IARIW 2022

Monday 22 - Friday 26 August

Long-Run Trends and Confidence Intervals in the Cost of Basic Needs and Global Poverty: A ballpark approach

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Paper prepared for the 37th IARIW General Conference

August 22-26, 2022

Session 2C-2: New Measures of Global Comparisons in Well-Being and Sustainability II

Time: Tuesday, August 23, 2022 [16:00 -17:30 CEST]

Long-Run Trends and Confidence Intervals in the Cost of Basic Needs and Global Poverty: A ballpark approach

Michail Moatsos*

Abstract

For long, global poverty has been measured with an array of extremely frugal poverty lines, to estimate the level of *extreme* poverty. From a 21st century stand-point this approach becomes all the more irrelevant, and this paper attempts to address this gap, by building upon methods pioneered by Allen (2017) and extended by Moatsos (2021b) as well as OECD (2021) to investigate three facets of global poverty. First in terms of unaffordability of basic foods as defined in the EAT–Lancet reference diet. Second, in terms of EAT–Lancet derived poverty lines that build upon those basic food costs, by adding relevant non-food expenses. And third, from the perspective of uncertainty in estimating global poverty. In turn, it is shown that for the first part of the 19th century unaffordability of basic foods was lower than the estimates of extreme poverty that use all prices in the economy as in the World Bank's dollar-a-day method. At the same time in recent years, most countries have higher unaffordability of basic foods than poverty in terms of the dollar-a-day approach. Moreover, in terms of EAT–Lancet derived poverty lines, global poverty estimates are substantially higher than what standard the extreme poverty measures suggest. In terms of percentage, the difference is rather small in early 19th century due to saturation, with the method employed here global poverty stands at 83% in 1820, or about 770 million individuals, contrasted with 79% of the dollar-a-day approach. For 2018 global poverty is estimated at about 31% or 2.4 billion people, while the dollar-a-day approach identifies poverty to stand some three times lower than that. When partially accounting for uncertainty –using a modeling approach– the level at which the global poverty statistics with a 97.5% confidence do not exclude individuals that may be poor, the global poverty rate rises to almost 35% or about 2.7 billion people in 2018. In relative terms this constitutes a reduction by a factor of ca. 2.4 between the two benchmark years and an increase in the absolute number of people living in conditions of poverty by a factor of ca. 3.3.

Keywords— Cost of Basic Needs, Global Poverty, Uncertainty, Healthy Diet, Diet Affordability, Long run poverty

JEL Codes— I32

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1. Introduction

Global measurement of poverty is a relatively recent possibility. It started in the late 70s by researchers at the World Bank (Ahluwalia et al., 1979), and was shaped to –practically– its present form in the late 80s (Ravallion et al., 1991). Data availability in terms of income and consumption distributions did not allow this type of exercises prior to that period. While constraints of global price data did not facilitate the adoption of a cost of basic needs based method in defining and measuring poverty on a global scale, albeit being the typical methodology in national poverty measurement across the development world.

Two new sources of price data have since become available that provide the possibility to measure global poverty in terms of specific consumption baskets, which can include not only food and other consumables, but also utilities and services. The first is the availability of price data from the periodical World Bank's ICP rounds that estimate the Purchasing Power Parities for almost all the economies around the globe, in recent years. This source has been used by Hirvonen et al. (2020) in estimating the cost and the affordability of health diets based on the EAT–Lancet framework. The second source is the retail prices for food stuff, energy and utilities from the October Inquiry of the International Labour Organization (ILO). This classic statistical exercise was being conducted every year from 1924 until 2008, when ILO resources were redirected to other activities. In this unprecedented statistical endeavor the ILO coordinated with National Statistical Offices around the world, covering at its peak more than 120 countries, and gathered price data relevant to working households. This treasure of largely unutilized data is freely available at ILO library, and has been digitized in two waves by de Zwart et al. (2014) and Moatsos (2021a). In the later, the ILO price data have been used for the purpose of historical estimation of global poverty, further demonstrating the possibility of measuring global poverty using cost of basic needs approaches following Moatsos (2017) and Allen (2017) who pioneered this for recent years.

This paper takes a further and necessary step towards a more defensible definition of global poverty from a 21st century standpoint. In retrospect, both Allen and Moatsos (ibid) use quite frugal consumption baskets in their poverty line definitions. In turn this means that they identify as poor only a fraction of those who may be characterized as poor. This is understandable as they both focused on extreme poverty, still is the affordability of 3 square meters of housing per person an appropriate level to identify poor from non-poor, while 4 square meters is not? Moreover, the underlying concept of the food component used is based upon the idea of meeting some general minimum dietary requirements on a small set of nutrients, instead of more up-to-date dietary guidelines such as the ones followed by the EAT-Lancet initiative (Hirvonen et al., 2020), or the work by FAO and the World Bank (Herforth et al., 2020) that focuses on UN member governments' food-based national dietary guidelines. These guidelines focus on food group recommendations, and are consistent with more recent evidence and government policies. The approach of fulfilling a checklist of nutrient levels, embedded in the current cost of basic needs literature for global poverty, reflects an earlier aspect of health science research and policy.

Therefore, the focus of this paper is to re-combine the aforementioned approaches (Allen, 2017; Moatsos, 2017, 2021a) to estimate the affordability of healthy diets on the long run since 1820, and the global poverty rate that results from a cost of basic needs poverty line that incorporates the aforementioned EAT–Lancet food component, for the same period. In doing so, I also identify the levels of the costs of these consumption baskets, and the trends of the food component costs. In addition, by building on the findings of Moatsos and Lazopoulos (2021), I investigate the evolution of the confidence interval of global poverty estimates for the EAT–Lancet–based global poverty estimates.

The rest of the paper is organized as follows: section 2 discusses the methods and the data used, section 3 presents and discusses the results, and section 4 concludes.

2. Methods and Data

2.1 Overview

In brief, the basic idea is to use the framework developed by Moatsos (2021a) in estimating a cost of basic needs (CBN) global poverty on the long run, but substituting the food component with the one estimated by Hirvonen et al. (2020). As it is discussed below in more length, this is done in two main steps: a) only using the EAT–Lancet food costs as a poverty line, to identify its long run unaffordability, and b) add non-food components on top of the EAT–Lancet food costs to deliver CBN poverty lines a la Allen (2017). In the above, the ILO food price data are used to estimate a food price index to deflate/inflate the EAT–Lancet diet food component, in order to move it through time.

2.2 Long run CBN poverty lines

Allen (2017) used linear programming to estimate the least cost diets at four levels of nutritional value. In terms of the food component, he opted for what he calls the "basic model" definition that allows for "2,100 calories per day, 50 g of protein, 34 g of fat [...] plus the Indian recommended daily allowances (RDA) of iron, folate, thiamine, niacin, and vitamins C and B12". This is an nuanced version of the Bare Bones Basket approach that Allen (2001) and Allen et al. (2010) have developed within the historical real wages literature. In terms of the non-food component his definition includes 3 square meters of housing per person, and costs for lighting, clothing, footwear, and bedding are estimated in proportion to the heating requirements of each country.[1]

Given that the historical price data from ILO mostly cover basic food prices, Moatsos (2021a) models the relationship of the food and non-food components as a function of GDP per capita in the "basic model" poverty line by Allen (2017), as shown in figure 11 in the supplement. The "CPF" food component (standing for the **c**alories, **p**roteins and **f**at use by Allen) can be estimated directly using the ILO price dataset (see below). Over that CPF food component, Moatsos (2021a) first applies a multiplier to account for the cost differences between the CPF and the Basic Model diets in Allen (this multiplier is not required in the present exercise). Over that amount, a second multiplier corresponding to the non-food component multiplier is applied in order to reach a full poverty line resembling the "basic model" poverty line as defined by Allen (2017). Here, I use the EAT–Lancet food component, instead of the CPF diet, so the first multiplier is redundant and not used, as the EAT–Lancet diet already accounts for offering a healthy diet.[2]

To go beyond the years covered by the ILO data, the last estimated poverty line in each country is extrapolated using available CPI information. For country-year combinations where CPI data are not available then the extrapolating assumption used by the World Bank in its dollar-a-day approach is applied, according to which the value of a poverty line in Purchasing Power Parity dollars is equivalent in welfare terms across time and countries. Here, I only use the first part of this assumption (equivalence across time) as each country uses different price data for calculating the local poverty lines (for the years that price data are available). This standard "equivalence across time" assumption, along with available CPI data, allow us to extend beyond the maximum of 1924 and 2008 boundaries allowed by the ILO

[1] Allen uses data for lighting, clothing, footwear, and bedding from two extreme cases, the cold St. Petersburg and the warm Bombay, and linearly interpolates all other locations base on their household heat energy requirements as calculated by Moatsos (2017) and Moatsos (2021b).

