Confidence Intervals and Long-Run Trends in Food Prices, the Cost of Basic Needs, and Global Poverty

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Abstract

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 builds upon methods pioneered by Allen (2017) and extended by Moatsos (2021b) as well as OECD (2021) to reveal that, in terms of affordability of basic foods, global poverty in the 19th century was lower than the estimates that use all prices in the economy as in the World Bank's dollar-a-day global poverty line. At the same time in recent years, most countries have lower affordability of basic foods than poverty in terms of the dollar-a-day approach. Moreover, in terms of poverty lines that add non-food components on top of the EAT–Lancet reference diet, global poverty estimates are substantially higher than what standard extreme poverty measures provide, and for 2018 global poverty is estimated at about 31% or 2.4 billion people. When partially accounting for uncertainty –using a modeling approach– the level at which the global poverty statistics with a 95% confidence do not exclude individuals that may be poor, the global poverty rises to almost 35% or about 2.7 billion people in 2018.

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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 un-utilized 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.

The focus of this paper is to re-combine the above approaches 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 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). This is done in two steps: a) only using the EAT–Lancet food costs as a poverty line, to identify its long run affordability, 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 advanced 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 1. The "CPF" food component (standing for the calories, proteins and fat 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 shown in figure 1, since it 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 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. This assumption, along with available CPI data, allow us to extend beyond the maximum of 1924 and 2008 boundaries allowed by the ILO price data, to a 1820–2018 timeframe.[3]

[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 heat energy requirements as calculated by Moatsos (2017) and Moatsos (2021b).

[2]Moreover, the imputed values from the relationship shown in figure 1, 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.

[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

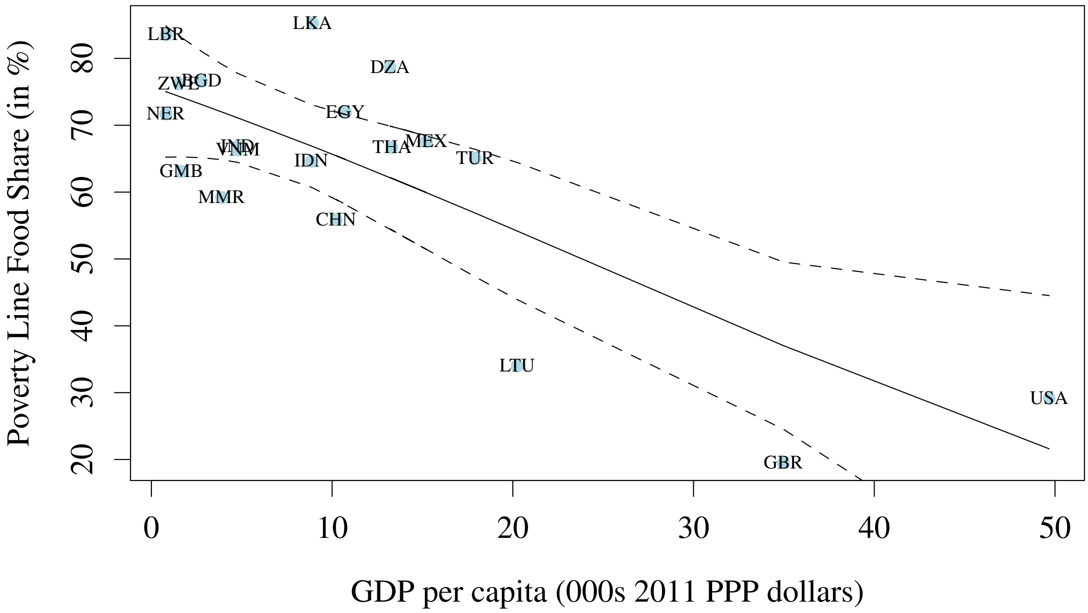

Figure 1: The relationship between the food share in the Allen's basic model poverty lines and GDP per capita. In both subplots the dotted lines denote the 95% confidence interval.

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. The EAT–Lancet healthy diet provides for 2503 kcal per day, which is an estimate corresponding to the average energy needs of a 30-year-old woman weighing 60 kg with a moderate to high physical activity level.

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.

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

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. For comparison, taking the average of the same countries underlying the \$1.9 international poverty line (identical to those for the \$1.25/day poverty line in 2005 PPP terms), 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. After the second world war a series of more products and several other cities are added (Moatsos, 2021b). Gradually, the geographic coverage increases, as shown in figure 2, and the price data are 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 corre-

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

spond 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.

