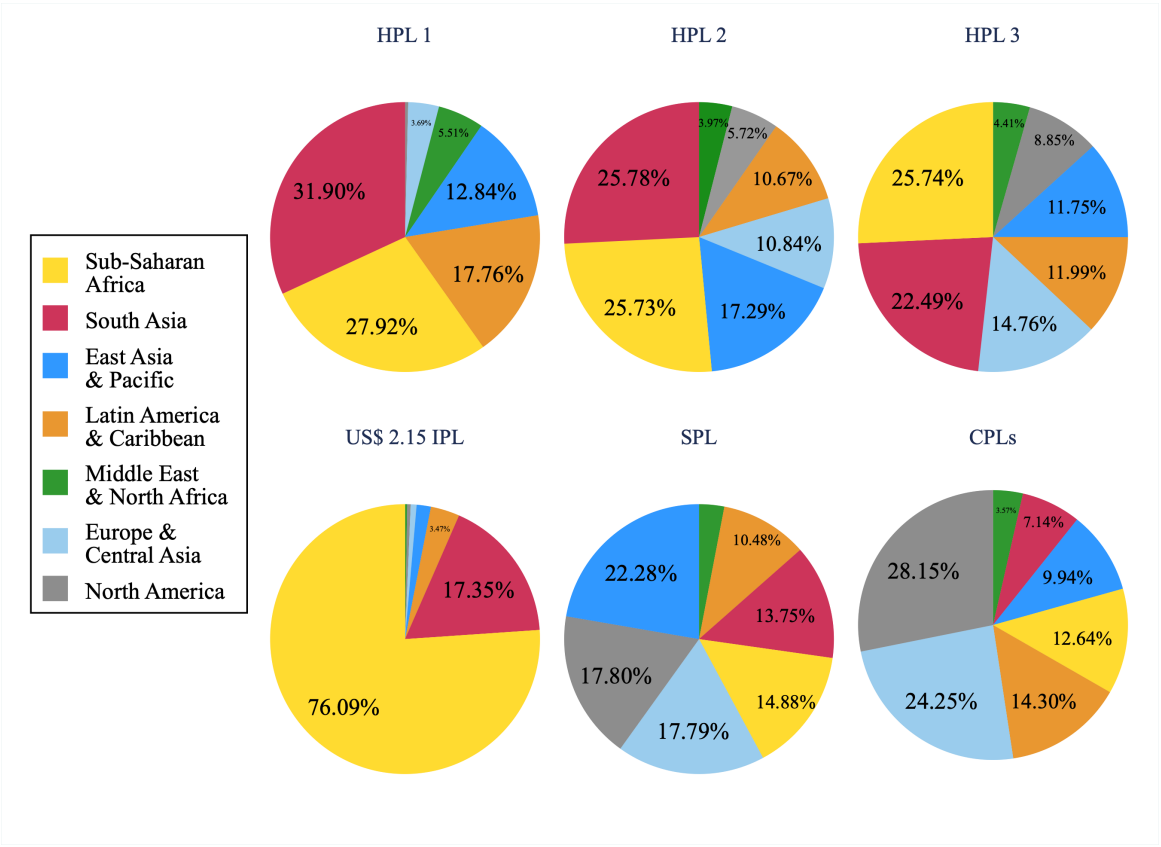

Figure 7: Income gap: proportion by world region in 2022

Particularly countries in sub-Saharan Africa face an enormous burden to close this gap given the high proportion of their GDP (*Figure A.14*). In Burundi, for instance, this income gap constitutes 64% (HPL 2) to 81% (HPL 1) of its GDP. According to HPL 1, this number even reaches values of 111% for Mozambique and 103% for the Central African Republic.

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 underlie 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, Cost of Healthy Diet indicators do not fully capture all essential dietary components needed for long-term health. The Healthy Diet Basket, designed to identify commonalities in locally available items across national dietary guidelines, lacks data on nuanced elements like whole grains and unsaturated fats. This limitation stems from insufficient comparable data in the ICP. Integrating these components into the HDB would likely raise costs and lead to an even larger number of people not being able to afford the healthy diets as defined in our analysis.

Third, 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., 2024).

Fourth, 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).

Fifth, 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 shares, 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.

Sixth, it is important to note that our data is limited to the period 2017-2022 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.

Seventh, we use income and consumption distributions that are based on per capita values. However, particularly in countries with younger populations, consumption may also be less due to less needs of households compared to households with adults only. However, income and consumption distributions are, to the best of our knowledge, not available in adult-equivalents. Such adjustments would lead to a decrease in poverty which may be about a similar size as the adjustment of dietary needs by demographic scaling factors in Figure A.5. This would be a valuable area for future research. Furthermore, like all other poverty measures, we have to assume equal distribution of resources within households. It is possible that there are non-poor individuals in poor households and poor individuals in non-poor households who we cannot observe.

Most of our limitations are related to data availability, emphasizing the potential for data initiatives around poverty and healthy diet costs. However, the increasing availability of income distributions by rural and urban populations in PIP data or the continuous monitoring of least-cost items of a HDB in Nigeria makes us optimistic that we will be able to further improve our estimates in the future.

5 Discussion and policy implications

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 2.3 to 2.9 billion people were living in poverty in 2022 indicating a poverty rate of 30 to 38 percent. Around 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$ 1.7 trillion to 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.

The global income gap to afford a healthy diet is substantial but manageable. To provide perspective on this figure, the income gap in 2022 amounts to 1.6 to 2.3 percent of the world's total annual income or 1.1 to 1.6 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[12] 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. Considerations of cost avoidance are

[12]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).

therefore reinforcing the human rights argument for the universal affordability of a nutritious diet.

5.2 Poverty measurement

A striking disparity emerges when comparing key metrics of our proposed poverty lines with those derived from the conventional extreme poverty line of US$ 2.15. Depending on the variant used, the number of individuals classified as poor increases by 3.5 to 4.4 times, and the income gap widens by 10 to 15 times, respectively. Without adjusting for demographic differences, the number of poor would even be around seven percent larger.

We argue that the understanding of basic needs has evolved alongside economic progress and reductions in global hunger since the development of the original national poverty lines. Standard poverty lines inadequately account for the nutritional requirements necessary for individuals to lead active and healthy lives—a key component of food security. As a result, these lines substantially underestimate the number of people who cannot afford to meet these essential needs. Access to a healthy diet is a fundamental human right, and disregarding nutritional quality leads to health issues in the long-term.

The US$ 2.15 IPL serves as a global absolute poverty measure which overlooks the relative dimensions of poverty (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. Jolliffe and Prydz (2021) introduced the Societal Poverty Line, a smoothed version of national poverty lines with a floor set at US$ 2.15, the IPL, ensuring an absolute measure at the lower end of the income spectrum, while still accounting for the changing evaluation of basic needs as income increases.

In this paper, we propose three measures of poverty, all of which base the food component on healthy diets but differ in their consideration of non-food minimum needs. HPL 1 is the least data-intensive approach, relying solely on the cost of a healthy diet, demographic scaling factors to account for varying dietary needs, and food expenditure shares. However, it assumes that non-food needs are similarly underrepresented in consumption baskets of the poor and therefore scales them proportionally to what the poorest quintile spends on both food and non-food items. In addition, changes in healthy diet costs implicitly result in changes in minimum

non-food needs. This may be true if these are caused by changing energy prices, also resulting in changes of fuel or heating costs.

HPL 2 incorporates non-food expenditures from societal poverty lines and adds them to minimum food costs, while HPL 3 uses non-food expenditures derived from national poverty lines. While HPL 2 draws non-food needs from the SPL, which, above US$2.15, is based on a country's median income, HPL 3 makes their adequacy dependent on each country's assessment of non-food needs. In practice, non-food needs in absolute poverty lines are typically based on actual expenditures of individuals around the food poverty line, which tends to be insufficient for lifelong health. Additionally, individuals may also first meet their food needs constituting individuals around the food poverty line a group too poor to meet basic non-food needs.

The SPL results in a poverty headcount of around two billion people in 2022 and an annual income gap of US$1.3 trillion—approximately 70% to 90% of the figures based on our HPLs. The differences arise primarily for two reasons: First, our HPLs yield higher poverty thresholds for extremely poor countries exceeding the floor of US$2.15, including highly populous nations in sub-Saharan Africa and South Asia, resulting in a larger number of poor individuals and a greater income gap. This is because healthy diets alone cost more than US$ 2 in most countries. Second, our proposed poverty lines are lower for richer countries, leading to fewer and less poor individuals in North America or Europe. While North America and Europa and Central Asia constitute more than 35% of global income shortfalls, with the United States being the country with the largest gap, these regions do not exceed 23% in any of our proposed approaches.

To ensure sustainable long-term health, poverty lines must account for economic access to healthy diets. Individuals should be classified as extremely poor if they cannot afford the recommended diets or essential nutrients required for an active and healthy lifestyle. Regardless of whether people actually consume a healthy diet, the ability to afford one is a fundamental human right. Our proposed measures provide a tool to monitor this affordability and to design suitable, targeted policy interventions.

6 Conclusion

In this paper, we propose a measure of poverty that is grounded in the economic costs of maintaining a healthy diet. Healthy diets are and always have been a basic need and current poverty measures do not meet this need. 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. While this has been addressed by the development of a societal poverty line, it does not fully capture essential dietary needs of the poor. An expansion to affordability of healthy diets enables individuals 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.

We explore the key metrics of our three proposed poverty measures and compare them with the conventional US$ 2.15 IPL, the SPL, and country-specific poverty lines. Our analysis reveals that, according to our proposed poverty lines 2.3 to 2.9 billion people are classified as impoverished, with the collective income deficit amounting to US$ 1.675 to US$ 2.370 trillion per year. These figures exceed those generated by the US$ 2.15 IPL by factors of 3.5–4.4 and 10.4–14.7 and those generated by the SPL by factors of 1.1–1.4 and 1.3–1.8, respectively. These findings underscore the significant challenges we face in achieving universal affordability of healthy diets and other basic needs.

Despite significant progress in reducing extreme poverty over recent decades, a large number of people continue to face food insecurity and malnutrition. Achieving the Sustainable Development Goal of "Zero Hunger" requires ensuring access to both sufficient and nutritious food for all. In this paper, we propose a target for monitoring economic access to nutritious food. While an adequate quantity of food suffices for short-term survival, long-term health depends on the quality of that food, as reflected in healthy diets. It is therefore critical to incorporate evolving nutritional standards into poverty measurements, expanding them to include those who lack the financial means to obtain recommended diets.

Data statement

Income distributions and Cost of Health Diet data are publicly available at World Bank Open Data. Collected food-expenditure shares will be made publicly available with the publication. Sources are stated in Table A.3.