[2] Moreover, the imputed values from the relationship shown in figure 11 of the supplement, are applied within the observed GDP per values in the Allen data (that have a range of 820∼49,675 2011 PPP dollars), and the GDP per capita values are clipped outside of that bracket. In addition, in this simple multiplier approach the relationship between the energy requirements and the expenses for light, clothing, footware and bedding is only indirectly used.

price data, to a 1820–2018 time-frame.[3]

2.3 EAT–Lancet healthy diets

In 2019, the EAT–Lancet Commission published its report on sustainable healthy diets (Willett et al., 2019). The EAT–Lancet Commission, comprised of "19 Commissioners and 18 co–authors from 16 countries in various fields of human health, agriculture, political sciences, and environmental sustainability" (ibid), defined a set of nutrient targets, shown in table 1, that would provide for a healthy diet within planetary environmental constraints in terms of food production. The EAT–Lancet healthy diet provides for 2503 kcal per day, which is an estimate corresponding to the "average energy needs of a 70-kg man aged 30 years and a 60-kg woman aged 30 years whose level of physical activity is moderate to high" (ibid).

Hirvonen et al. (2020) have used the EAT–Lancet recipe for healthy diets and have estimated the costs for 2011 using data from the 2011 World Bank International Comparison Program PPP estimates. However, although the ICP is the largest statistical activity worldwide, not all necessary (average[4]) price information to estimate the EAT–Lancet diet cost is available at the ICP dataset. Therefore, some imputations have been used when necessary (Hirvonen et al., 2020). The intention of the authors was not to estimate poverty per se, but to highlight the affordability of these reference diets. However, they are excellent in reflecting the actual cost of the food component of a globally defined poverty line. These food costs have a mean value of $2.89 (in 2011 PPP) a standard deviation of $0.66, and cover the values from $1.69 to $5.18, figure 1 provides an overview. For comparison, taking the average of the same countries underlying the $1.9 international poverty line,[5] one gets a value of $2.41. In this comparison, one needs to keep in mind that this value only reflects costs for a proper nutrition per person per day, and excludes any other expenses (such as housing, heating, clothing, and even food preparation).

As described above, here their estimates are used in two ways: first, as poverty lines on their own, and second, to substitute the food component from the Allen (2017) "basic model" described above, on top of which the aforementioned non-food multipliers from Moatsos (2021a) are applied to get the full poverty lines.

2.4 Data

The ILO's October Inquiry collected the data on 15 basic food items initially from a small set of large cities around the world (see figure 2). These included: white bread, rye or black bread, wheat flour, rice, beef, mutton, bacon, margarine, milk, sugar, coffee, tea, cocoa, beer, firewood, coal, electricity, gas, paraffin oil, soap, etc. After the second world war a series of more products and several other cities are added (Moatsos, 2021b). Gradually, the geographic coverage increases, and the price data are

[3]An important note on China: The case of pre-1995 China is a particular one in Moatsos (2021a). Using two price sources the author shows that the price data produce unrealistically low poverty rates in the 1980-1995 period. This result is driven by the large differences in the national consumption price indices (both for urban and rural areas), and the much larger price changes in the price dataset. As we go back in time the prices drop at a much faster rate than the general inflation making the consumption basket much more affordable, and leading to almost zero absolute extreme poverty, which is very unlikely to be the case. To accommodate this the author builds the scenario where all changes in CPI are assumed to be linked to changes in food prices and the costs of the non-food component are kept fixed. This scenario on the other hand produces unrealistically high poverty rates, and the usual compromise of taking the average of the two prevails. It has to be noted that this issue with the reported food prices is not related only to CBN, but also to the dollar-a-day method, although there it is not visible.

[4]The ICP price data are made available without any confidence interval.

[5]These are 15 mostly sub-saharan African countries and are the same as those used for the estimation of the $1.25/day poverty line in 2005 PPP terms

Table 1: The healthy reference diet described by Willett et al. (2019).

	Macronutrient intake (possible range), g/day	Caloric intake, kcal/day
Whole grains		
Rice, wheat, corn, and other	232 (total gains 0–60% of energy)	811
Tubers or starchy vegetables		
Potatoes and cassava	50 (0–100)	39
Vegetables		
All vegetables	300 (200–600)	
Dark green vegetables	100	23
Red and orange vegetables	100	30
Other vegetables	100	25
Fruits		
All fruit	200 (100–300)	126
Dairy foods		
Whole milk or derivative equivalents (eg, cheese)	250 (0–500)	153
Protein sources		
Beef and lamb	7 (0–14)	15
Pork	7 (0–14)	15
Chicken and other poultry	29 (0–58)	62
Eggs	13 (0–25)	19
Fish	28 (0–100)	40
Legumes		
Dry beans, lentils, and peas	50 (0–100)	172
Soy foods	25 (0–50)	112
Peanuts	25 (0–75)	142
Tree nuts	25	149
Added fats		
Palm oil	6·8 (0–6·8)	60
Unsaturated oils	40 (20–80)	354
Dairy fats (included in milk)	0	0
Lard or tallow	5 (0–5)	36
Added sugars		
All sweeteners	31 (0–31)	120
Total		2503

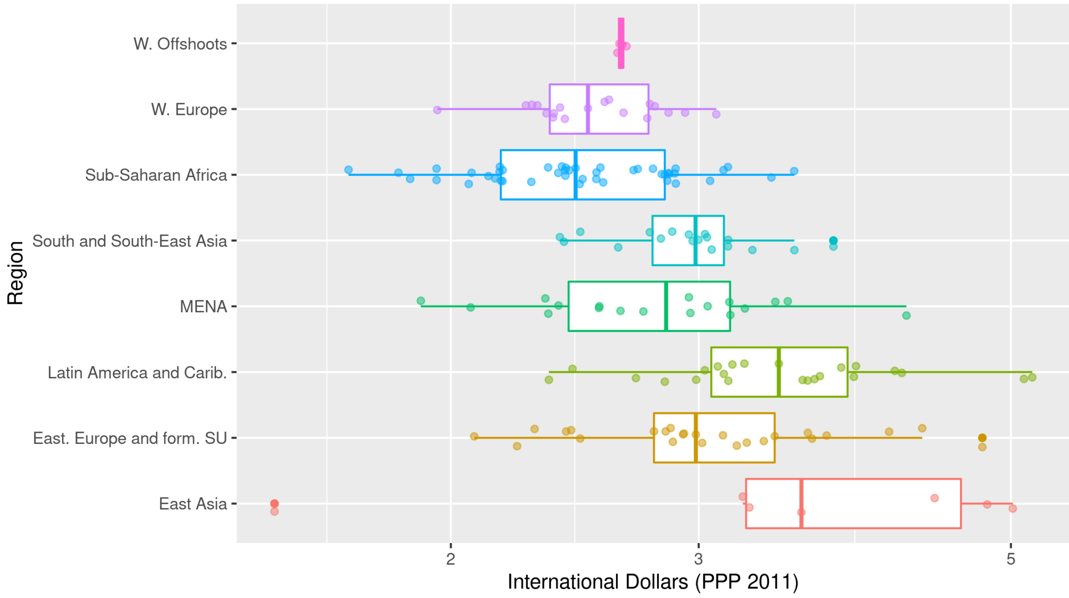

Figure 1: Costs of the EAT–Lancet reference diet across the world from Hirvonen et al. (2020) estimated in 2011 PPP dollars.

reported on a country rather than a city level. By 1967, 129 countries and 33 products are included. In 1985, the products covered are updated, now reaching 47–49 products across 12 categories: main staple, beans/peas, meat, fish, oil/butter, sugar, soap, fuel, fruits, vegetables, dairy, and other. Broadly speaking these elements correspond to the items included in the EAT–Lancet reference diet. In 2008, which is the last year that these data were collected, 91 countries have participated. Throughout most of the period the average number of products reported per country hoovers around 20 and 23 products, with an overall average at about 21 products per country and year.

The data gaps in the ILO price data are interpolated and extrapolated using the best available CPI information or with the evolution of prices from the ILO data itself, along with the corrections detailed in Moatsos (2021a).[6] Using an average CPI indicator may include bias in the data, as the extrapolation of specific product prices using the average CPI may well diverge from the actual missing price. For example, extrapolating the price of wheat flour in France from 1984 (last year with available ILO data from France) using the average CPI rate up to 2011 gives a more than double a price compared to the price present in the ICP data for 2011. However, this is only relevant for a handful of cases in the data, and in many of those cases it is for countries that have a very low poverty rate, which implies a very small absolute bias on the aggregate. Using the aforementioned method, the initial 158,500 total price data observations from the original sources become 443,478. For China in 1911 and 1913, and for the 1929–1938 period I also use prices from "Economic growth in pre-war China" (Rawski, 1989).