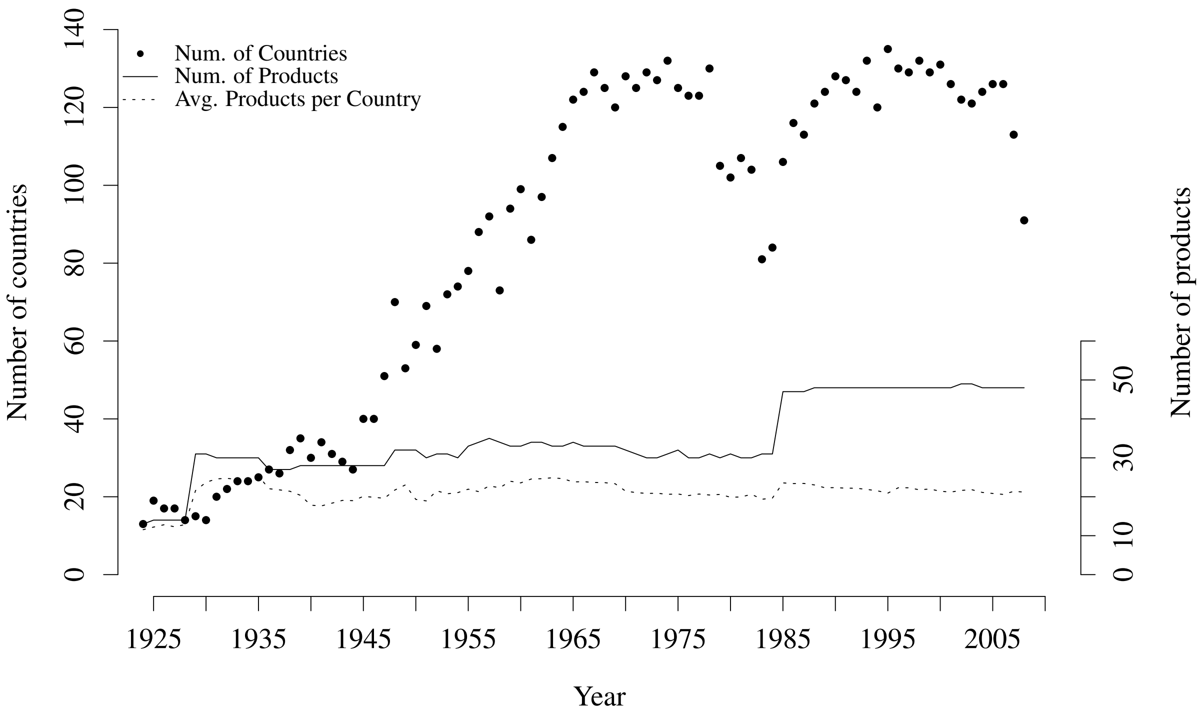

Figure 2: ILO October Inquiry unique country and product counts, 1924-2008

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).[5] Using this imputation method, the initial 158,500 total price data observations from the original sources become 443,478.

[5]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.

Beyond the necessary data to compute a poverty line, information on the income or consumption distributions is also necessary to estimate the poverty rate. For the recent period, since about 1980, I have relied on the detailed distributional information made available by World Bank's PovcalNet.[6] For the period before the years covered by PovcalNet, I have relied on historical sources such as WIID and Zanden van et al. (2013), that provide estimates of Gini indices, along with the lognormal assumption to covert the Gini estimate to a full distribution.[7] Given that those estimates usually come without their measured mean income, I follow Moatsos (2021a) in estimating unobserved household mean income for these distributions.[8]

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 3).

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 poverty estimates from countries that have available estimates both for the reference and the imputation year, which are also 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]

Using the aforementioned data under these assumptions the resulting population coverage

[6] Last accessed on December 13th, 2021

[7] See Moatsos (2021a) for further details on the sources used.

[8] Moatsos (2021a), 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.