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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)

Table A.2: Demographic scaling factors

Age category	**Males**		**Females**	
	kcal	per adult female	kcal	per adult female
0-4	1,169	0.47	1,075	0.43
5-9	1,710	0.68	1,570	0.63
10-14	2,565	1.03	2,250	0.90
15-19	3,300	1.32	2,500	1.00
20-29	2,950	1.18	2,350	0.94
30-59	2,500	1.00	2,500*	1.00
60-	2,450	0.98	2,350	0.94

Source: Headey et al. (2024). Values taken from FAO (2004), except ($*$) which is from Willett et al. (2019).

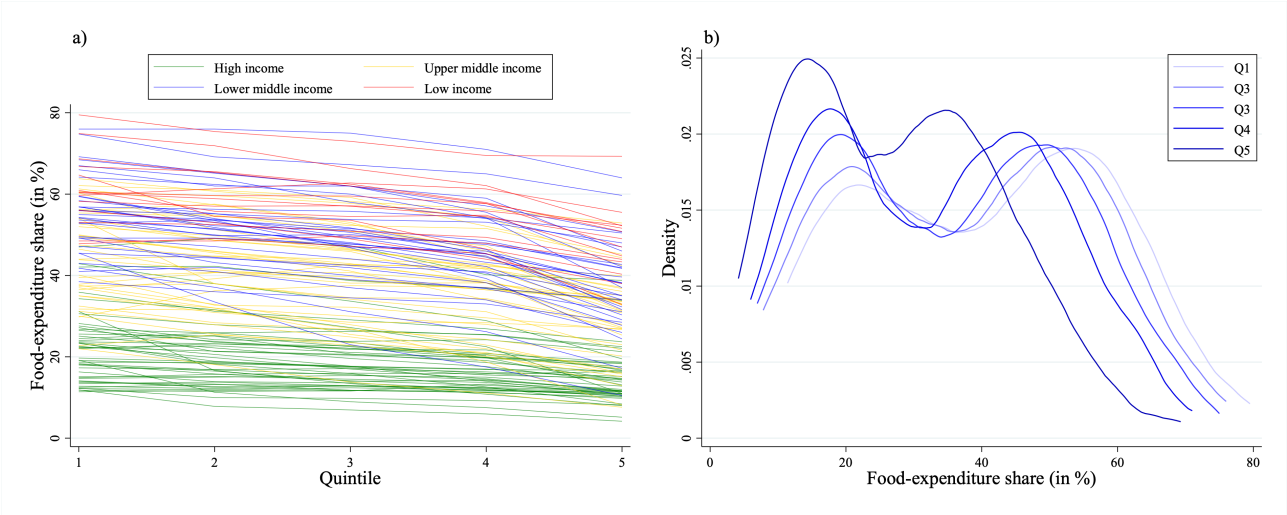

Figure A.1: Food-expenditure shares by income quintile

Note: Graph (a) depicts food-expenditure shares across income or consumption quintiles for 127 countries for which we obtained data on quintile-level from 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 with income quintile.

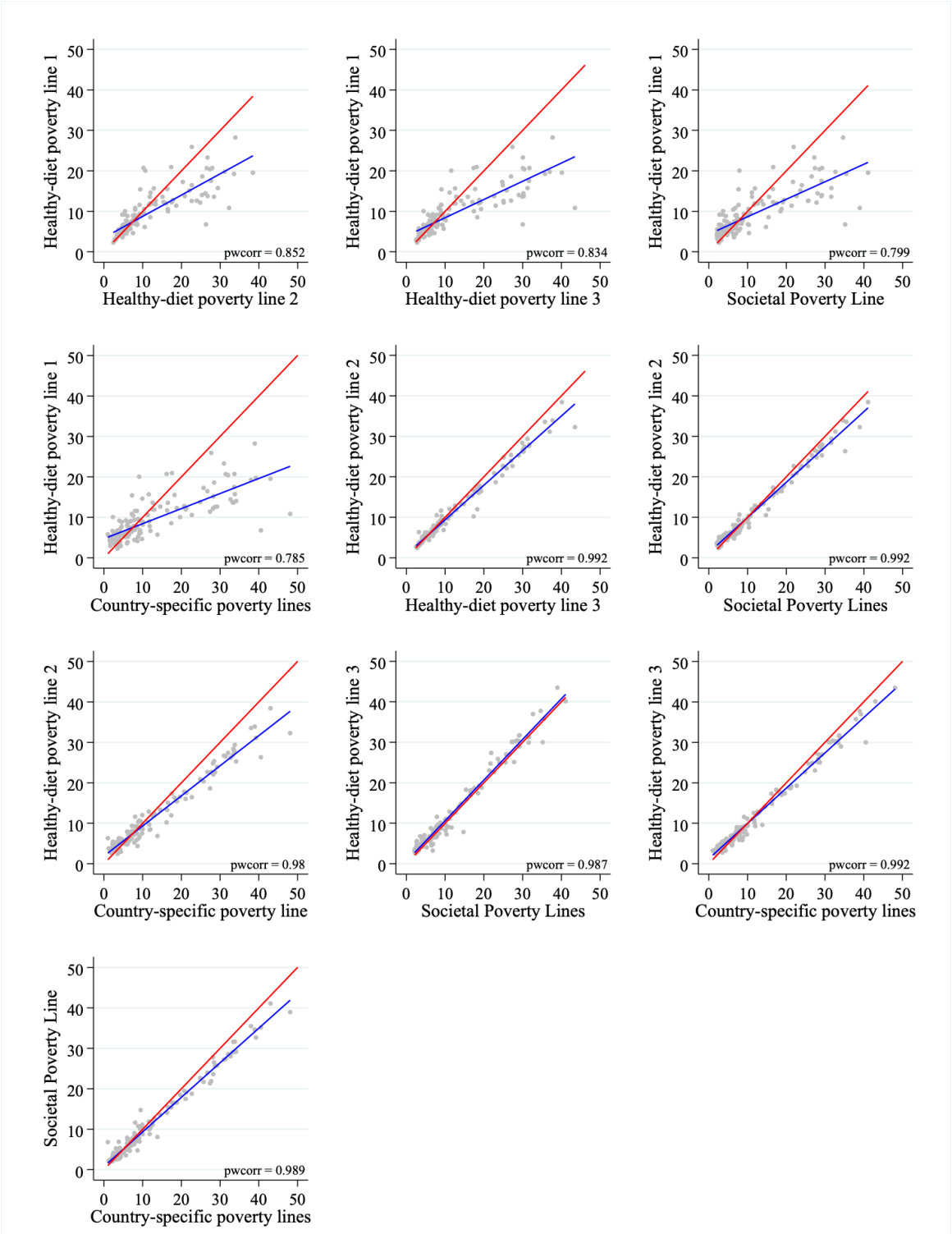

Figure A.2: Correlation of poverty lines

Note: This graph depicts the correlation of poverty lines of our three proposed variants, the Societal Poverty Line, and country-specific poverty lines in 2022. The blue line shows a linear fit of both lines. The red line depicts a 45-degree line. The numbers on the bottom right show the respective correlation coefficient between two poverty approaches.

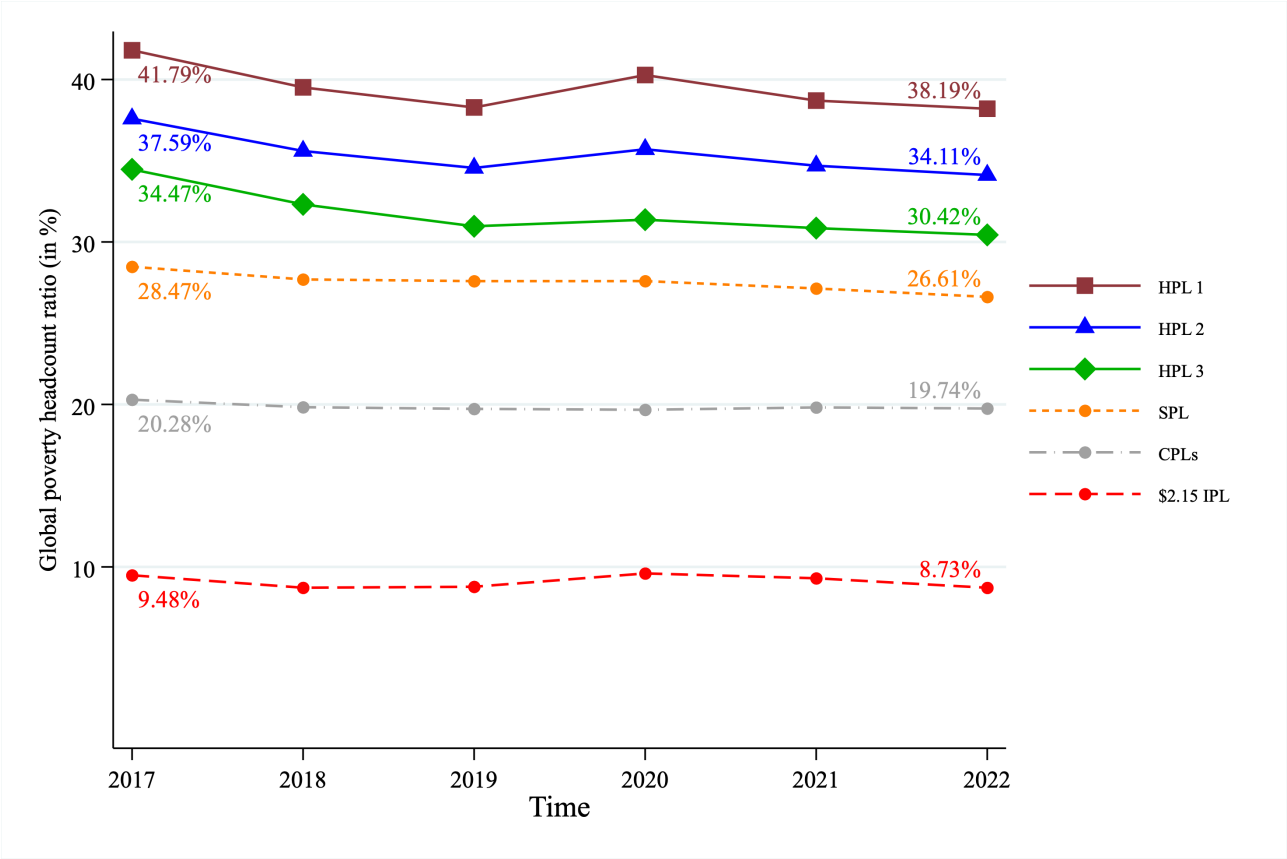

Figure A.3: Global poverty headcount ratio by variant

Note: This figure shows global poverty rates based on our three proposed healthy-diet based poverty lines (HPL), the US$ 2.15 International Poverty Line (IPL), country-specific harmonized poverty lines (CPLs), and the Societal Poverty Line (SPL). For six countries without CPLs, we imputed the headcount ratios.