Beyond the necessary data to compute a poverty line, information on the income or consumption

[6]Sources used for the CPI include: Balkans Historical Central Bank Data, Clio Infra (de Zwart, 2015); IMF data `https://www.imf.org/external/datamapper/PCPIPCH@WEO/OEMDC/` last accessed in August, 13, 2015; World Bank World Development Indicators CPI, last accessed on May 24th, 2019; LABORSTA ILO CPI indices on clothing, and general, `http://laborsta.ilo.org/applv8/data/SSM1_NEW/E/SSM1.html` last accessed on August 14th, 2015 (these data are no longer available online); FAOSTAT CPI data `https://www.fao.org/faostat/en/#data/CP` last accessed on October 9th, 2015; the JORDÀ-SCHULARICK-TAYLOR MACROHISTORY DATABASE (Jordà et al., 2016), `https://www.macrohistory.net/database/` last accessed on May 24th, 2019; and OECD CPI last accessed on October 19th, 2019.

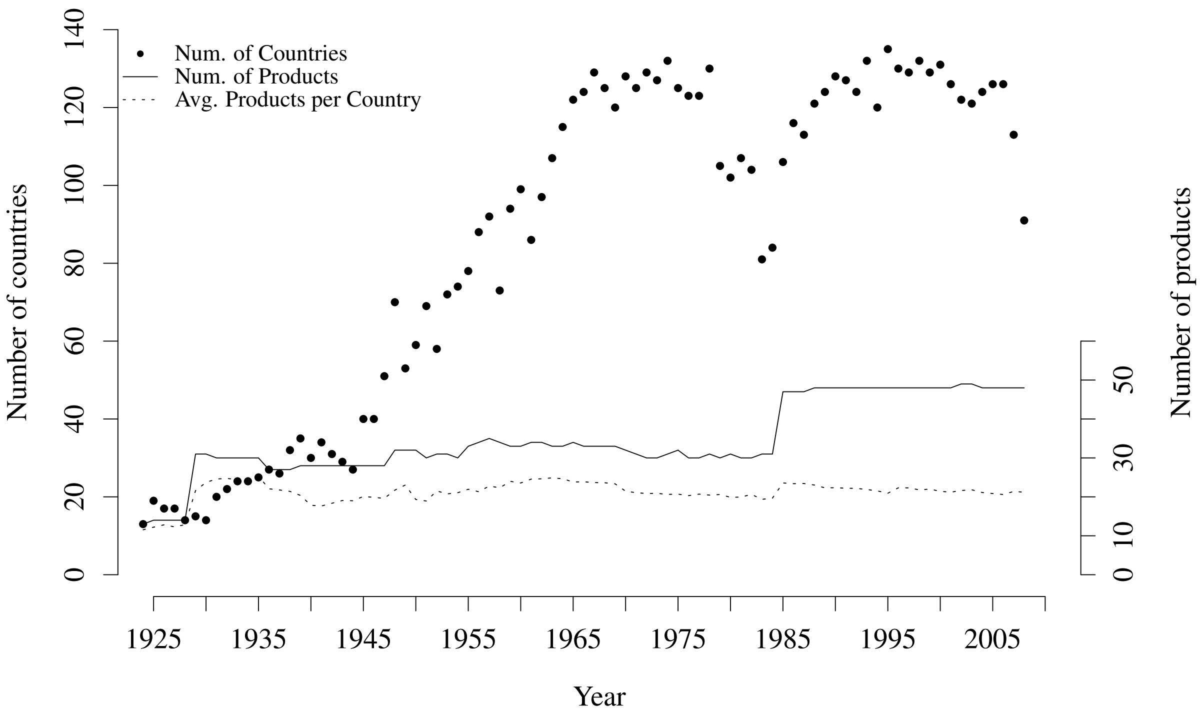

Figure 2: ILO October Inquiry unique country and product counts, 1924-2008

distributions is also necessary to estimate the poverty rate. For the recent period, since about 1980, I have relied on the detailed distributional information from household surveys (HHS) made available by World Bank's PovcalNet.[7] Data taken from PovcalNet concern 1834 distributions across 159 countries, from the period 1967–2019. However, as figure 3 shows, the vast majority of the distributions –1817 to be exact– from the PovcalNet data concern the period 1981–2018.

For the period before the years covered by PovcalNet, I have relied on more historical sources such as World Income Inequality Database maintained by UNU-WIDER and Zanden van et al. (2013), that provide estimates of Gini indices, along with the log-normality assumption to covert the Gini estimate to a full distribution. In total, some 2369 Gini datapoints were used for the period not covered by PovcalNet in each country (that period typically starts 4 years prior to the first PovcalNet estimate). In country-years were only one source for Gini was available then this was used.[8] For country-years with more than one available estimate for Gini then preference is given to distributions of disposable income, and if that was not available, gross (i.e. pre-tax) income Ginis where used, and if that was not available, distributions without a detailed specification are used. When more than one estimate of comparable quality and specification are available, I average their values, which were typically already relatively close to one another. To impute years between available Gini estimates I relied on databases that provide synthetic Gini estimates, namely Solt (2016) and the Estimated Household Income Inequality Data Set (EHII) V2017 v.1 from the University of Texas. Figure 4 provides an overview of the non-PovcalNet

[7] Last accessed on December 13th, 2021

[8] Unless in that country-year a new type of Gini was becoming available that was clearly incompatible with Gini estimates from the years before and after, as for example a consumption based survey between years with income based survey.

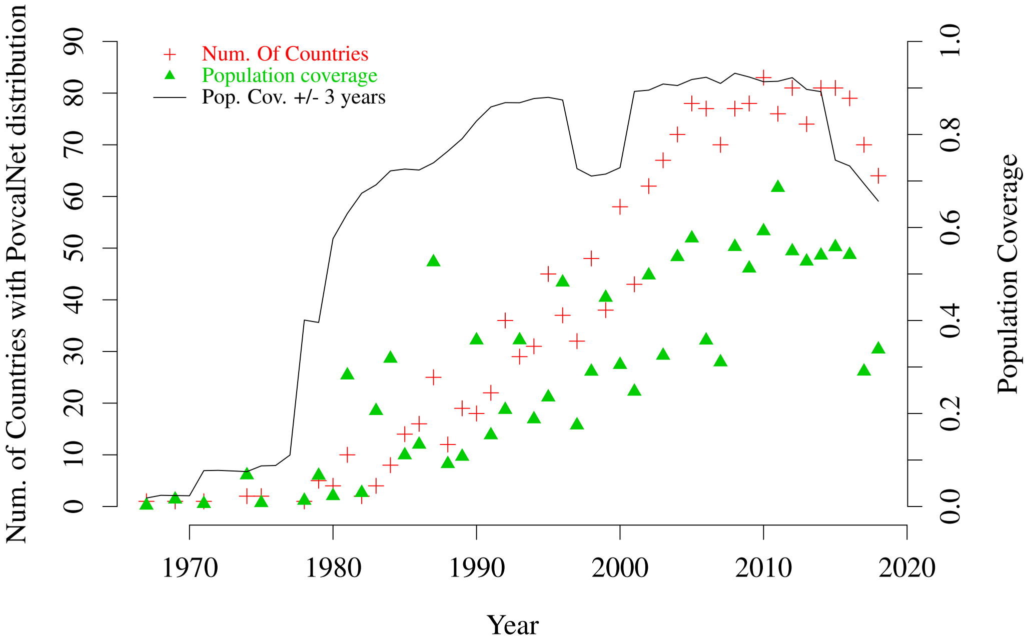

Figure 3: Year and Population coverage of PovcalNet distributional data. Left axis: number of countries per year with a PovcalNet distribution (red). Right axis: aggregate population coverage per year (green) and aggregate population coverage where if a country has a household survey estimate +/- 3 years around a year it counts as having one in that particular year (black). The big drop in population coverage around 2000 has to do with omitting the much criticized Indian household survey from 1999/2000.

Gini data used.

In terms of overall population coverage from the perspective of distributional data, including both PovcalNet and non-PovcalNet data, for the post 1950 period it reaches 83% on average, for 1900-1950 32%, and for the 19th century 28% on average.

In any case, and given that those estimates usually come without their measured mean income, I follow Moatsos (2021a) in estimating unobserved household mean income for these distributions. More specifically, Moatsos (ibid), largely following Ferreira et al. (2016), uses a simple method to account for the observation by Deaton (2001) that there is a divergence in the ratio of mean household consumption measured by the National Accounts Statistics over that of the survey on the distribution of household expenditures, by discounting the growth rates between NAS GDP per capita or Household Final Consumption per capita, to impute missing HHS income or consumption values.