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

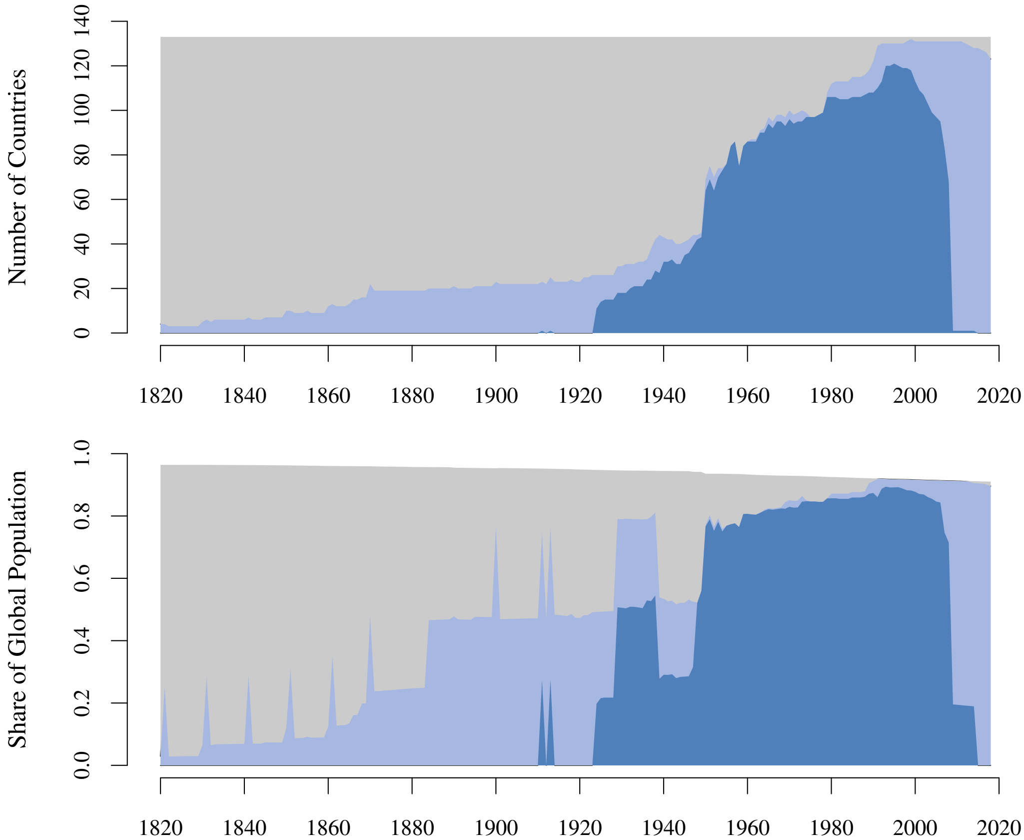

Figure 3: Adapted from Moatsos (2021a): Upper subplot shows the number of poverty lines calculated in three different ways: (i) original and imputed ILO price data (dark blue), (ii) the total costs of food baskets imputed using the best available CPI or the PPP assumption (lighter blue), (iii) interpolations and regional extrapolations (grey). Lower subplot shows the share of the global population covered by these different approaches. As noted in Moatsos (2021a): "[t]he spikes in population coverage are due to China and India (large spikes) or India (small spikes) in the 19th century, and China in the early 20th century."

(at three different levels) is shown on figure 3. For the 1950-2018 period the average population coverage is about 73%, while using the CPI extrapolation, the average yearly coverage falls to 74% for 1900-2018, while for the 19th century average population coverage drops to 20%. The remaining 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.

3. Results

3.1 Trends and levels

Figure 4 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.