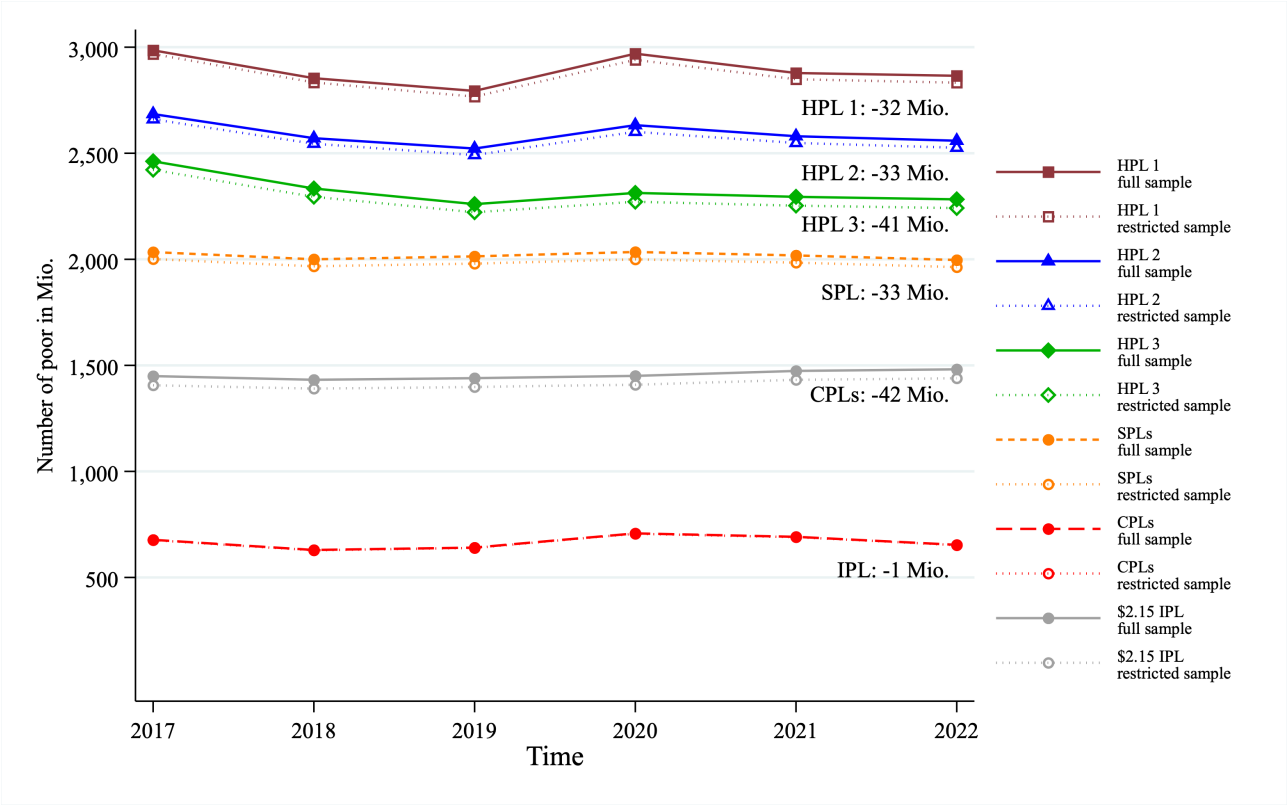

Figure A.4: Number of poor by variant: Restricted ($n = 139$) versus non-restricted sample ($n = 145$)

Note: This figure shows global poverty headcount estimates based on the full sample with imputed values for country-specific harmonized poverty lines (CPLs) ($n = 145$) in comparison with the restricted sample ($n = 139$) for our three proposed healthy-diet based poverty lines (HPL), the US$ 2.15 International Poverty Line (IPL), country-specific harmonized poverty lines (CPLs), and the Societal Poverty Line (SPL). The restricted sample excludes Guyana, Iran, Japan, Suriname, Trinidad and Tobago, and United Arab Emirates

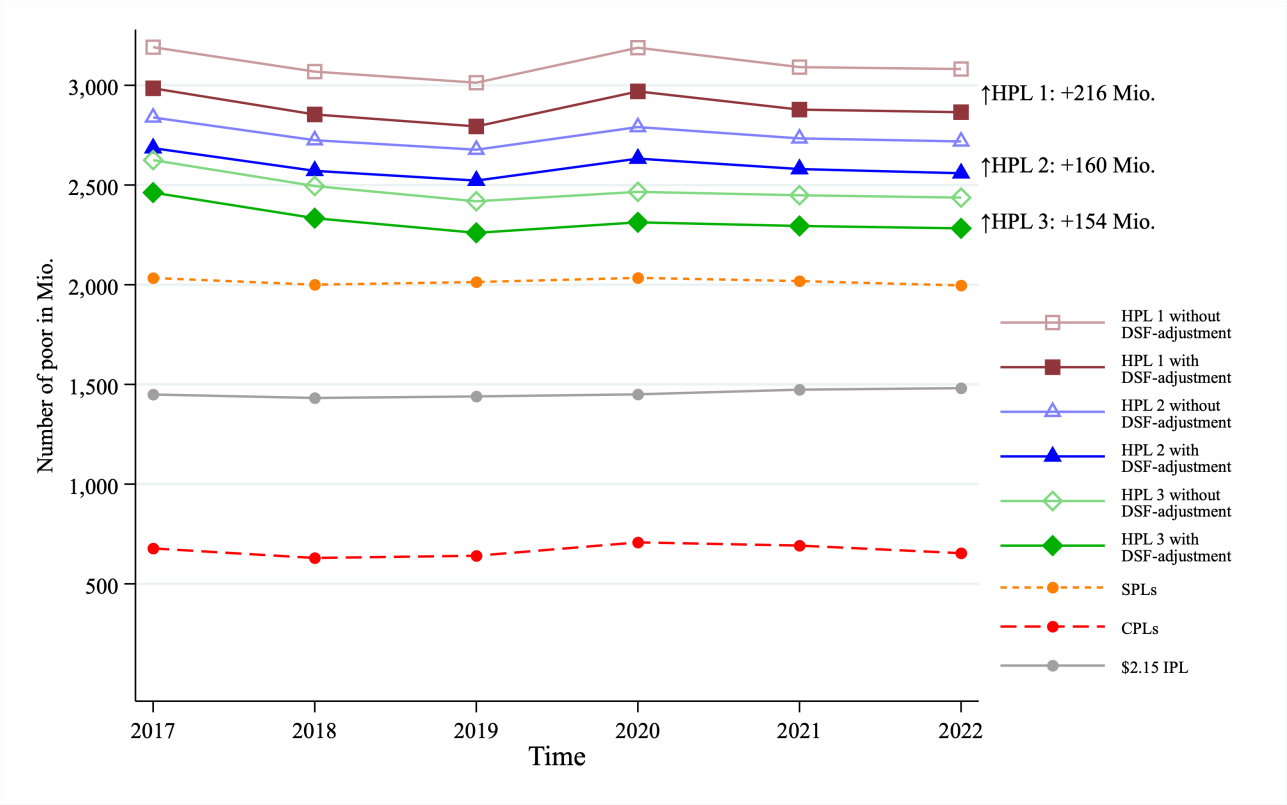

Figure A.5: Number of poor by variant: DSF-adjusted versus not DSF-adjusted

Note: This figure shows the global poverty headcount estimates from Figure 2 in comparison with estimates without adjusting for demographic scaling factors (DSFs). Note that country-specific harmonized poverty lines (CPLs), the US$ 2.15 International Poverty Line (IPL), and the Societal Poverty Line (SPL) is based on per capita values and thus not adjusted for demographic differences across countries.