GDP per capita and population data come from the Maddison project (Bolt et al., 2018).

2.5 Global Aggregation

To reach a reasonably high global coverage for such a long period additional, imputations are needed for country-year combinations that are missing (as shown on figure 5).

Following Moatsos (2021a), direct poverty rate imputations are based on the observed change of the average poverty rate among countries of the same region with available observations. This is done using

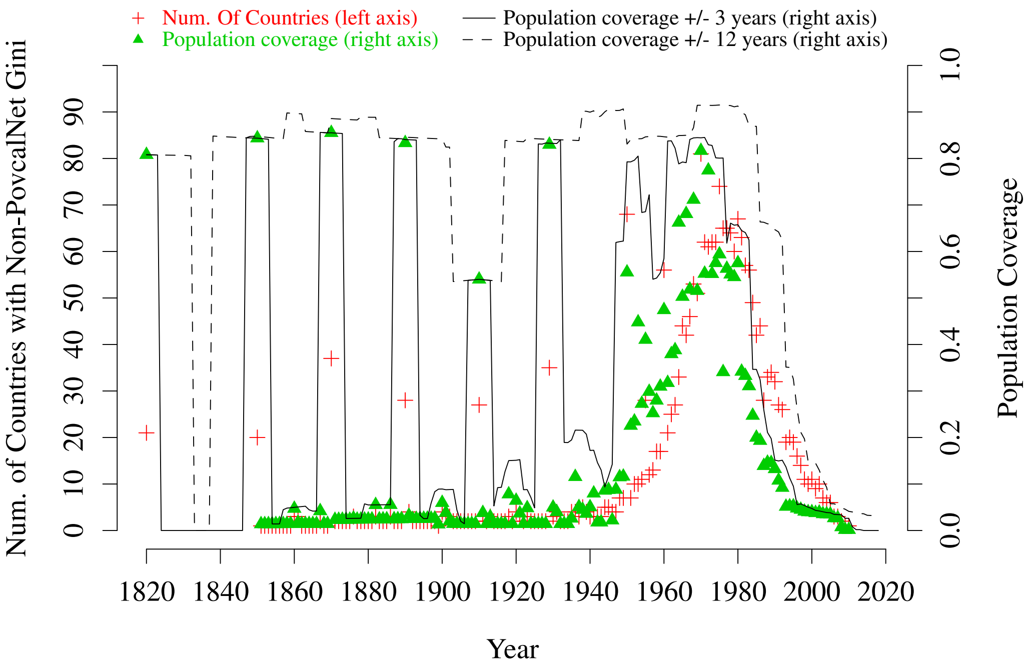

Figure 4: Year and Population coverage of non-PovcalNet Gini data. Left axis: number of countries per year with a non-PovcalNet Gini estimate (red). Right axis: aggregate population coverage per year (green) and aggregate population coverage where if a country has a non-PovcalNet Gini estimate estimate +/- 3 years around a year it counts as having one in that particular year (black). The dashed black line shows the aggregate population coverage with at least one distribution in a 25 year window.

poverty estimates from countries that have available estimates both for the reference and the imputation year, which themselves are not a result of regional imputation or linear interpolation. This approach requires less strong assumptions than the aggregation method used by the World Bank, according to which the poverty rate among the missing countries is equal to that of the observed countries on a global scale. Here the last estimated poverty rate from a particular country is moved in time using the observed mean change of poverty rate in the same region. Moreover, when there are distant poverty rate observations for a particular country, the years in between are linearly interpolated (mostly relevant for the 19th century).[9]

For the 1950-2018 period the average population coverage with direct or interpolated ILO data is about 83% (see also figure 5). For a long 20th century, 1900-2018 the average population coverage drops to about 53%, while using CPI extrapolation or the PPP assumption the average yearly coverage increases to 76%. For the 19th century the average population coverage with direct or interpolated ILO data drops to 0%, while using CPI extrapolation or the PPP assumption it reaches on average 12%, with almost a considerable western countries bias, and lacking any country from Africa. Throughout the period the residual coverage up until the 94% average overall population coverage is achieved through regional imputations and linear interpolations. For the remaining ca. 6% the aforementioned aggregation assumption by the World Bank is used.

[9] See Moatsos (2021a) for additional details.

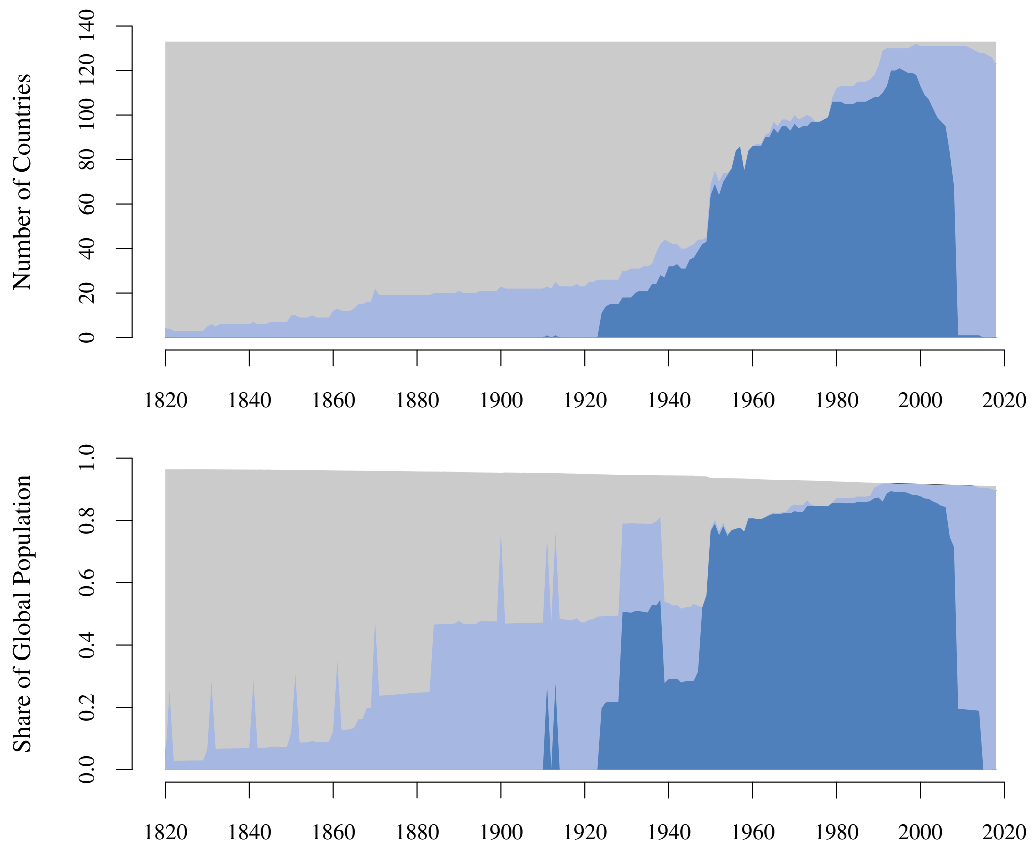

Figure 5: Adapted from Moatsos (2021a): Upper subplot shows the number of poverty lines calculated in three different ways: (i) original and imputed ILO price data (dark blue), (ii) the total costs of food baskets imputed using the best available CPI or the PPP assumption (lighter blue), (iii) interpolations and regional extrapolations (grey). Lower subplot shows the share of the global population covered by these different approaches. The dark blue spikes in 1911/1913, and the light blue hump in population coverage during the 1929–1938 period reflect price data from China. The light blue spike in 1900 is also due to China. The light blue spikes in 1821, 1841, 1851, 1861, and 1870 are due to India.

The final level of coverage is similar to the one used by Bourguignon and Morrisson (2002) in their seminal "Inequality Among World Citizens: 1820-1992" article, although the general method and the imputations routes used therein and here differ in a number of key ways. First, countries are grouped into 33 sets, while here all countries existing in 2018 remain in the data throughout the whole period. Second, they are using gdp growth rates for neighboring countries from the Maddison dataset to estimate gdp per capita backward to 1820 for the 33 entities they use, here the extrapolation takes place at the final stage prior to aggregation and it is based directly on the evolution of poverty rates not on GDP per capita rates. Third, they use decile level information on the distribution of income, while here it is either detailed distributional information from PovcalNet, either the inverted distribution that obtains from a given Gini coefficient using the log-normality assumption (Lopez and Servén, 2006). Fourth, they provide estimates on a set of benchmark years 20 or 30 years until 1950 and then every decade. Here, I provide yearly estimates on global poverty statistics. Fifth, they do not use a specific concept for poverty definition, instead they calibrate their estimates to produce the same global poverty rate as the World Bank does for 1992. This is of particular importance as with the advent of the 2005 PPP estimates from the World Bank International Comparison Program, the global poverty rate has been updated upward. This development is highlighted by the title of the relevant article by the World Bank researchers Chen and Ravallion (2010) "The Developing World is Poorer than We Thought, But No Less Successful in the Fight Against Poverty". Nonetheless, their effort within the scarcity of data prevailing in ca. 2000 when Bourguignon and Morrisson developed their paper is certainly laudable, and the approach they take in steering across the methodological difficulties radiates effectiveness and simplicity.