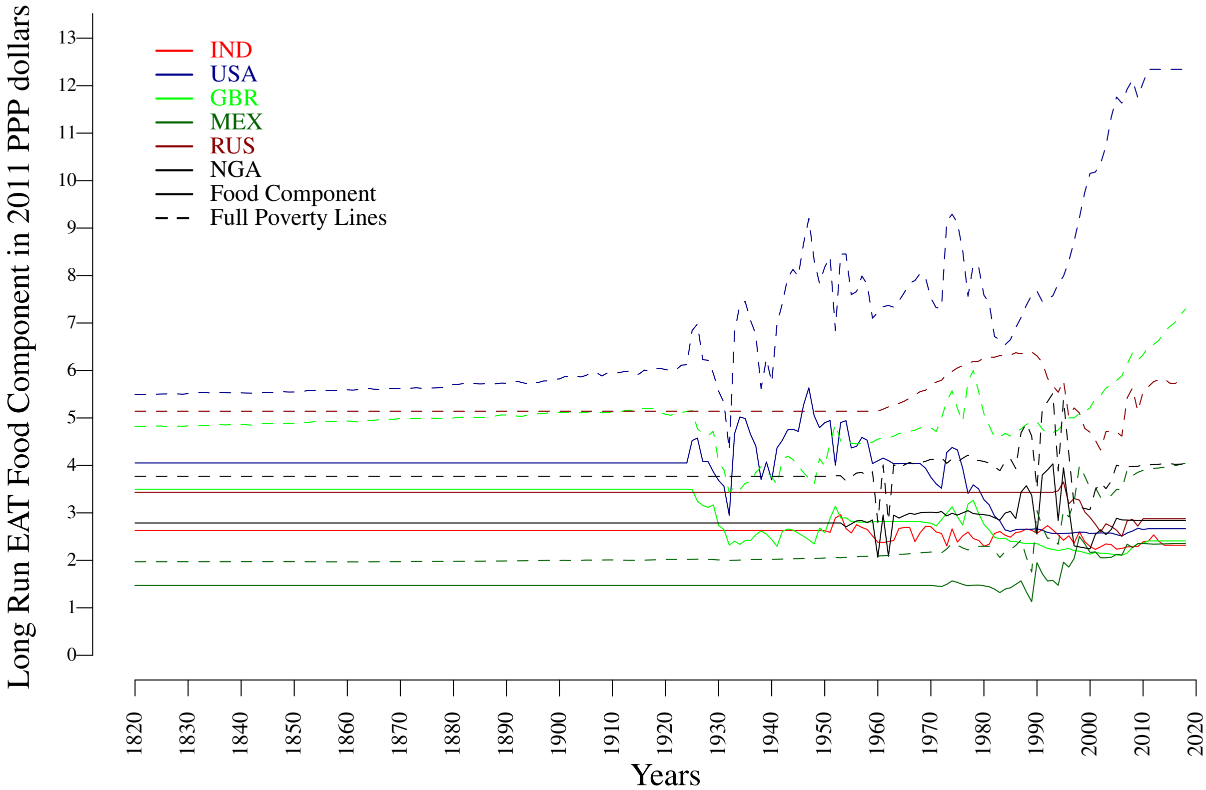

Figure 4: Yearly evolution of the costs of the EAT–Lancet healthy diet (continuous lines) and that of the full EAT–Lancet based poverty lines (dotted lines) for six countries (in 2011 PPP dollars). The from the CBN Global Poverty lines by Moatsos (2021a).

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 affordability of a healthy diet

Using the extrapolated EAT–Lancet healthy diet cost series, figure 4 shows the evolution of the affordability 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.

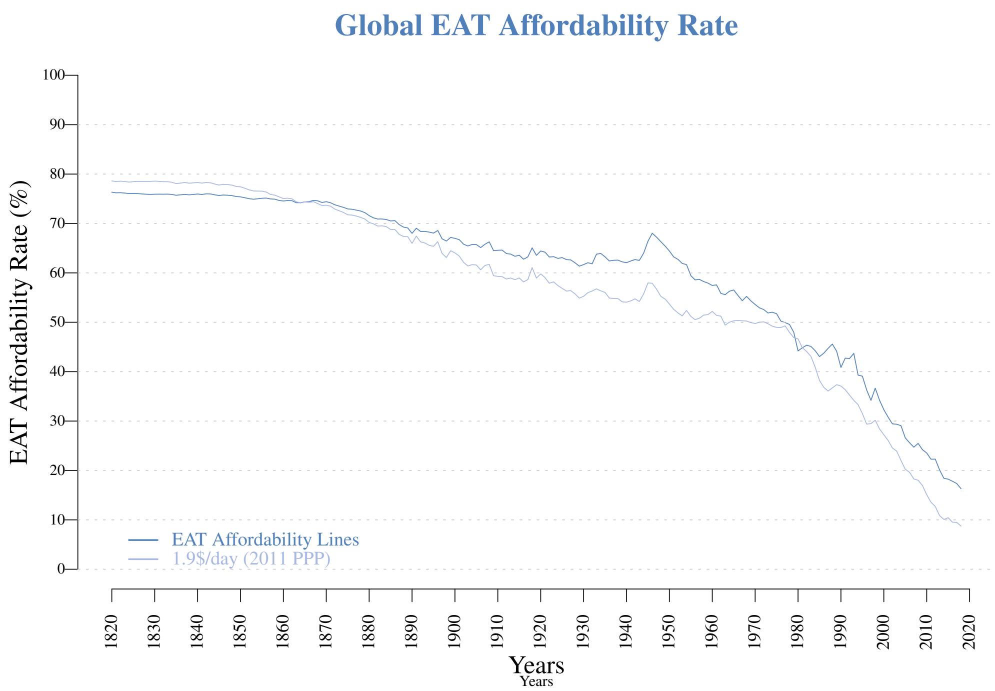

Figure 5: Long run global affordability of the EAT–Lancet reference diet, shown in comparison with the 1.9$/day global poverty estimates by Moatsos (2021a).

