Long run trails of poverty, 1925–2010

Michail Moatsos[1,2]

Abstract

What use has a poverty line when we do not know what it actually allows for? I exploit this weaknesses of the dollar-a-day methodology to motivate a relatively more consistent alternative in global poverty measurement. Poverty lines targeting well-defined welfare levels are constructed as consumption baskets, following recommendation 15 of the World Bank Commission on Global Poverty which promotes the use of a cost of basic needs approach in global poverty measurement. Those baskets are priced locally and separately for each year, and account for basic nutrition, heating, housing, health, education and other expenses. This transparent method is here applied on long run poverty measurement for a group of eight countries. A second contribution is the error accounting approach using Monte Carlo technique for micro-simulations. This is in line with recommendation 5 for "total error" accounting, published in the recent *Commission on Global Poverty* report. Thus, statistical analysis of global poverty becomes possible. The evolution of the poverty profile in five key western countries along with three countries from Africa, seen from a broader global perspective, allows for a comparative analysis. Among this small group of countries, the Netherlands appear to be the champions in fighting extreme absolute poverty, with all poverty lines producing zero absolute poverty rates since 1987. An important caveat in interpreting these results is the use of sub-optimal distributional data for these estimates, in order to keep the quality of the underlying data comparable throughout the estimation period.

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1 Two missed opportunities

The literature of the last 40 years has investigated global poverty, both historically and contemporary, only via the assumption of purchasing power parity (PPP) equivalence (Ravallion et al. 1991; Bourguignon and Morrisson 2002; Zanden van et al. 2011, among others). This translates to the use of poverty lines (henceforth PL) expressed in a number of PPP dollars per day. However, the methodology applied to derive these poverty lines has received extensive criticism by scholars for requiring the application of PPP exchange rates and consumption price indexes (CPI) that are not constructed to capture the consumption habits of those who live in poverty (Deaton 2010; Reddy and Pogge 2010; Srinivasan 2009, among others). Those methodological objections cast reasonable doubts over the available estimates for the evolution of global poverty in recent years (Moatsos 2017), and even more so historically.

In light of these shortcomings the Commission on Global Poverty has issued recommendation 15, calling for a "basic needs-based estimate of extreme poverty".[1] However, this recommendation was quickly dismissed by the World Bank officials, on the questionable grounds of being paternalistic. Thus, no World Bank official numbers will be provided for (The World Bank 2016, p. 6).[2] The alternative that I follow is to construct a set of goal-oriented welfare-specific PLs using local prices. This approach falls well within the letter and the spirit of recommendation 15 in monitoring extreme poverty. Those PLs are often dubbed as bare bone consumption baskets (BBB) in their most basic form (Allen 2013). Calories and proteins are used as achievement elements, and linear programming is applied to estimate the minimum cost that allows an individual to reach the defined welfare level. The main advantage of this methodology is its consistency in measuring poverty in time and space, as the welfare component is, to a large extend, maintained fixed (Allen 2017).

Furthermore, according to the World Bank, the ("perhaps") most important recommendation of the Report of the Commission on Global Poverty concerns the estimation of the error in the poverty estimates (recommendation 5).[3] So far the World Bank

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[1] "Recommendation 15: The World Bank should develop a programme of work, in conjunction with other international agencies, on a basic needs-based estimate of extreme poverty; these estimates would, when developed, form an alternative indicator to be included in the portfolio of Complementary Indicators, and serve to provide an interpretation of what the International Poverty Line would buy" (Atkinson 2016, p. 130). Do note that the focus here is on extreme poverty, not poverty as monitored, for example, in advanced economies.

[2] The majority of the recommendations in the report have been sidelined or straight-out dismissed by the World Bank within days after its publication; in particular all recommendations that suggest to the World Bank to collaborate with other international organizations, such as the United Nations.

[3] "Recommendation 5: The World Bank poverty estimates should be based on a "total error" approach, evaluating the possible sources, and magnitude, of error, particularly nonsampling error and the error introduced by the process of determining the International Poverty Line." With respect to this last source of error, Moatsos (2017) estimated that for 2012 the 95% confidence interval for the global poverty rate is

disclosed only the point estimates in its global poverty counts and rates. As any other measurement, poverty rates must be accompanied by a confidence interval. No meaningful statistics can be performed upon figures that are delivered only as point estimates; for example, one cannot say when and if the goal for halving poverty between 1990 and 2015 (MDG 1) has been fulfilled with any specific level of statistical certainty. The approach taken here addresses this by following recommendation 5 to a considerable extend.

The method, despite its global reach, it is applied here on a few countries scattered around the globe to demonstrate the feasibility of the method in research beyond strictly contemporary times.[4] To account for various sources of uncertainty in the estimates, and provide appropriate confidence intervals, the Monte Carlo technique for microsimulations is applied. In doing so the "goal is not to provide definitive answers to these questions, but rather to be comprehensive, consistent, and explicit about what assumptions we are making and why" (Piketty et al. 2016, p. 3).