3. Results

3.1 Trends and levels

Figure 6 shows in comparison the costs of the EAT–Lancet healthy diet and the poverty lines base on the EAT–Lancet diet (dotted lines) for a group of six countries around the world.

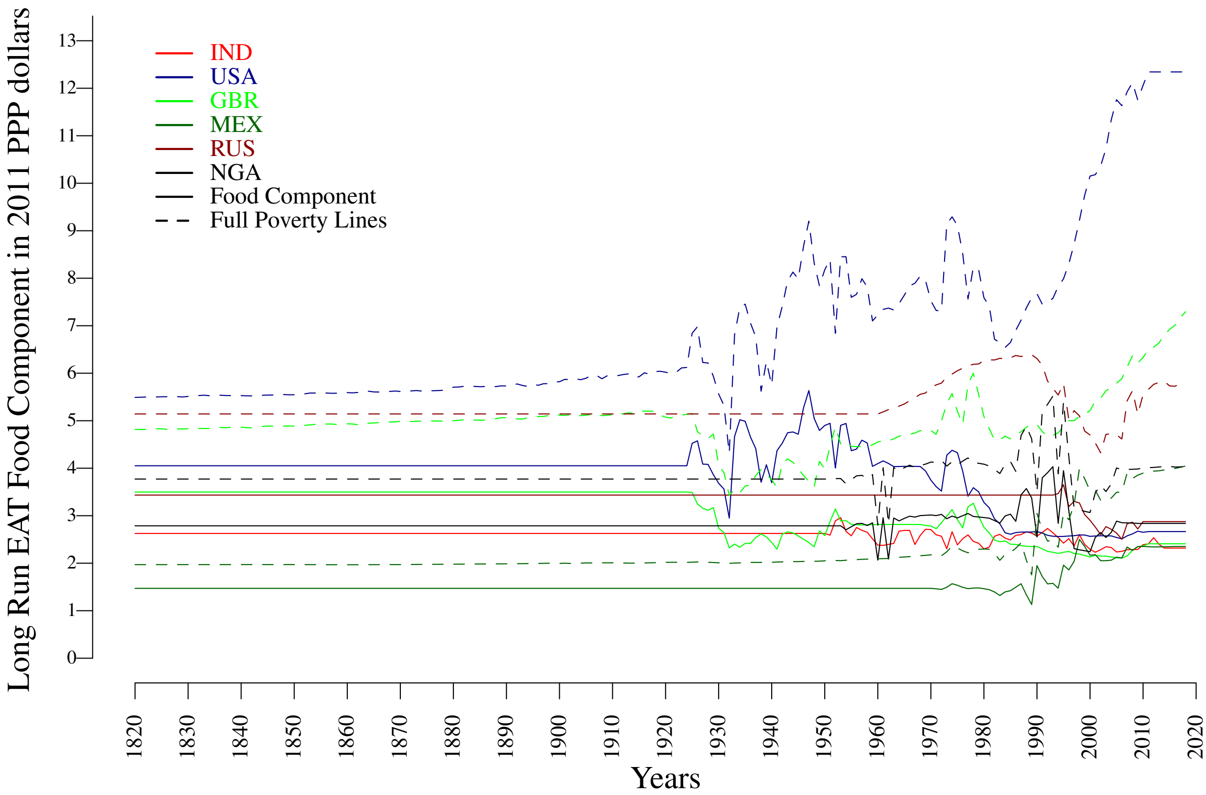

Figure 6: Yearly evolution of the costs of the EAT–Lancet healthy diet (continuous lines) and that of the full EAT–Lancet based poverty lines (dotted lines) for six countries (in 2011 PPP dollars). The from the CBN Global Poverty lines by Moatsos (2021a).

The values, outside the 2011 baseline year for the EAT–Lancet estimates, obtain by applying the price index from the CPF food component estimated by Moatsos (2021a). When no further CPI data are available, then the price is held fixed at its last estimated value (going back in time), following the PPP extrapolation assumption from the dollar-a-day methodology of the World Bank.

The EAT–Lancet food component lines vary in shape according to the divergence between the CPF price index, and the average CPI. For the USA, United Kingdom and Russia, the trend is a declining one, starting from about a 4, 3.5 and 3.5 PPP dollars respectively, down to 2.7, 2.4 and 2.87. This implies that the food component is becoming relatively cheaper as a product of time in those countries. For India, it is less so the case, as it starts at 2.6 and ends at 2.31 PPP dollars. Nigeria, although quite volatile the start and the end values are very close, at 2.8 PPP dollars, although the trajectory in between is rather volatile. For Mexico the trend is upward, starting from a low value of 1.5, and reaching 2.4 at the end of the period.

3.2 Long run unaffordability of a healthy diet

Using the extrapolated EAT–Lancet healthy diet cost series, figure 7 shows the evolution of the unaffordability of a healthy diet (shown in blue), in comparison with the results obtaining from the World Banks Dollar-A-Day approach (in light blue) throughout almost 200 years.

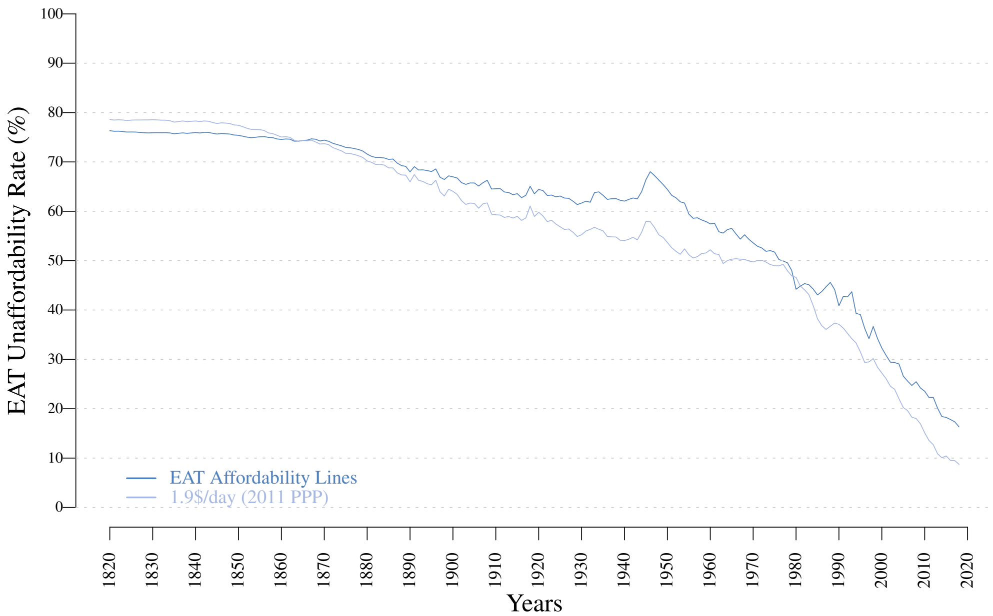

Figure 7: Long run global unaffordability of the EAT–Lancet reference diet, shown in comparison with the 1.9$/day global poverty estimates by Moatsos (2021a).

For most of the 19th century more than 70% of the global population lies below the threshold of purchasing an EAT–Lancet healthy diet, with a maximum at 76% in 1820, or 708 million people. The 60% barrier is crossed in late 1950s, and the 50% in early 1980s. The rate of non-affordability reduction accelerates after that, and by 2018 it drops at a historical minimum of a little over 16%.

For the most part the healthy diet unaffordability line lies above the dollar-a-day poverty rate. In those years the average absolute difference is at 5 percentage points (with a maximum at 11 percentage points in 1948). However, before 1864 it is the dollar-a-day poverty rate that stands above, albeit with a smaller mean absolute difference at 2 percentage points. The reversal however shows that the price trend in the food component, compared with the trend of the average price evolution is divergent enough to allow for the crossing of the two lines in the second part of the 19th century. The divergence appears to have its roots in the 1950–1980 period, while global population coverage is still high. In the 1930s, the break seems to be stabilizing, again over a period that population coverage with ILO/CPI data is around or above 50%. In any case, the bulk of the effect is attributable to China, and although the global rate of unaffordability lies below the dollar-a-day line, still for most countries this rate is higher that the dollar-a-day poverty rate.