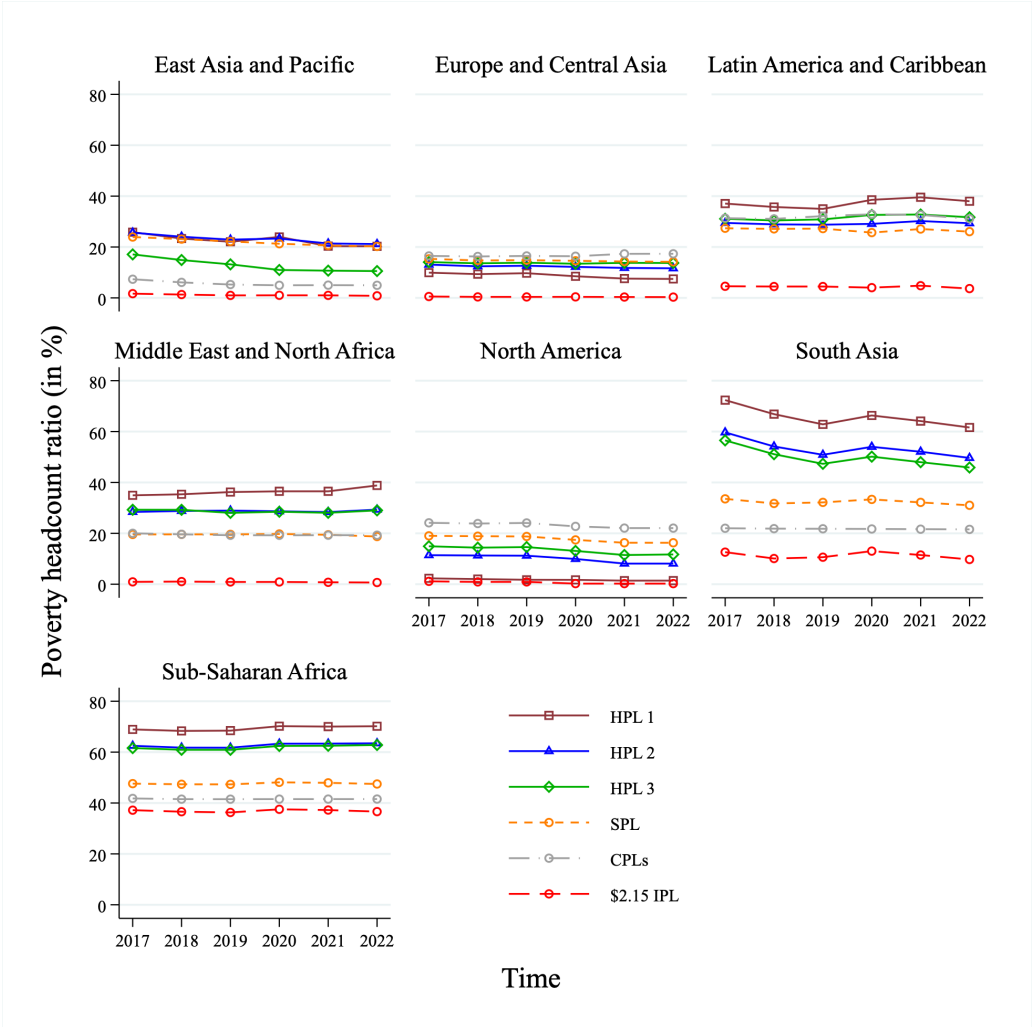

Figure A.6: Headcount ratios over time by region

Table A.3: Data sources - Food Expenditure Shares

Country	**Data**	**Type**	**Provider**
Albania	Trend in Household Expenditures in Albania (Survey: LSMS 2012)	Journal Article	European Scientific Journal
Algeria	Enquête sur les dépenses de consommation et le niveau de vie des ménages 2011	Report	Office National des Statistiques
Angola	Inquérito Sobre Despesas, Receitas e Emprego em Angola 2018/19	Authors' own calculation	Instituto Nacional De Estatísticas
Armenia	Integrated Living Conditions Survey 2017	Report	Statistical Committee of the Republic of Armenia
Australia	Household Expenditure Survey 2015/16	Table	Australian Bureau of Statistics
Austria	Household Budget Survey 2020	Database	Eurostat
Azerbaijan	Household Budget Survey 2021	Table	The State Statistical Committee of the Republic of Azerbaijan
Bangladesh	Global Consumption Database	Database	World Bank
Belarus	Household Living Standards Survey 2021	Report	National Statistical Committee of the Republic of Belarus
Belgium	Household Budget Survey 2020	Database	Eurostat
Belize	Imputed		
Benin	Enquête Harmonisée sur le Conditions de Vie des Ménages 2018/19	Authors' own calculation	World Bank
Bhutan	Bhutan Living Standards Survey 2017	Report	National Statistics Bureau
Bolivia	Regional Overview of Food Security and Nutrition – Latin America and the Caribbean 2022	Report	FAO, IFAD, PAHO, WHO, UNICEF, WFP
Bosnia and Herzegovina	Global Consumption Database	Database	World Bank
Botswana	Multi-Topic Household Survey 2015/16	Report	Statistics Botswana
Brazil	Regional Overview of Food Security and Nutrition – Latin America and the Caribbean 2022	Report	FAO, IFAD, PAHO, WHO, UNICEF, WFP
Bulgaria	Household Budget Survey 2020	Database	Eurostat
Burkina Faso	Enquête Harmonisée sur le Conditions de Vie des Ménages 2018/19	Authors' own calculation	World Bank
Burundi	Global Consumption Database	Database	World Bank
Cabo Verde	Global Consumption Database	Database	World Bank
Cameroon	Global Consumption Database	Database	World Bank
Canada	Survey of Household Spending 2019	Table	Statistics Canada

Central African Republic	Imputed		
Chad	Global Consumption Database	Database	World Bank
Chile	Regional Overview of Food Security and Nutrition – Latin America and the Caribbean 2022	Report	FAO, IFAD, PAHO, WHO, UNICEF, WFP
China	Global Consumption Database	Database	World Bank
Colombia	Global Consumption Database	Database	World Bank
Congo, Dem Rep	Resultats de l'enquete sur l'emploi, le secteur informel et sur consommation des menages 2012	Report	Institut National de la Statistique
Congo, Rep	Global Consumption Database	Database	World Bank
Costa Rica	Regional Overview of Food Security and Nutrition – Latin America and the Caribbean 2022	Report	FAO, IFAD, PAHO, WHO, UNICEF, WFP
Cote d'Ivoire	Enquête Harmonisée sur le Conditions de Vie des Ménages 2018/19	Authors' own calculation	World Bank
Croatia	Household Budget Survey 2020	Database	Eurostat
Cyprus	Household Budget Survey 2020	Database	Eurostat
Czech Republic	Household Budget Survey 2015	Database	Eurostat
Denmark	Household Budget Survey 2020	Database	Eurostat
Djibouti	Global Consumption Database	Database	World Bank
Dominican Republic	Regional Overview of Food Security and Nutrition – Latin America and the Caribbean 2022	Report	FAO, IFAD, PAHO, WHO, UNICEF, WFP
Ecuador	Panorama of Food and Nutrition Security in Latin America and the Caribbean	Report	PAHO, iris
Egypt, Arab Rep	Estimating equivalence scales and non-food needs in Egypt: Parametric and semiparametric regression modeling (Survey: Egyptian Household Income, Expenditure, and Consumption Survey)	Journal Article	PLoS One
Estonia	Household Budget Survey 2020	Database	Eurostat
Eswatini	Global Consumption Database	Database	World Bank
Ethiopia	Ethiopian Household Consumption - Expenditure Survey 2015/16	Report	Central Statistics Agency
Fiji	Household Income and Expenditure Survey 2019/20	Report	Fiji Bureau of Statistics
Finland	Household Budget Survey 2015	Database	Eurostat
France	Household Budget Survey 2020	Database	Eurostat
Gabon	Global Consumption Database	Database	World Bank

Gambia, The	Comprehensive Food Security and Vulnerability Analysis (CFSVA)	Report	Gambia Bureau of Statistics, Planning Service Unit of Ministry of Agriculture, Ministry of Health and Social Welfare, National Nutrition Agency, National Disaster Management Agency, The Gambia Red Cross Society, FAO, UNICEF, UNDP
Germany	Household Budget Survey 2020	Database	Eurostat
Ghana	Ghana Living Standards Survey 2016/17	Report	Ghana Statistical Services
Greece	Household Budget Survey 2020	Database	Eurostat
Guinea	Global Consumption Database	Database	World Bank
Guinea-Bissau	Enquête Harmonisée sur le Conditions de Vie des Ménages 2018/19	Authors' own calculation	World Bank
Guyana	Imputed		
Haiti	Imputed		
Honduras	Toward a Path of Poverty Reduction and Inclusive Growth (Survey: Simulated consumption imputed from the 2004 Encuesta de Condiciones de Vida de los Hogares (ENCOVI) into the 2019 EPHPM)	Report	World Bank
Hungary	Household Budget Survey 2020	Database	Eurostat
Iceland	Imputed		
India	Status Seeking Behavior of the Poor: A Study on India (Survey: National Sample Survey 68th round 2011/12)	Working Paper	CESifo
Indonesia	Households Distribution of Income and Expenditure (Survey: National Socio-Economic Survey March 2020)	Presentation	Banca d'Italia
Iran, Islamic Rep	Household Income and Expenditure Survey 2019/20	Report	Statistical Centre of Iran
Iraq	Iraq Welfare Monitoring Survey 2017	Authors' own calculation	Central Organization for Statistics
Ireland	Household Budget Survey 2015	Database	Eurostat
Israel	Household Income and Expenditure Survey 2018	Table	Central Bureau of Statistics
Italy	Imputed		
Jamaica	Jamaica Survey of Living Conditions 2019	Authors' own calculation	Statistical Institute of Jamaica

Japan	Family Income and Expenditure Survey 2017	Table	Statistics of Japan
Jordan	Household Expenditure and Income Survey 2013/2014	Report	Department of Statistics Jordan
Kazakhstan	Living Standards in Kazakhstan 2017-2021	Report	Statistic Bureau Republic of Kazakhstan
Kenya	Kenya Integrated Household Budget Survey 2015/16	Authors' own calculation	Kenya National Bureau of Statistics
Korea, Rep	Household Income and Expenditure Survey: Trends in the First Quarter 2013	Table	Statistics Korea
Kyrgyz Republic	National Security Indicators	Database	OECD
Lao PDR	Global Consumption Database	Database	World Bank
Latvia	Household Budget Survey 2020	Database	Eurostat
Lesotho	Continuous Multipurpose Survey/ Household Budget Survey	Report	Lesotho Bureau of Statistics
Liberia	Household Income and Expenditure Survey 2014	Report	Liberia Institute of Statistics & GeoInformation Services (LISGIS)
Lithuania	Household Budget Survey 2020	Database	Eurostat
Luxembourg	Household Budget Survey 2020	Database	Eurostat
Madagascar	Global Consumption Database	Database	World Bank
Malawi	Fifth Integrated Household Survey	Authors' own calculation	National Statistics Office
Malaysia	Global Consumption Database	Database	World Bank
Maldives	Household Income and Expenditure Survey 2019	Report	National Bureau of Statistics
Mali	Enquête Harmonisée sur le Conditions de Vie des Ménages 2018/19	Authors' own calculation	World Bank
Malta	Household Budget Survey 2020	Database	Eurostat
Mauritania	Global Consumption Database	Database	World Bank
Mauritius	Household Budget Survey 2017: Analytical Report	Report	Ministry of Finance and Economic Development - Statistics Mauritius
Mexico	Regional Overview of Food Security and Nutrition – Latin America and the Caribbean 2022	Report	FAO, IFAD, PAHO, WHO, UNICEF, WFP
Moldova	Household Budget Survey 2022	Report	Biroul Național de Statistică al Republicii Moldova
Mongolia	Household Socio-Economic Survey 2018	Report	National Statistics Office of Mongolia, World Bank
Montenegro	Household Budget Survey 2020	Database	Eurostat

Morocco	Enquête Nationale sur la Consommation et les Dépenses des Ménages 2013/2014: Rapport de synthèse	Report	Haut-Comissariat au Plan
Mozambique	Inquérito sobre Orçamento Familiar – IOF 2022	Report	Instituto Nacional de Estatística – Moçambique
Myanmar	An analysis of poverty in Myanmar	Report	World Bank
Namibia	Namibia Household Income and Expenditure Survey (NHIES) 2015/2016	Report	Namibia Statistics Agency
Nepal	Nepal Annual Household Survey 2015/16	Report	Central Bureau of Statistics
Netherlands	Household Budget Survey 2020	Database	Eurostat
Nicaragua	Household Census and Survey Data Quality Report: Second Follow-up Measurement	Report	Iniciativa Salud Mesoamerica
Niger	Enquête Harmonisée sur le Conditions de Vie des Ménages 2018/19	Authors' own calculation	World Bank
Nigeria	Trends in Household Consumption Expenditure among the Six Geopolitical Zones in Nigeria (Survey: Nigeria General Household Survey 2012/13)	Dissertation	University of the Western Cape
North Macedonia	Household Budget Survey 2015	Database	Eurostat
Norway	Household Budget Survey 2015	Database	Eurostat
Pakistan	Household Integrated Economic Survey 2018/19	Table	Pakistan Bureau of Statistics
Panama	Imputed		
Paraguay	Global Consumption Database	Database	World Bank
Peru	Living Conditions and Poverty Survey – ENAHO 2016	Report	PAHO, WHO
Philippines	Family Income and Expenditure Survey 2021	Report	Philippines Statistics Authority
Poland	Household Budget Survey 2020	Database	Eurostat
Portugal	Household Budget Survey 2015	Database	Eurostat
Romania	Household Budget Survey 2020	Database	Eurostat
Russian Federation	Household Budget Sample Survey 2021	Report	Russian Federal State Statistics Service
Rwanda	Comprehensive Food Security & Vulnerability Analysis (CFSVA)	Report	National Institute of Statistics of Rwanda