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 affordability 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, as although the global rate of un-affordability lies below the dollar-a-day line, for most countries this rate is higher that the dollar-a-day poverty rate.

3.3 Global Poverty

Figure 6 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%.

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.

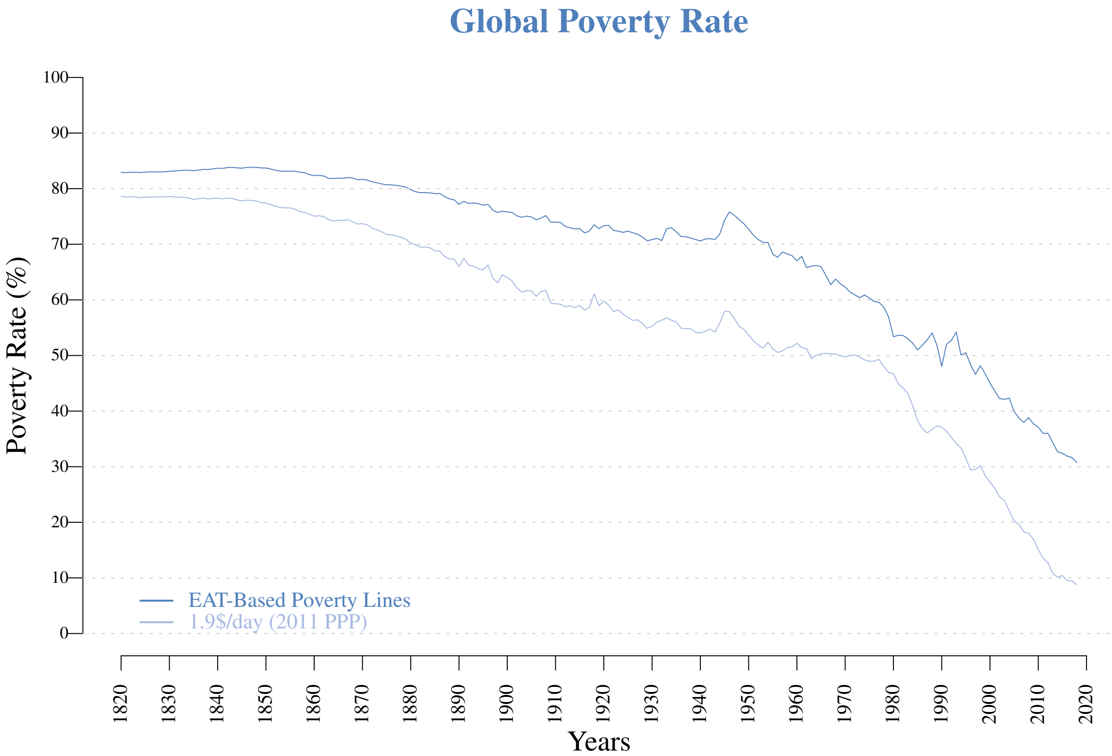

Figure 6: Long run global poverty rates using the EAT–Lancet based full poverty lines, shown in comparison with the 1.9$/day global poverty estimates by Moatsos (2021a).

Figure 7 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.