3.3 Global Poverty

Figure 8 shows the global poverty rate evolution according to the EAT–Lancet healthy diet based full poverty lines and the standard $1.9/day approach. The EAT–Lancet approach provides an estimate at around 83% in 1820, and the 80% barrier does not break until 1880. Slow reduction takes place until the second World War, while in the period after that the reduction accelerates. The reduction achieved between the first Millennium Development Goal years is 32.5%, with a poverty rate at 48% in 1990 and 32% in 2015. By 2018, the all times minimum is reached at around 35%.

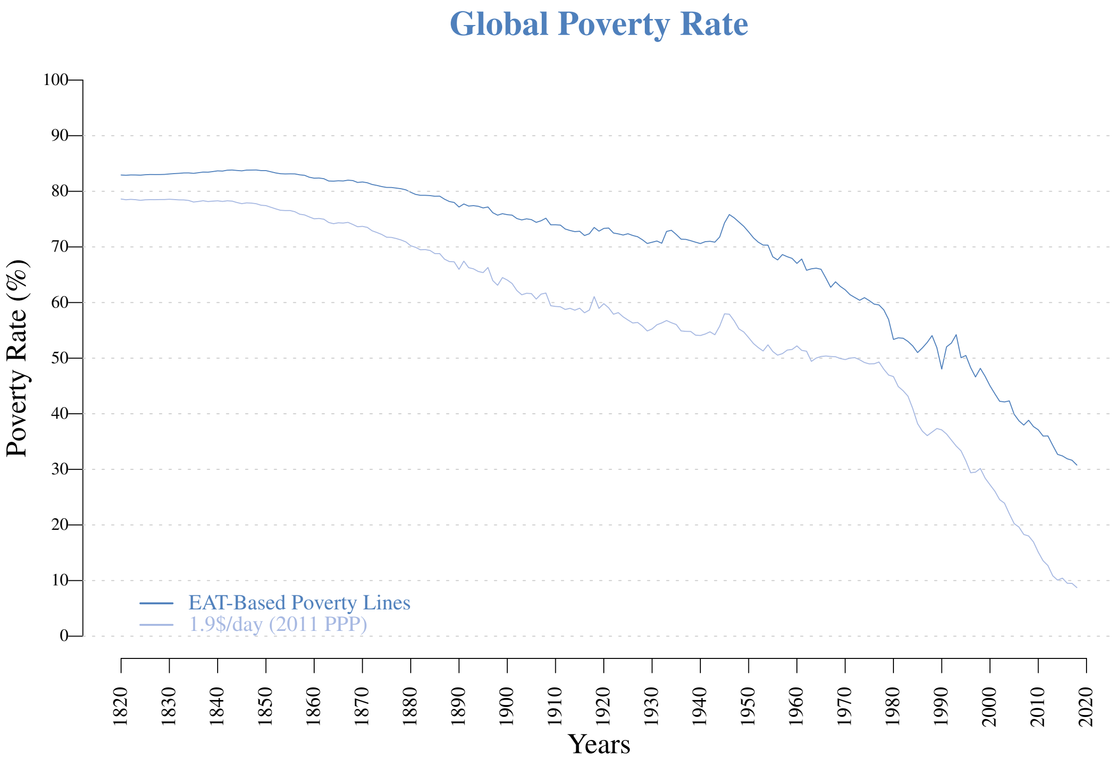

Figure 8: Long run global poverty rates using the EAT–Lancet based full poverty lines, shown in comparison with the 1.9$/day global poverty estimates by Moatsos (2021a).

The EAT–Lancet poverty rates stand substantially above the dollar-a-day results throughout the period. The gap has been almost monotonically increasing from 1820 (at about 4 percentage points) until the late 1940s (at ca. 19 percentage points in 1948). Thereafter is decreasing until a minimum of about

7 percentage points in 1980, to steadily increase until its maximum in 2013 at 23.5 percentage points, while remaining at above 22 percentage points thereafter. The overall reduction identified by the dollar-a-day approach stands at 89%, while the EAT–Lancet poverty reduction is a more conservative one at 63% across 199 years.

Figure 9 shows the global poverty counts according to the EAT–Lancet healthy diet based full poverty lines and the standard $1.9/day approach. In 1820 the EAT–Lancet approach identifies 770 million people living in conditions of poverty, and by 2018 the number is almost 2.4 billion. The maximum number appears in 1993 at almost 3 billion people. The estimates between the two methods diverge increasingly as a product of time. In 1820, there is a discrepancy of about 40 million people, while by 2018 this difference stands at more than 1.6 billion. The divergence accelerates after the 1980s, and during the high dollar-a-day poverty reduction years of the 1990s, the gap is widening faster.

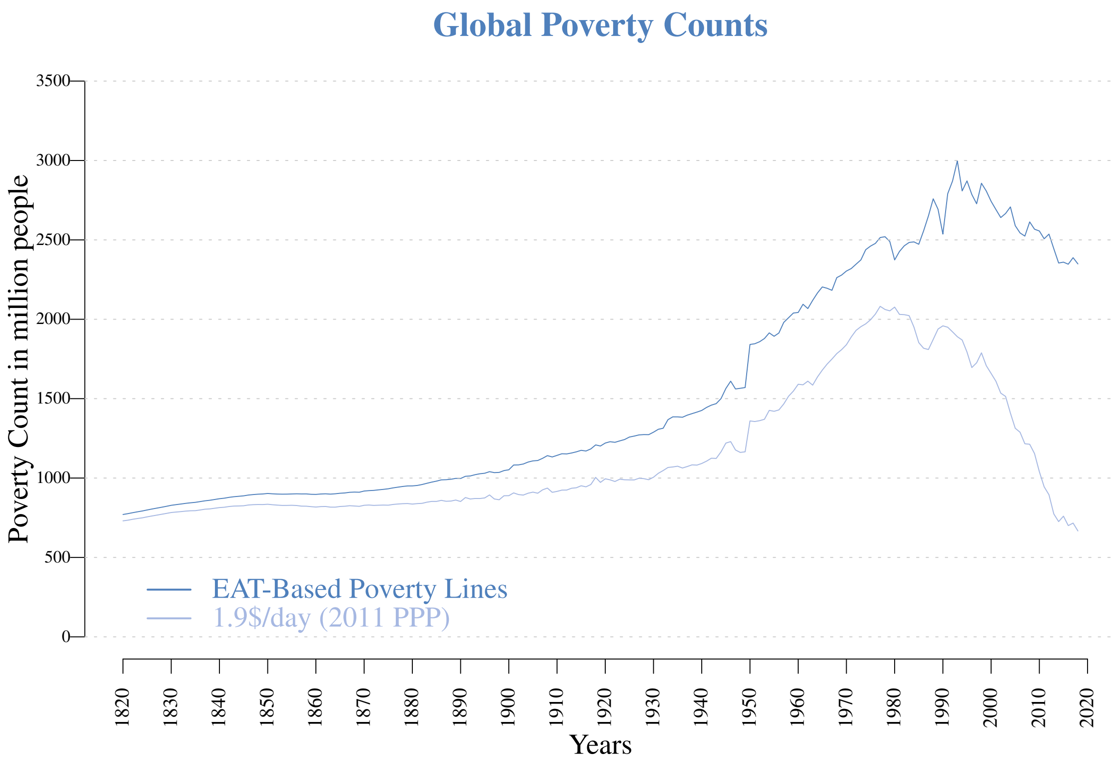

Figure 9: Long run global poverty population counts using the EAT–Lancet based full poverty lines, shown in comparison with the results of the 1.9$/day international poverty line.

3.4 Uncertainty

Based on the error estimates by Moatsos and Lazopoulos (2021), and the results presented here for global poverty, we can draft a rough model of the behavior of uncertainty for the dollar a day and the cost of basic needs in time (shown in figure 12 in the appendix). Moatsos and Lazopoulos (2021) identify 8 points in the poverty-rate and 95%-confidence-interval domain. Four of those points are for the dollar-a-day method and four for the cost of basic needs method. The 95%-confidence-interval is expressed as a ratio over the poverty rate where it corresponds (as shown in figure 12 in the appendix). The main assumption of this model is how the relative uncertainty is becoming suppressed as poverty estimates are reaching higher levels. This is assumed so because the income and consumption distributions are more sparsely populated on their upper range. More people are compressed at the mid or lower parts of the distribution around similar values of income or consumption than in the higher parts. For example, if a poverty line was given with a 95% confidence interval between $3 and $5/day more people would be captured *within* that range if average income is $10 rather than $5. This means that for a given confidence interval of the poverty line the uncertainty in poverty rates in 1820 would be lower than in 2018, only because the global poverty rate in 1820 is around 80%, while in 2018 it is around 9 or 30% (depending on the method).