Sao Tome and Principe	Global Consumption Database	Database	World Bank
Senegal	Enquête Harmonisée sur le Conditions de Vie des Ménages 2018/19	Authors' own calculation	World Bank
Serbia	Household Budget Survey 2020	Database	Eurostat
Seychelles	Household Budget Survey 2013	News article	National Bureau of Statistics
Sierra Leone	Integrated Household Survey 2018	Authors' own calculation	Statistics Sierra Leone
Slovak Republic	Household Budget Survey 2020	Database	Eurostat
Slovenia	Household Budget Survey 2020	Database	Eurostat
South Africa	Living Conditions Survey 2014/15	Report	Statistics South Africa
Spain	Household Budget Survey	Database	Eurostat
Sri Lanka	Household Income and Expenditure Survey 2019	Report	Department of Census and Statistics Sri Lanka
St Lucia	Imputed		
Sudan	Imputed		
Sweden	Household Budget Survey 2015	Database	Eurostat
Switzerland	Detaillierte Haushaltsausgaben nach Einkommensklasse (Survey: Haushaltsbudgeterhebung 2015-2017)	Database	Bundesamt für Statistik
Tajikistan	Household Budget Survey 2017	Report	Agency of Statistics under president of the Republic of Tajikistan
Tanzania	Household Budget Survey 2017-18 - Tanzania Mainland: Final Report	Report	Tanzania National Bureau of Statistics
Thailand	Myths and Facts about Inequalities in Thailand (Survey: Thailand Household Socio-Economic Survey 2019)	Discussion Paper	Puey Ungphakorn Institute for Economic Research
Trinidad and Tobago	Imputed		
Tunisia	Enquête Nationale sur les Dépenses et les Consommations des Ménages 2015/2016	Report	Institut National de la Statistique
Turkey	Household Budget Survey 2020	Database	Eurostat
Turkmenistan	Global Consumption Database	Database	World Bank
Uganda	Household Income and Expenditure Survey 2016/17	Report	Uganda Bureau of Statistics

Ukraine	Household Budget Survey 2020	Database	Eurostat
United Arab Emirates	Global Consumption Database	Database	World Bank
United Kingdom	Family Spending: The Living Costs and Food Survey 2018	Report	Office for National Statistics
United States	Consumer Expenditure Survey 2019	Report	U.S. Bureau of Labor Statistics
Uruguay	Global Consumption Database	Database	World Bank
Uzbekistan	Household Budget Survey 2020	Database	Eurostat
Vanuatu	Vanuatu Household Income and Expenditure Survey 2016	Report	Vanuatu National Statistics Office
Venezuela	Regional Overview of Food Security and Nutrition – Latin America and the Caribbean 2022	Report	FAO, IFAD, PAHO, WHO, UNICEF, WFP
Vietnam	Vietnam Household Living Standards Survey 2016	Report	General Statistics Office of Vietnam
West Bank and Gaza	Palestinian Household Expenditure and Consumption Survey 2017/18	Report	Palestinian Central Bureau of Statistics
Yemen, Rep	Integrated Household Survey 2018/19	Report	Central Statistical Organization
Zambia	Living Conditions Monitoring Survey 2015	Report	Central Statistical Office
Zimbabwe	Poverty Income Consumption and Expenditure Survey 2017	Report	Zimbabwe National Statistics Agency

Table A.4: Regression results

	(1) CPLs	(2) Poorest quartile	(3) HPL 1	(4) Poorest quartile	(5) HPL 2	(6) Poorest quartile	(7) HPL 3	(8) Poorest quartile
Panel A: linear-linear								
Mean consumption exp. p.c.	0.491***	0.487***	0.192***	0.114*	0.376***	0.156***	0.430***	0.208***
	(0.000)	(0.000)	(0.000)	(0.027)	(0.000)	(0.000)	(0.000)	(0.000)
Constant	0.131	0.700***	4.400***	3.828***	1.757***	3.002***	1.238***	2.762***
	(0.100)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
R^2	0.965	0.477	0.635	0.021	0.971	0.123	0.955	0.207
Median consumption exp. p.c.	0.571***	0.650***	0.222***	0.120	0.437***	0.173***	0.502***	0.259***
	(0.000)	(0.000)	(0.000)	(0.072)	(0.000)	(0.000)	(0.000)	(0.000)
Constant	0.671***	0.746***	4.639***	4.070***	2.179***	3.138***	1.692***	2.874***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
R^2	0.979	0.531	0.635	0.008	0.984	0.088	0.974	0.148
Panel B: log-log								
Log. mean consumption exp. p.c.	0.880***	0.677***	0.450***	0.056	0.666***	0.125***	0.704***	0.186***
	(0.000)	(0.000)	(0.000)	(0.135)	(0.000)	(0.000)	(0.000)	(0.000)
Constant	-0.343***	0.020	0.824***	1.358***	0.294***	1.111***	0.218***	1.019***
	(0.000)	(0.724)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
R^2	0.926	0.507	0.698	0.008	0.913	0.091	0.897	0.193
Log. median consumption exp. p.c.	0.838***	0.651***	0.420***	0.036	0.631***	0.101***	0.668***	0.171***
	(0.000)	(0.000)	(0.000)	(0.304)	(0.000)	(0.000)	(0.000)	(0.000)
Constant	-0.015	0.265***	1.010***	1.418***	0.549***	1.180***	0.487***	1.104***
	(0.438)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Observations	864	216	864	216	864	216	864	216
R^2	0.941	0.571	0.683	0.003	0.919	0.068	0.904	0.159

Standard errors in parentheses

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

Table A.5: International poverty lines 2017-2022

Income classification	CPLs		HPL 1		HPL 2		HPL 3	
	Median	**N**	**Median**	**N**	**Median**	**N**	**Median**	**N**
2017								
Low income	2.42	22	4.17	22	3.52	22	3.47	22
Lower middle income	3.36	39	4.89	39	4.63	39	4.35	39
Upper middle income	6.86	41	6.51	41	6.89	41	6.74	41
High income	23.62	43	12.77	43	20.09	43	21.44	43
Total		145		145		145		145
2018								
Low income	2.51	22	4.19	22	3.51	22	3.44	22
Lower middle income	3.64	39	4.95	39	4.68	39	4.4	39
Upper middle income	7.03	41	6.54	41	7.03	41	6.8	41
High income	25.1	43	12.82	43	20.34	43	22.17	43
Total		145		145		145		145
2019								
Low income	2.6	22	4.17	22	3.5	22	3.43	22
Lower middle income	3.72	39	4.97	39	4.73	39	4.43	39
Upper middle income	7.44	41	6.57	41	7.04	41	6.78	41
High income	25.73	43	13.27	43	20.41	43	23.14	43
Total		145		145		145		145
2020								
Low income	2.64	22	4.16	22	3.5	22	3.49	22
Lower middle income	3.69	39	4.97	39	4.64	39	4.43	39
Upper middle income	7.61	41	6.69	41	6.78	41	6.96	41
High income	25.51	43	13.77	43	20.6	43	23.57	43
Total		145		145		145		145
2021								
Low income	2.73	22	4.26	22	3.54	22	3.46	22
Lower middle income	3.73	39	5.09	39	4.71	39	4.47	39
Upper middle income	7.8	41	6.71	41	7.22	41	7.25	41
High income	26.79	43	13.47	43	21.33	43	24.11	43
Total		145		145		145		145
2022								
Low income	2.79	22	4.36	22	3.63	22	3.52	22
Lower middle income	3.66	39	5.33	39	4.77	39	4.51	39
Upper middle income	7.91	41	6.98	41	7.51	41	7.44	41
High income	27.7	43	13.77	43	22.65	43	25.04	43
Total		145		145		145		145