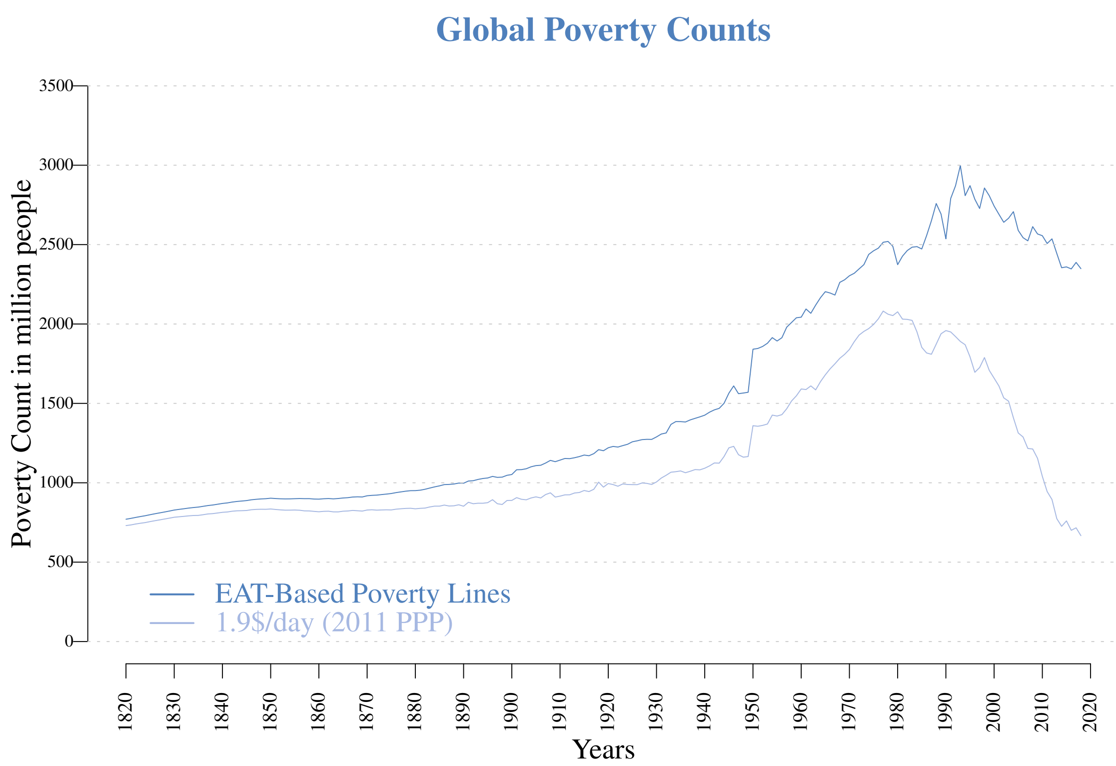

Figure 7: Long run global poverty population counts using the EAT–Lancet based full poverty lines, shown in comparison with the 1.9$/day global poverty estimates by Moatsos (2021a).

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 9 in the appendix). The main element of this model is how the relative uncertainty is becoming suppressed as poverty estimates are reaching higher levels. This is 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 9 in the appendix outlines this linear modeling, which follows the 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 (small deviations from this assumption have limited impact on the outcomes). Then, I linearly interpolate/extrapolate between those three pairs of values for each method separately. Figure 8 shows the result of this ball park exercise (and table 3 in the appendix shows the numeric results in detail).