I model the limits of the confidence intervals estimated by Moatsos and Lazopoulos (ibid). Figure 12 in the appendix outlines this linear modeling, which follows the aforementioned limits of the confidence intervals (expressed as a ratio over the mean value of the estimates) for 1990 and 2015 from both DAD and CBN, and the assumption that at 100% poverty rate the confidence interval will be singular.[10]. Then, I linearly interpolate/extrapolate between those three pairs of values for each method separately. Figure 10 shows the result of this ball park exercise (and table 3 in the appendix shows the numeric results in detail).

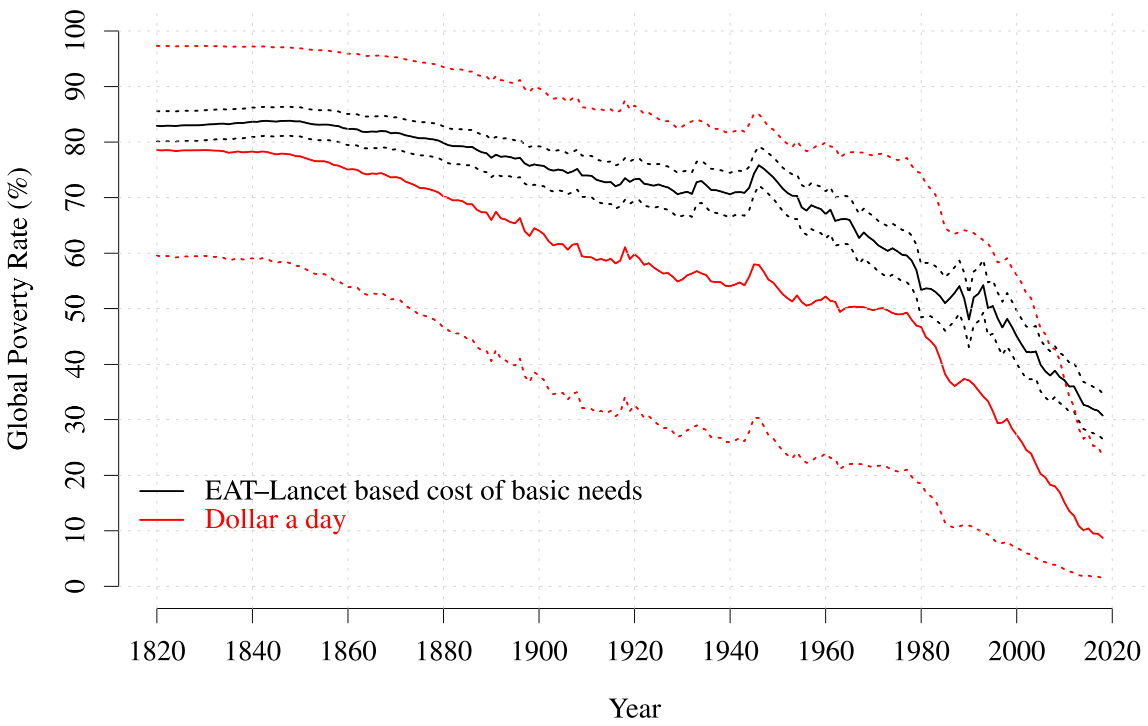

Figure 10: Global scale comparison of the EAT–Lancet CBN (in black) and DAD (in red) methods, using an approximation of the expected 95% confidence interval by modelling upon the findings of Moatsos and Lazopoulos (2021).

Figure 10 clearly demonstrates the large difference in the ability of the two methods to accurately pinpoint the level and trend of global poverty. The large uncertainty of the DAD method is a direct

[10]Small deviations from this assumption have limited impact on the outcomes.

result of the derivation method of the \$1.9/day international poverty line, and the large differences of the national poverty lines included in that exercise (Moatsos and Lazopoulos, 2021). The model does not account for many sources of error, like uncertainty in the GDP per capita estimates, and the non-food component multiplier used or interpolated household surveys. However, it does provide for a first approximation of the low boundaries for uncertainty in the estimates.

Finally, there are two ways of reading this figure. The first is to contrast the accuracy of the two methods, and evaluate global poverty with each method separately. The second is to choose the appropriate estimate based on a rule of high risk aversion with respect to global poverty. According to the latter, when we want to maximize our certainty –within a given confidence interval– of not excluding from the poverty statistics someone who is in poverty according to these methods, the upper limit of the 95% confidence interval would be preferred. This reading would be a conservative estimate in that set of preference. Antithetically, when we wish to minimize including in the poverty statistics individuals that are not in poverty, but are categorized as such because of each method's uncertainty, then we would choose the lower limit of that interval. From the conservative point of view the poverty rate in 2018 stands at about 35% or 2,650,665,260 individuals. Such an estimate is in high contrast with prevailing poverty counts from the World Bank, and it is only comparable to the \$5.5/day poverty line, albeit characteristically different in nature (Reddy and Pogge, 2010).[11] Using the same approach global poverty in 1820 stands at 85% or 794,916,520 individuals. In relative terms this constitutes a reduction by a factor of ca. 2.4 between the two benchmark years and an increase in the absolute number of people living in conditions of poverty by a factor of ca. 3.3. The corresponding results of the dollar-a-day approach paint a broadly similar –yet rosier– picture, and in any case at a considerably higher level in 1820 (97% or 904,242,944 persons) and a considerably lower level in 2018 (23.4% or 1,788,468,649 persons), which translates to a poverty reduction factor of ca. 4.2 in terms of poverty rate and an increase by a factor of about 2 in terms of the absolute number of people.

4. Conclusions

Measuring long-run changes and comparing living standards across very different countries can be facilitated by the establishment of absolute poverty lines based on the least-cost ways of attaining a minimum standard of health as well as housing and other requisites. This paper extends the methods pioneered by Allen (2001), Allen et al. (2011), Allen (2017) and extended by Moatsos (2017), Moatsos (2021b) and Moatsos (2021a) to reveal that, in terms of affordability of basic foods, on a global aggregate level there was less poverty in the 19th century but more poverty in recent years than is estimated using all prices in the economy as in the World Bank's dollar-a-day global poverty lines.

Moreover, global poverty in terms of a consumption basket that includes a healthy diet, and frugal additional expenses per Allen (2017), for example 3 square meters per person, has –at least since 1820– been higher in comparison to the dollar-a-day findings. The divergence between the two approaches has an increasing trend since 1990. The number of individuals living in conditions of poverty according to the the EAT–Lancet based poverty lines has increased by more than threefold since 1820, to reach almost 2.7 billion in 2018.

Furthermore, modeling confidence intervals constructed in Moatsos and Lazopoulos (2021), it is estimated that the limit of a conservative global poverty count for 2018 stands at almost 35%, a number multiple times higher than the prevailing numbers that appear across the media, rooted in the standard dollar-a-day approach.

Finally, this line of research can be improved in at least four directions: (A) additional work is needed in more firmly connecting the dots with the 19th century. Sources used in historical real wages literature

[11] Also the trends are different, see `https://pip.worldbank.org/poverty-calculator` and select the \$5.5/day option.

can provide price data to establish additional price index series to better impute the relevant evolution of food prices. (B) estimate the value of the EAT–Lancet reference diet (including its uncertainties, and adjusting for population age/gender profile as in Moatsos (2017)) directly from price data, instead of extrapolating it using the ILO based price index. (C) Make direct estimate of the uncertainty instead of using a short-cut modeling approach. (D) Further investigate the divergence between the average CPI rate and the food items based price index in China for the decade around 1990.