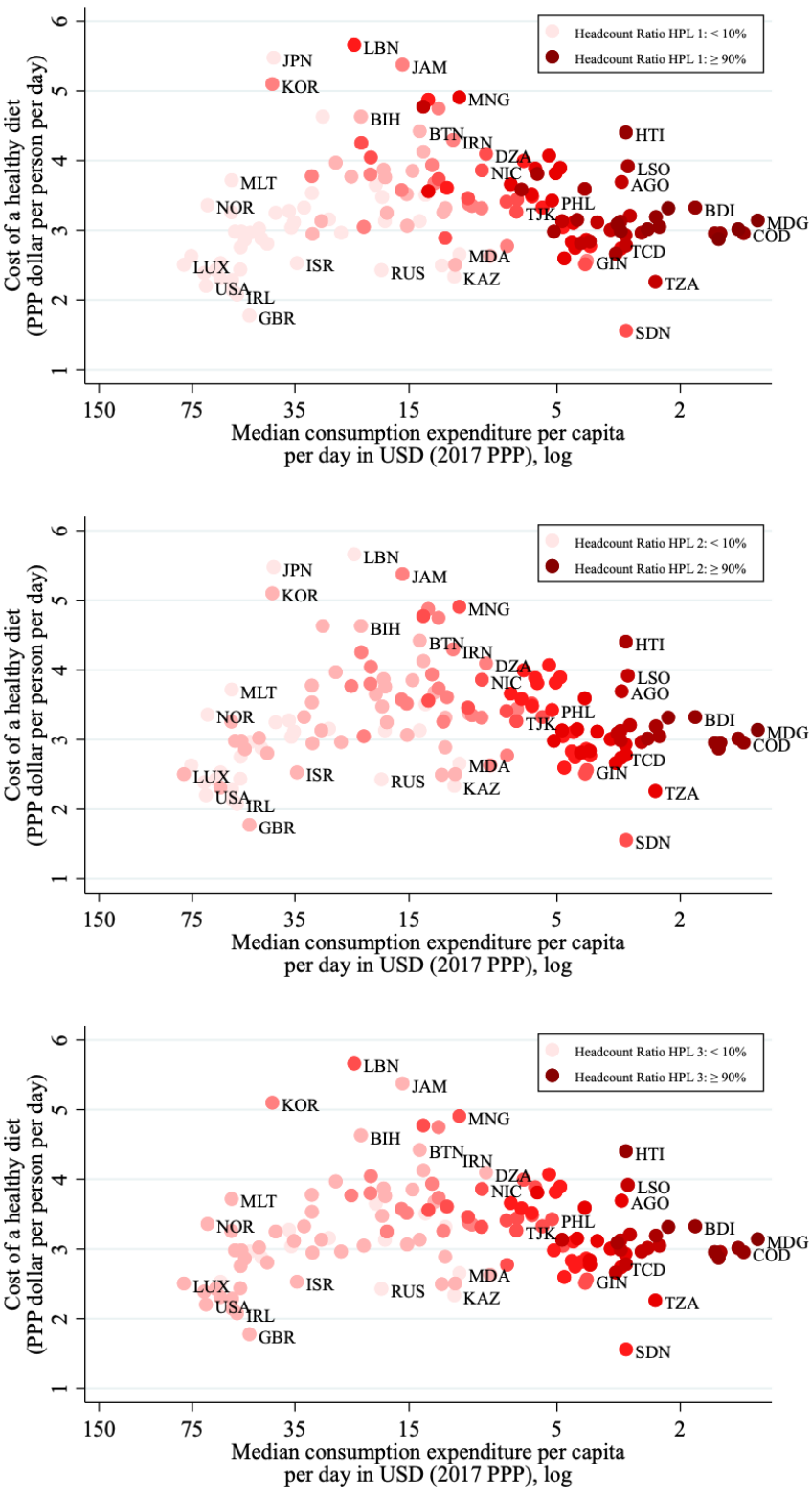

Figure A.7: Poverty Line Determinants

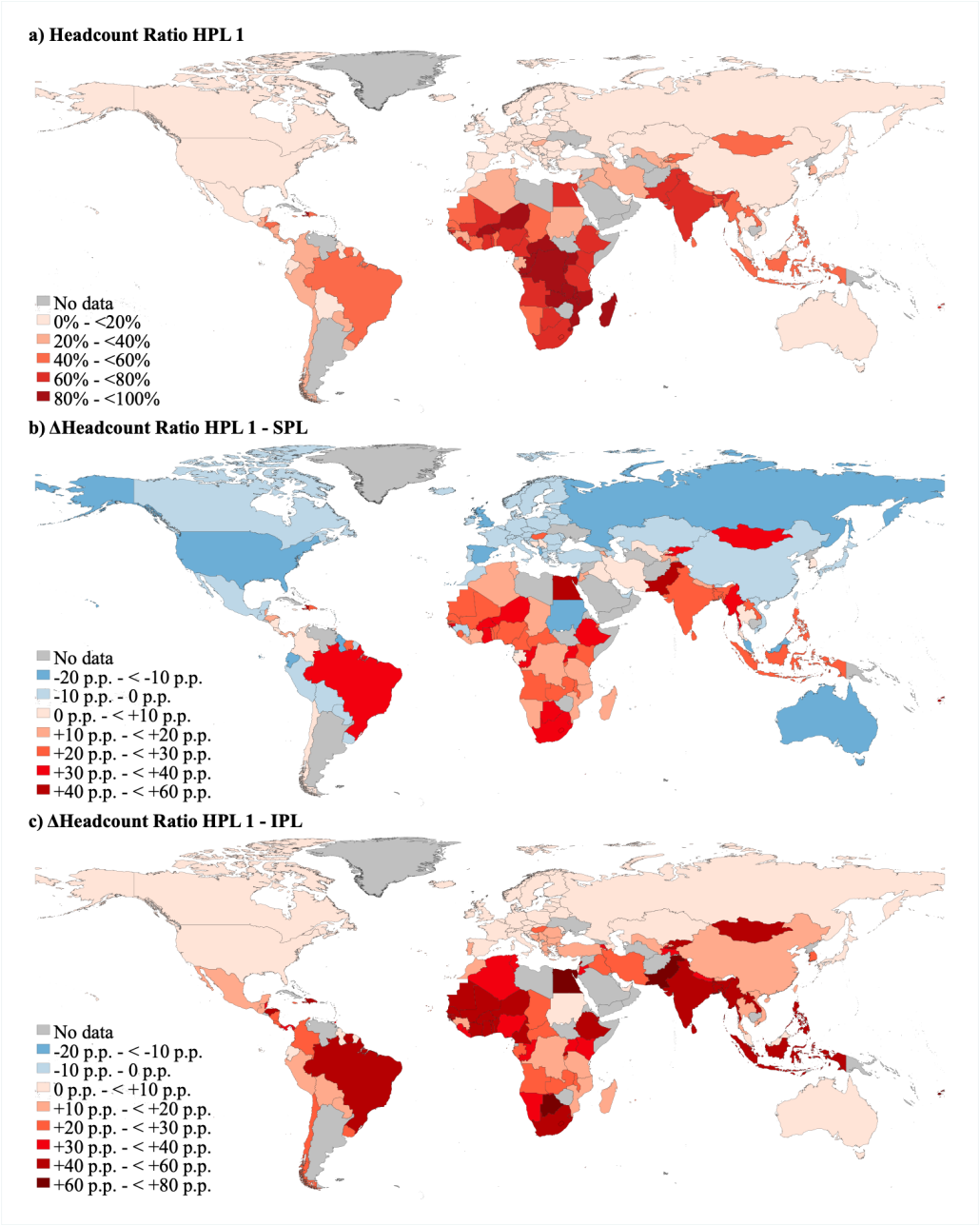

Figure A.8: HPL 1 poverty headcount ratio in 2022

Note: Panel a) shows poverty headcount ratios in 2022 based on healthy diet poverty line 1 (HPL 1). Panel b) depicts the absolute difference in poverty headcount ratios between HPL 1 and the Societal Poverty Lines (SPLs). Blue shades depict countries for which the SPL headocunt ratio is higher than the HPL 1 headcount ratio. Panel c) shows the difference between HPL 1 and the US$ 2.15 IPL in 2022.

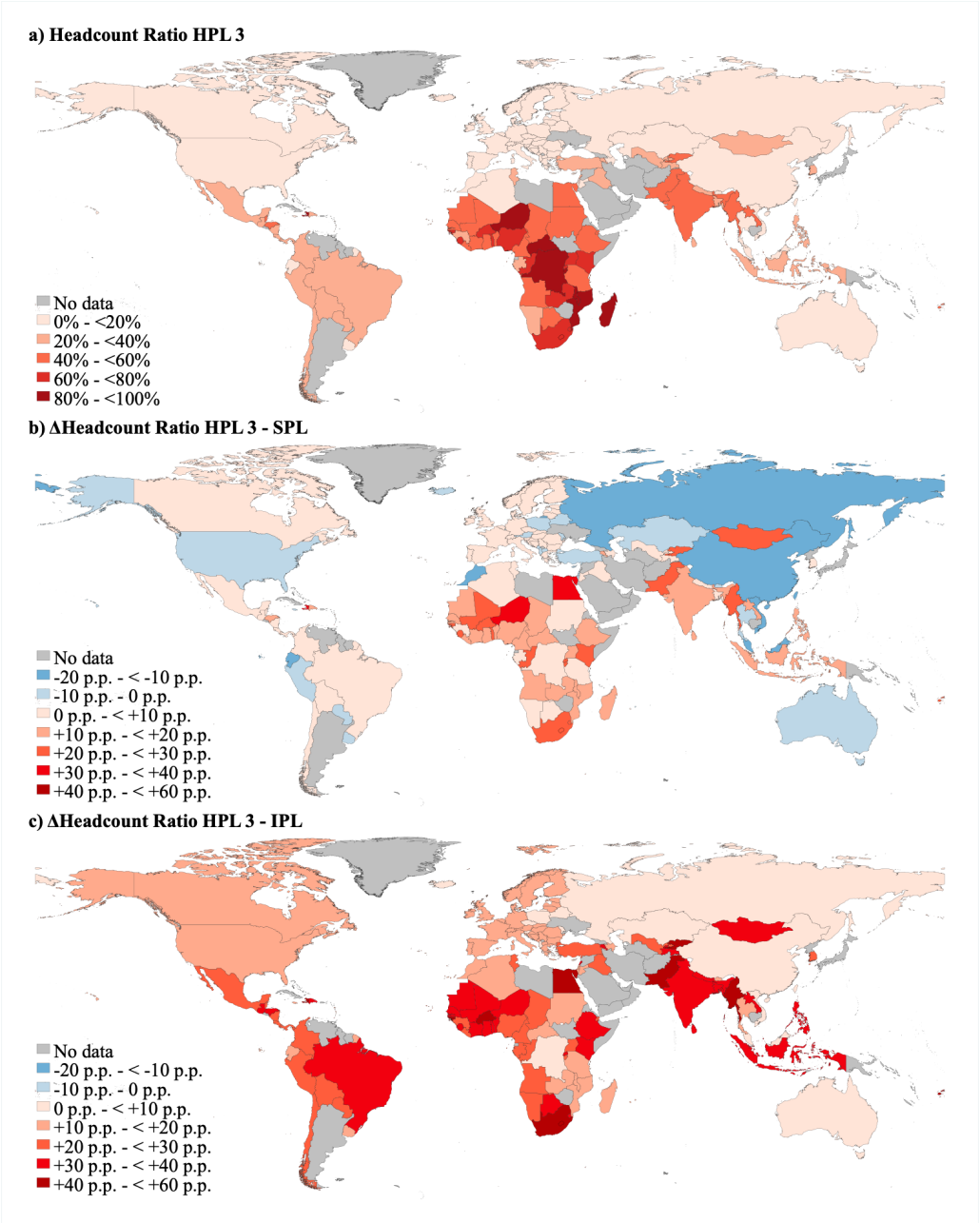

Figure A.9: HPL 3 poverty headcount ratio in 2022

Note: Panel a) shows poverty headcount ratios in 2022 based on healthy diet poverty line 3 (HPL 3). Panel b) depicts the absolute difference in poverty headcount ratios between HPL 3 and the Societal Poverty Lines (SPLs). Blue shades depict countries for which the SPL headocunt ratio is higher than the HPL 3 headcount ratio. Panel c) shows the difference between HPL 3 and the US$ 2.15 IPL in 2022.