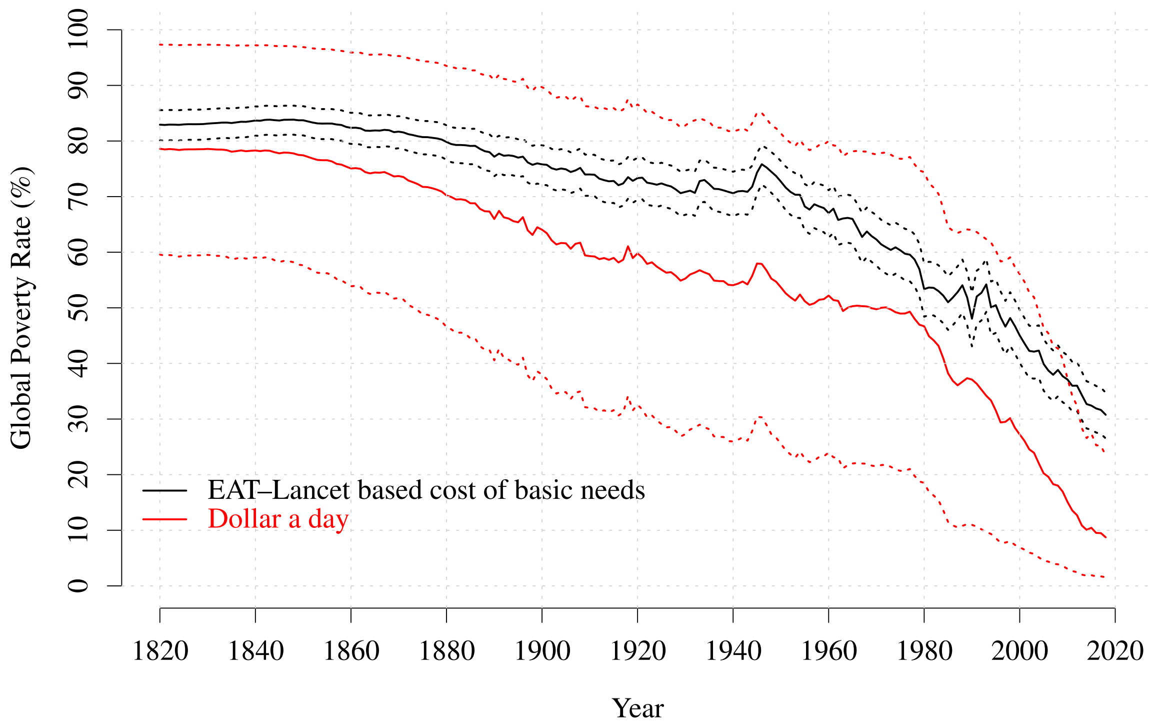

Figure 8: Global scale comparison of the EAT–Lancet CBN (in black) and DAD (in red) methods, using an approximation of the expected 95% confidence interval by modelling upon the findings of Moatsos and Lazopoulos (2021).

Figure 8 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 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. 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).[10]

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

[10] Also the trends are different, see `http://iresearch.worldbank.org/PovcalNet/povDuplicateWB.aspx` and select the \$5.5/day option.

by Moatsos (2017), Moatsos (2021b) and Moatsos (2021a) to reveal that, in terms of affordability of basic foods, on a global 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), we estimate 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 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 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

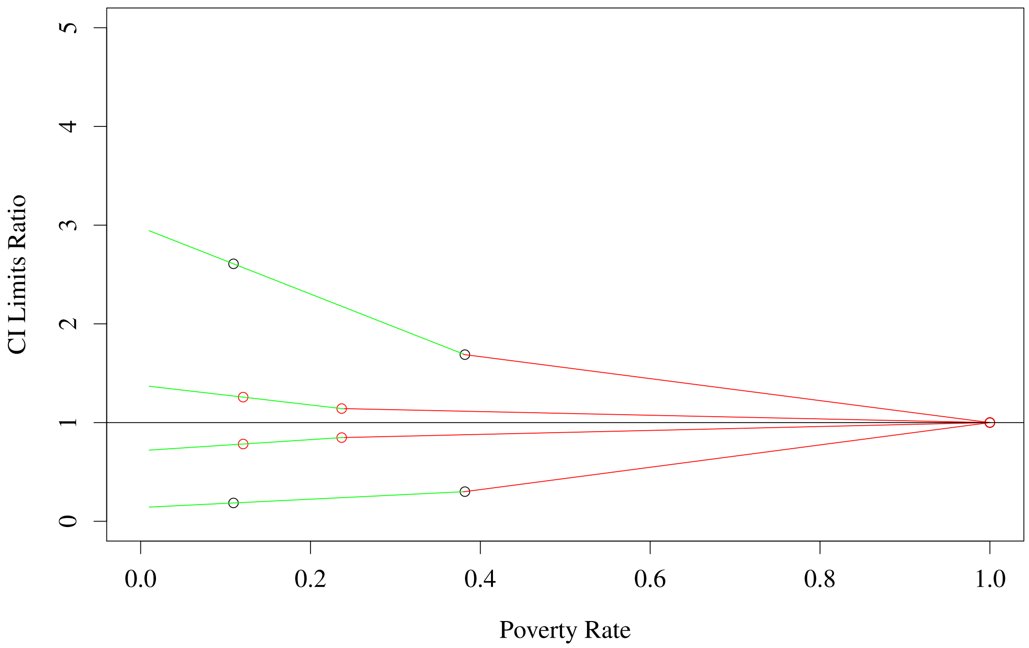

Figure 9: Modelling of the Confidence Interval ratios over the main estimate using the results from Moatsos and Lazopoulos (2021). Lower CI limits appear below the horizontal line for 1 and Upper limits above. Black circles are from DAD and red from CBN methods.

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

. . . continued

Region	Year	EAT–L. CBN Pov. Rate (%)	95% CI	DAD Pov. Rate (%)	95% CI
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