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5. Appendix A: Additional figures and tables

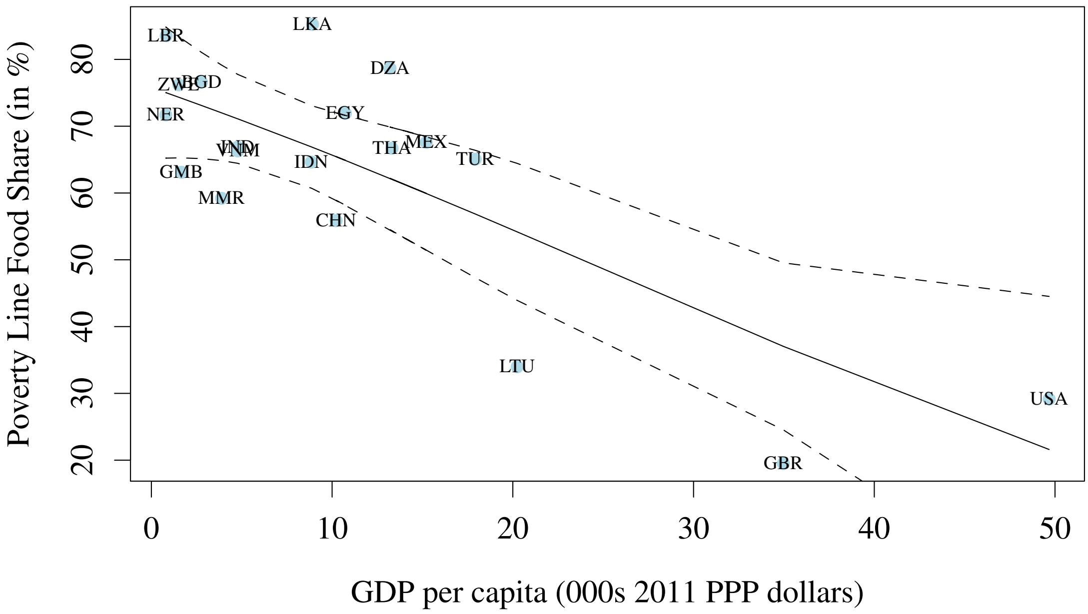

Figure 11: The relationship between the food share in the Allen's basic model poverty lines and GDP per capita. In both subplots the dotted lines denote the 95% confidence interval.

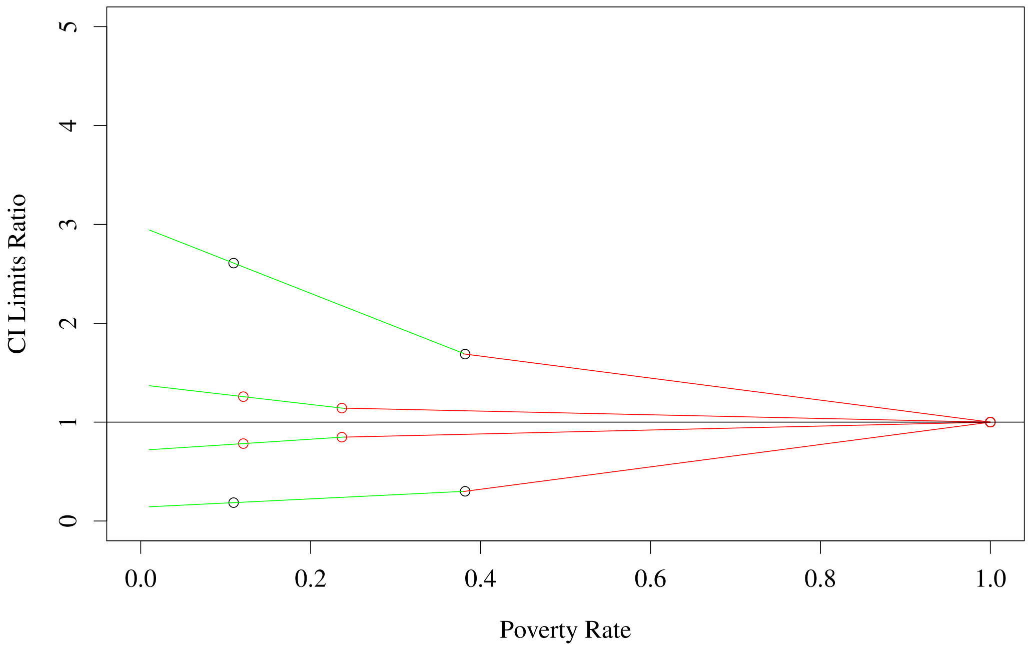

Figure 12: Modelling of the Confidence Interval ratios over the main estimate using the results from Moatsos and Lazopoulos (2021). Lower CI limits appear below the horizontal line for 1 and Upper limits above. Black circles are from DAD and red from CBN methods.

Table 2: Numeric comparison of the global poverty rates using the EAT–Lancet based full poverty lines, and the World Bank's $1.9/day approach (highlighted in light gray).

Year	East Asia	East. Europe and form. SU	Latin America and Carib.	MENA	South and South-East Asia	Sub-Saharan Africa	W. Europe	W. Offshoots	World
1820	82	79	95	98	90	99	68	86	83
	91	85	85	78	69	94	56	57	79
1840	85	76	95	97	90	100	65	80	84
	95	83	86	76	69	95	49	39	78
1860	86	60	94	97	91	99	60	70	82
	95	68	82	73	71	92	42	30	75
1880	85	46	92	96	93	95	53	59	80
	95	48	79	68	72	76	33	19	70
1900	84	38	89	96	92	98	45	42	76
	93	31	78	63	67	93	24	9	64
1920	84	40	85	94	89	96	42	27	73
	90	32	64	61	62	89	21	3	60
1940	84	38	81	90	86	92	36	16	71
	85	19	57	46	59	81	13	1	54
1960	78	56	71	86	87	83	29	4	67
	82	14	41	38	72	73	3	0	52
1980	54	30	37	70	82	79	2	2	53
	83	2	14	16	58	66	0	0	47
2000	21	34	30	61	76	77	1	3	45
	32	5	11	7	36	60	0	1	27
2018	6	6	21	37	48	70	2	3	31
	0	0	5	5	8	38	0	1	9

Table 3: EAT–Lancet CBN and DAD Global Poverty Rates and their confidence intervals based on Moatsos (2021a) and Moatsos and Lazopoulos (2021).

Region	Year	EAT–L. CBN Pov. Rate (%)	95% CI	DAD Pov. Rate (%)	95% CI
World	1820	82.93	80.11-85.57	78.61	59.59-97.33
World	1825	82.98	80.17-85.61	78.47	59.36-97.28
World	1830	83.12	80.33-85.73	78.57	59.52-97.32
World	1835	83.23	80.45-85.82	78.08	58.71-97.14
World	1840	83.68	80.95-86.22	78.30	59.07-97.22
World	1845	83.68	80.96-86.22	77.78	58.23-97.02
World	1850	83.73	81.01-86.26	77.43	57.65-96.89
World	1855	83.15	80.35-85.75	76.54	56.23-96.53
World	1860	82.36	79.47-85.07	75.06	53.87-95.9
World	1865	81.90	78.94-84.65	74.34	52.75-95.58
World	1870	81.68	78.7-84.47	73.70	51.76-95.28
World	1875	80.70	77.6-83.6	71.75	48.82-94.32
World	1880	79.83	76.62-82.82	70.21	46.54-93.5
World	1885	79.11	75.82-82.19	68.80	44.51-92.7
World	1890	77.17	73.66-80.45	65.97	40.56-90.97
World	1895	77.01	73.48-80.3	65.38	39.77-90.58
World	1900	75.80	72.14-79.21	64.04	37.99-89.68
World	1905	74.91	71.16-78.4	61.60	34.83-87.94
World	1910	73.98	70.15-77.56	59.30	31.99-86.17
World	1915	72.82	68.87-76.5	58.98	31.6-85.92
World	1920	73.33	69.43-76.96	59.80	32.59-86.57
World	1925	72.37	68.39-76.09	56.86	29.1-84.17
World	1930	70.85	66.73-74.69	55.26	27.28-82.79
World	1935	72.24	68.25-75.97	56.04	28.17-83.47
World	1940	70.61	66.47-74.47	54.07	25.96-81.72
World	1945	74.32	70.51-77.87	57.97	30.39-85.1
World	1950	72.70	68.74-76.39	53.69	25.55-81.37
World	1955	68.23	63.91-72.26	51.20	22.92-79.02
World	1960	67.04	62.64-71.15	52.20	23.97-79.98
World	1965	65.98	61.51-70.16	50.29	22-78.13
World	1970	62.29	57.61-66.66	49.75	21.45-77.58
World	1975	60.34	55.58-64.79	48.97	20.69-76.79
World	1980	53.36	48.4-57.99	46.68	18.52-74.4
World	1985	51.01	46.03-55.65	38.22	11.5-64.52
World	1990	48.04	43.07-52.69	37.10	10.98-63.99
World	1995	50.48	45.5-55.12	31.52	8.59-60.31
World	2000	45.02	40.09-49.63	27.23	6.92-56.04
World	2005	39.91	35.13-44.37	20.25	4.55-46.44
World	2010	37.11	32.46-41.45	15.10	3.07-37.27
World	2015	32.42	28.05-36.49	10.44	1.92-27.4
World	2018	30.77	26.53-34.73	8.74	1.54-23.43