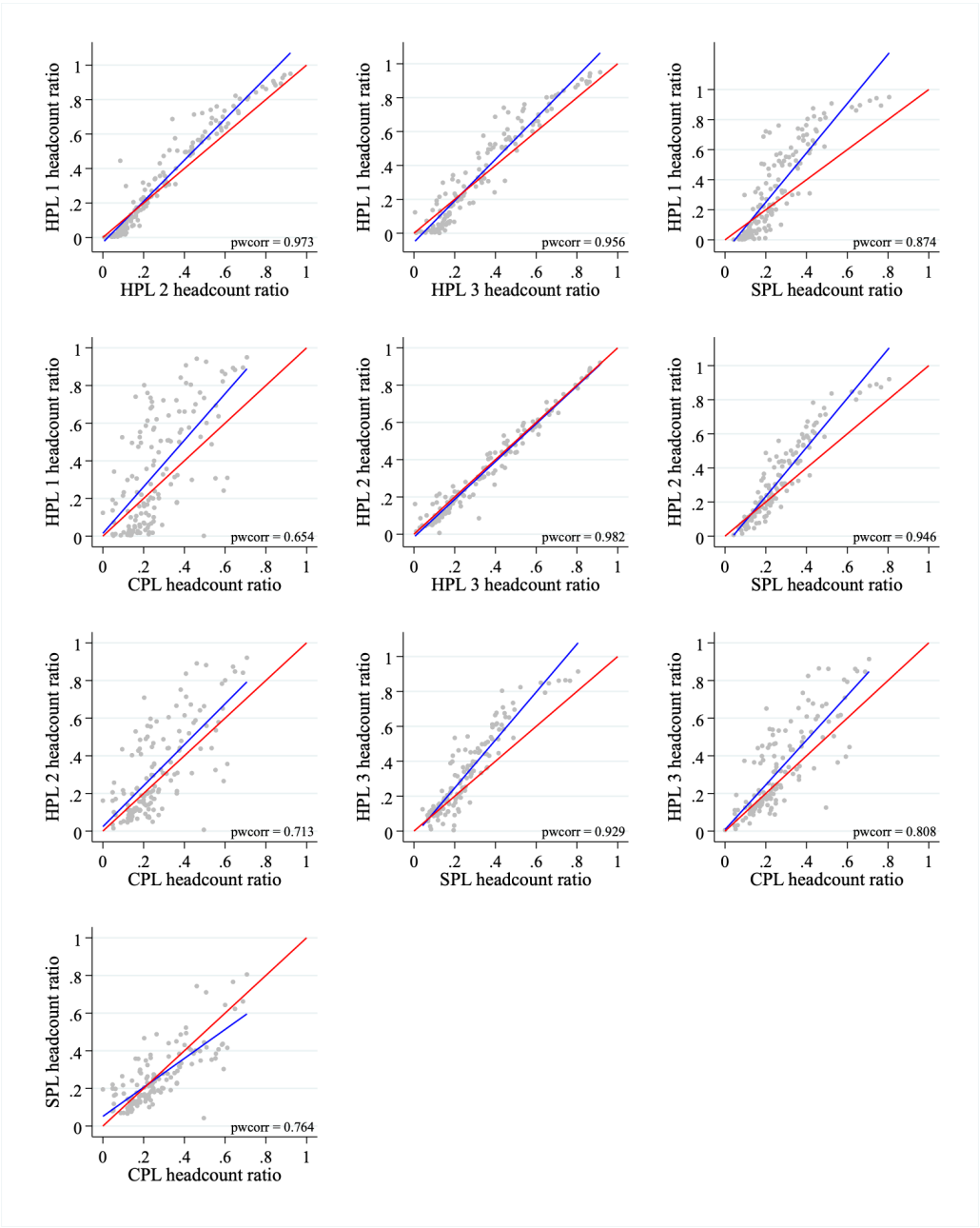

Figure A.10: Correlation of headcount ratios in 2022

Note: This graph depicts the correlation of poverty headcount ratios based on our three proposed variants, the Societal Poverty Line, and country-specific poverty lines. The blue line shows a linear fit of the two approaches. The red line depicts a 45-degree line. The numbers on the bottom right show the respective correlation coefficient between the headcount ratios of the two poverty approaches.

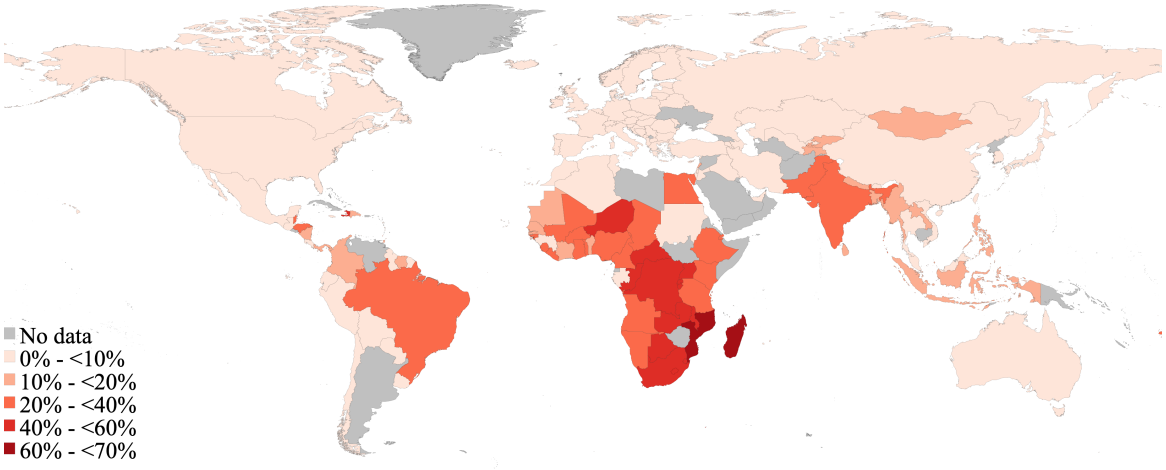

Figure A.11: Poverty gap index HPL 1 in 2022

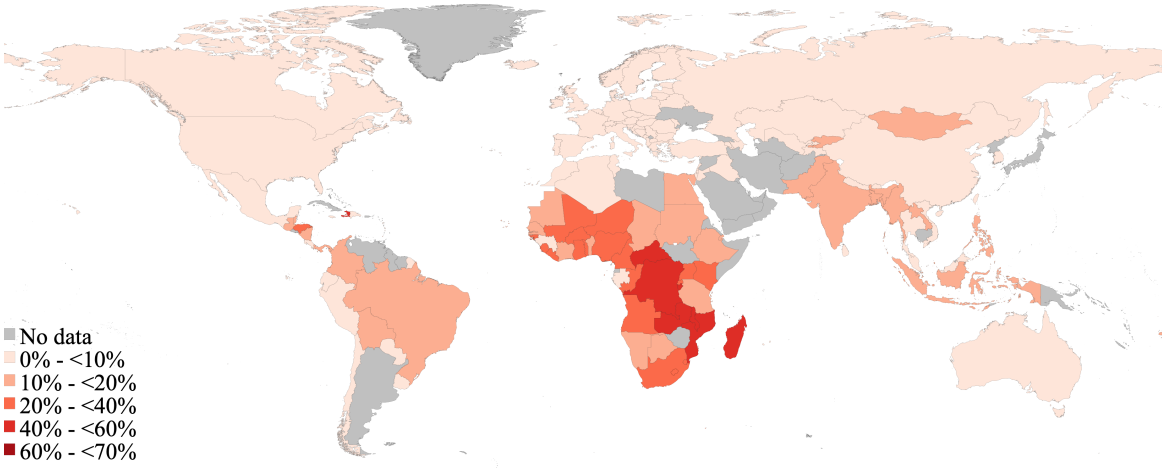

Figure A.12: Poverty gap index HPL 3 in 2022

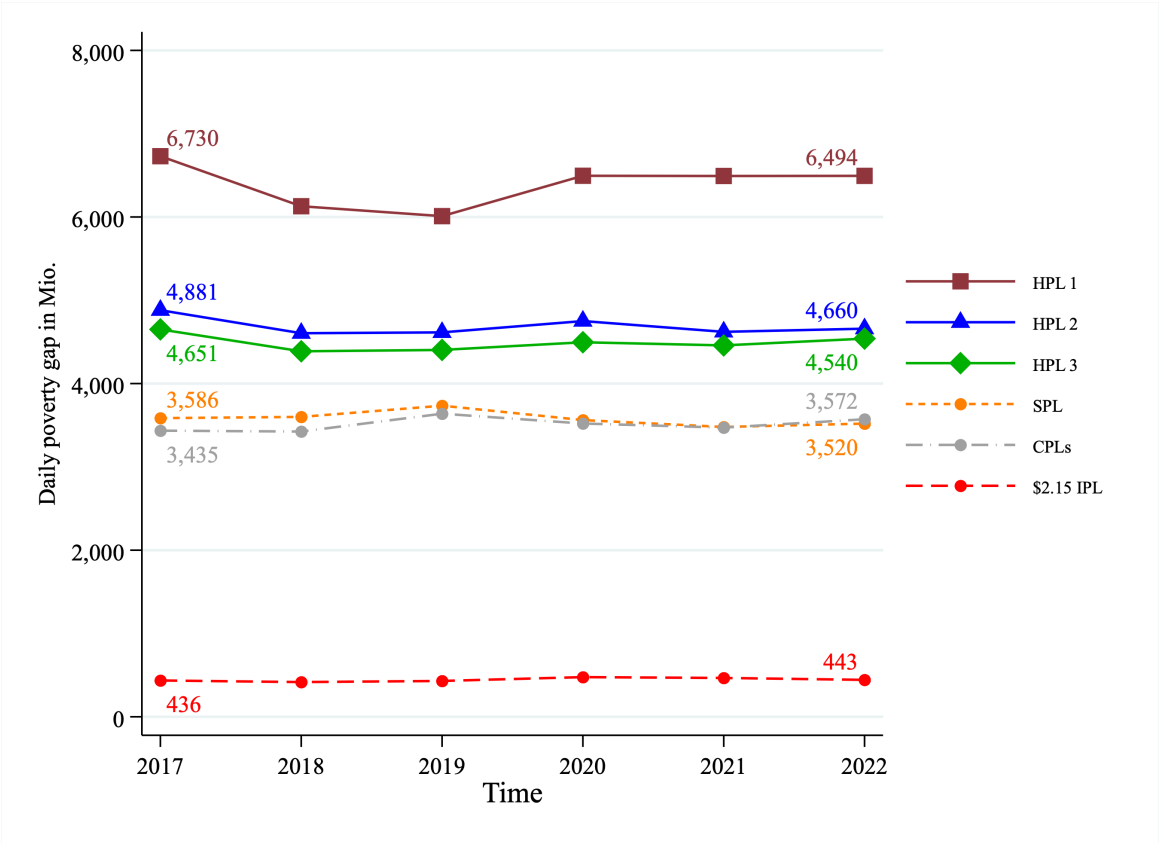

Figure A.13: Daily income gaps

Note: This figure shows global daily income gaps according to our three proposed healthy-diet based poverty lines (HPL), the US$ 2.15 International Poverty Line (IPL), country-specific harmonized poverty lines (CPLs), and the Societal Poverty Line (SPL) in 2017 Purchasing Power Parities. For six countries without CPLs, we imputed the headcount ratios.

Table A.6: Number of poor in mio. by year, world region and variant

Year	World Region	IPL	CPLs	SPL	HPL 1	HPL 2	HPL 3
2017	East Asia and Pacific	37	164	534	576	572	382
	Europe and Central Asia	5	142	132	85	112	121
	Latin America and Caribbean	25	168	147	199	158	167
	Middle East and North Africa	3	71	69	124	101	104
	North America	4	87	69	8	41	54
	South Asia	225	392	598	1291	1064	1008
	Sub-Saharan Africa	379	426	485	702	636	627
	Total	678	1450	2034	2985	2685	2462
2018	East Asia and Pacific	30	137	519	524	540	334
	Europe and Central Asia	3	140	127	81	107	117
	Latin America and Caribbean	24	169	147	194	157	165
	Middle East and North Africa	4	71	71	127	104	105
	North America	3	87	69	7	41	52
	South Asia	182	394	573	1206	977	922
	Sub-Saharan Africa	383	434	495	715	646	637
	Total	630	1432	2000	2854	2571	2334
2019	East Asia and Pacific	22	119	500	498	517	298
	Europe and Central Asia	3	143	128	84	109	120
	Latin America and Caribbean	25	177	150	192	158	169
	Middle East and North Africa	3	70	72	133	106	103
	North America	3	88	69	6	41	53
	South Asia	194	398	587	1146	928	863
	Sub-Saharan Africa	390	446	508	735	663	654
	Total	641	1440	2014	2794	2522	2260
2020	East Asia and Pacific	23	112	483	543	529	249
	Europe and Central Asia	4	142	127	74	106	116
	Latin America and Caribbean	22	182	142	214	161	181
	Middle East and North Africa	3	71	73	136	106	106
	North America	1	84	64	6	37	48
	South Asia	240	400	615	1223	996	924
	Sub-Saharan Africa	414	458	531	774	698	688
	Total	708	1450	2035	2970	2633	2313
2021	East Asia and Pacific	23	114	468	462	486	243
	Europe and Central Asia	3	150	124	66	102	120
	Latin America and Caribbean	27	182	151	221	169	183
	Middle East and North Africa	3	73	73	137	107	106
	North America	1	82	60	5	30	43
	South Asia	214	403	599	1194	970	893
	Sub-Saharan Africa	421	470	542	792	717	707
	Total	692	1474	2018	2878	2580	2295
2022	East Asia and Pacific	19	113	461	462	482	240
	Europe and Central Asia	3	151	124	65	101	120
	Latin America and Caribbean	21	175	147	214	165	178
	Middle East and North Africa	3	73	72	148	112	111
	North America	1	82	61	5	30	44
	South Asia	183	405	583	1157	932	862
	Sub-Saharan Africa	425	482	551	814	736	729
	Total	654	1480	1997	2863	2559	2281

Note: This table shows the global estimates in the number of poor people according to the US$ 2.15 International Poverty Lines (IPL), country-specific national poverty lines (CPLs), the Societal Poverty Line (SPL), and our three proposed healthy-diet based poverty lines (HPLs).

Table A.7: Annual poverty gap by year, world region and variant (in mio. US$)

Year	World Region	2.15 IPL	CPLs	SPL	HPL 1	HPL 2	HPL 3
2017	East Asia and Pacific	5,202	151,342	336,917	387,665	365,382	245,387
	Europe and Central Asia	1,972	266,992	216,772	112,899	181,004	216,653
	Latin America and Caribbean	6,762	173,500	134,335	360,213	168,941	178,074
	Middle East and North Africa	480	44,053	38,788	111,428	60,044	69,008
	North America	2,604	392,702	267,475	15,265	130,094	182,979
	South Asia	32,972	75,247	145,913	889,788	487,692	424,289
	Sub-Saharan Africa	109,013	149,917	168,515	579,104	388,406	381,127
	Total	159,005	1,253,752	1,308,715	2,456,364	1,781,563	1,697,517
2018	East Asia and Pacific	4,085	133,502	337,192	346,369	344,347	220,220
	Europe and Central Asia	1,366	257,362	204,363	101,910	168,962	205,717
	Latin America and Caribbean	6,714	174,414	138,008	340,069	168,707	175,704
	Middle East and North Africa	522	43,416	38,011	113,990	60,610	68,520
	North America	2,231	405,323	275,267	13,357	130,874	185,131
	South Asia	26,797	83,716	148,704	761,149	429,214	375,210
	Sub-Saharan Africa	110,421	152,300	172,626	560,320	378,081	370,999
	Total	152,137	1,250,033	1,314,172	2,237,165	1,680,796	1,601,500
2019	East Asia and Pacific	2,847	129,437	321,757	316,161	321,345	199,764
	Europe and Central Asia	1,242	276,011	216,960	113,546	181,283	222,110
	Latin America and Caribbean	6,890	194,503	144,532	343,539	174,261	185,333
	Middle East and North Africa	497	43,544	38,555	111,476	61,226	65,013
	North America	2,034	439,810	290,817	12,149	133,645	196,043
	South Asia	30,597	88,852	173,235	731,294	430,778	364,492
	Sub-Saharan Africa	112,878	155,929	177,331	565,490	381,888	374,811
	Total	156,985	1,328,087	1,363,188	2,193,655	1,684,427	1,607,566
2020	East Asia and Pacific	3,181	123,392	287,033	359,357	323,368	192,818
	Europe and Central Asia	1,366	273,967	216,855	99,644	179,546	218,267
	Latin America and Caribbean	6,309	195,400	120,749	347,210	158,243	188,342
	Middle East and North Africa	526	41,901	38,038	104,464	59,249	64,142
	North America	672	409,387	270,127	9,723	120,805	175,749
	South Asia	40,195	86,946	182,363	846,023	487,662	408,306
	Sub-Saharan Africa	121,630	154,097	184,959	604,217	405,267	393,488
	Total	173,880	1,285,091	1,300,123	2,370,638	1,734,139	1,641,111
2021	East Asia and Pacific	3,232	126,043	288,123	309,101	296,849	195,498
	Europe and Central Asia	1,202	299,886	219,036	83,697	176,419	232,088
	Latin America and Caribbean	7,328	191,443	133,763	444,980	182,014	199,951
	Middle East and North Africa	479	43,951	39,021	106,846	60,693	65,528
	North America	668	357,429	223,013	8,441	94,565	142,229
	South Asia	34,428	88,988	178,579	791,979	458,525	385,974
	Sub-Saharan Africa	122,905	159,352	188,361	624,560	417,720	406,069
	Total	170,242	1,267,092	1,269,895	2,369,603	1,686,784	1,627,336
2022	East Asia and Pacific	2,757	129,651	286,268	304,320	294,056	194,804
	Europe and Central Asia	1,146	316,162	228,534	87,483	184,320	244,655
	Latin America and Caribbean	5,616	186,472	134,658	421,062	181,410	198,675
	Middle East and North Africa	419	46,534	38,757	130,579	67,487	73,147
	North America	669	367,039	228,651	8,904	97,315	146,624
	South Asia	28,070	93,104	176,578	756,090	438,526	372,690
	Sub-Saharan Africa	123,062	164,784	191,207	661,875	437,645	426,613
	Total	161,740	1,301,313	1,284,652	2,364,586	1,700,348	1,654,078

Note: This table shows the global estimates in the global income gap according to the US$ 2.15 International Poverty Lines (IPL), country-specific national poverty lines (CPLs), the Societal Poverty Line (SPL), and our three proposed healthy-diet based poverty lines (HPLs).

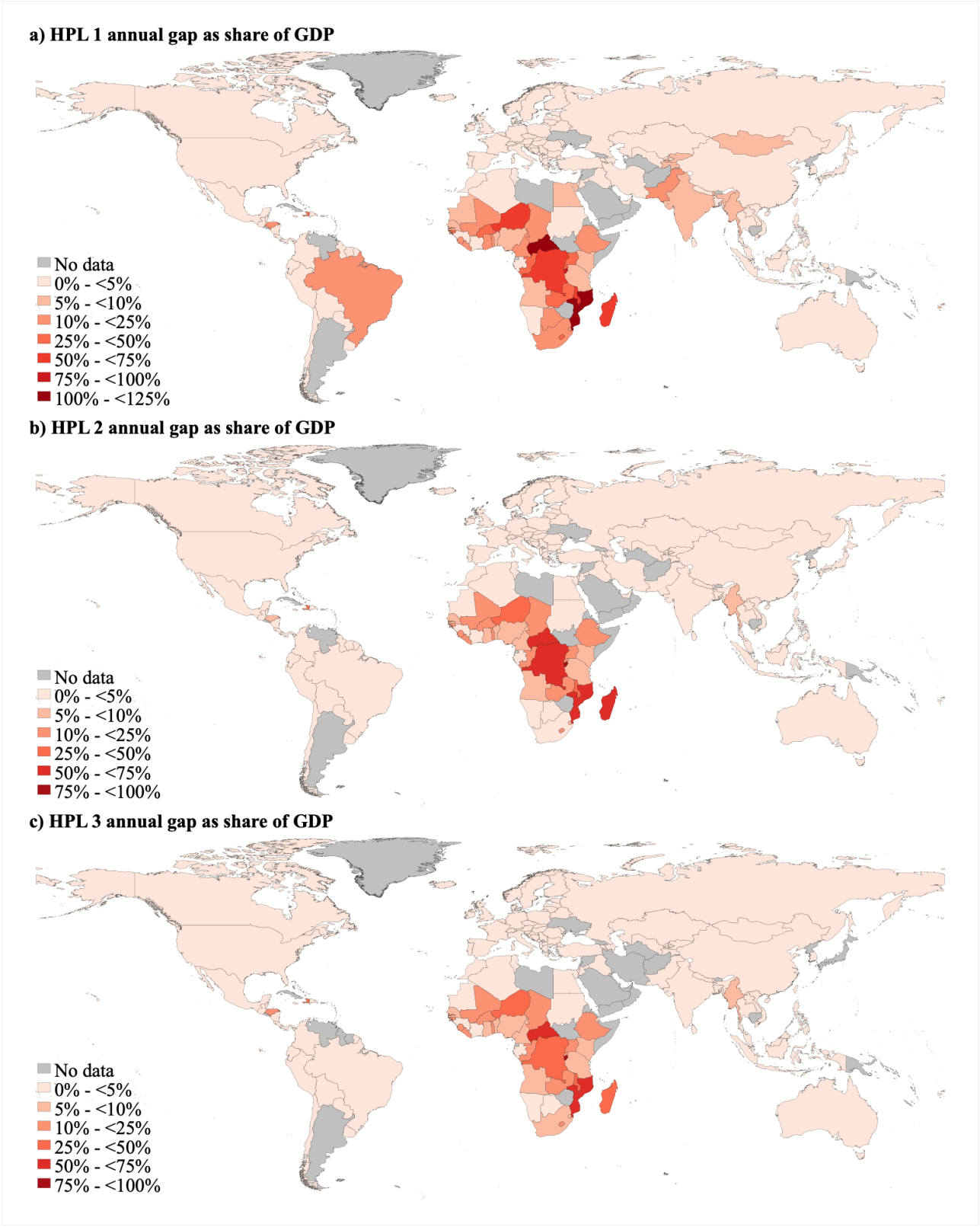

Figure A.14: Annual income gap as share of GDP in 2022