A final word of caution: as pointed out by an anonymous reviewer, echoing Sen (1983) and Fuchs (1967) among others, absolute poverty lines may be "too low to meaningfully capture those who are considered poor in society". This is certainly the case in advanced economies, although more historically speaking, and echoing Bowley,[5] investigation of poverty in absolute terms provides an indispensable tool for measuring and comparing poverty within and across countries. The work presented here strictly follows the absolute poverty line approach, and this after considering the apparent trade-off between inter-national comparability and intra-national representativeness of what poverty is, for which the present approach opts for the former. International comparability in terms of poverty rates is better served using an absolutist approach as the relative component is thought to be linked with the overall level of economic development in a country (Atkinson and Bourguignon 2001).

The remaining of the paper is organized as follows: Sect. 2 discusses the main problems with the dollar-a-day approach and paves the ground for the alternative applied here. Section 3 describes the methodology applied, and Sect. 4 provides information about the data used and their limitations. Section 5 presents and discusses the findings, and Sect. 6 concludes.

2 Retiring strong and unnecessary assumptions

Beyond the fruitful ground provided by recommendation 15 of the Report of the Commission on Global Poverty, one needs to effectively discuss the problems with the

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Footnote 3 continued
(8.9, 20.6), and the corresponding mean estimate is 14.5%. This translates to a relative uncertainty level of 40% for the 2012 World Bank global poverty estimate.

[4] Those are Kenya, Egypt, Italy, the Netherlands and the USA.

[5] "There is, perhaps, no better test of the progress of the nation than that which shows what proportion are in poverty, and for watching the progress the exact standard selected as critical is not of great importance, if it is kept rigidly unchanged from time to time.", (Bowley 1915, p. 213).

readily applicable method of the dollar-a-day approach.[6] The required computations in applying the dollar-a-day method are relatively easy. Once one has a set of distributions expressed in international dollars (see below), subsequently getting the dollar-a-day poverty estimate is a rather trivial step. Today, this is as easy as accessing the World Bank PovcalNet web page, and all the tedious calculations are done for you based on your dollar-a-day poverty line-specific preference. At work, however, are a set of assumptions that have been extensively criticized by scholars, and recently have been empirically challenged (Moatsos 2017). Thus, a brief account is due.

The focus here is on the explicit assumptions and requirements of the dollar-a-day global poverty estimates.[7] The dollar-a-day method has been conceptualized and first applied in Ravallion et al. (1991), and has remained in spirit and in essence unchanged since (Chen and Ravallion 2001; Ravallion et al. 2009; Ferreira et al. 2015). The line itself is simply calculated by taking the average of a set of national poverty lines (NPL) of a group of poor countries that are selected based on a (variable) rule of thumb.[8] However, before taking the average, one needs to express these NPLs in the same denomination. For this the purchasing power parity (PPP) exchange rates are used that translate local currency units to so-called international dollars. The implicit assumption needed is that the PPP is the appropriate exchange rate to hold the purchasing power between population groups living in poverty in different countries constant. Alas, the statistical exercise that produces the PPP rates every 6 years or so, known as the ICP round, has the purpose of holding the purchasing power parity among the entire set of consumers, and not among those living in poverty.[9] The explicit effect of this mismatch has not been adequately investigated on a global scale despite its importance.

A detailed examination in both Deaton and Dupriez (2009) and Deaton and Dupriez (2011), tries to address this concern. However, as the authors clearly acknowledge upfront, they provide only a partial recalculation due to important data limitations, mainly the lack of item-level prices. Nonetheless, in their calculations they show that the impact brought about could be as high as half a billion people less in extreme poverty (see Table 5 in Deaton and Dupriez (2011), and in particular the three last columns which correspond to their favorable specifications). More recently, Dikhanov et al. (2017), using item-level prices from household surveys and investigating the 2011 ICP round, conclude that for Sub-Saharan Africa the difference between the generic and poverty-specific PPPs is negligible in practice. Do note that for Sub-Saharan

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[6] Do note that the aforementioned Commission was asked to proceed by taking the dollar-a-day method as a given (Atkinson 2016, p. 2, para.2). Thus, a committee did not have the liberty to investigate the appropriateness of the dollar-a-day method per se.

[7] Although there is a long list of methodological issues in measuring global poverty, it is best for the interested reader to consult other sources (Atkinson 2016) for important and very interesting considerations.

[8] In the last two ICP rounds, the same set of countries was used: Malawi, Mali, Ethiopia, Sierra Leone, Niger, Uganda, Gambia, Rwanda, Guinea-Bissau, Tanzania, Tajikistan, Mozambique, Chad, Nepal and Ghana. This is certainly an improvement compared to simply "eyeballing" (Ravallion 2010, p. 89) that was applied in Ravallion et al. (1991), but scholars are still concerned that it falls short in ameliorating the problems of the method (Reddy and Pogge 2010). Do notice that India or China, the two largest contributors in the global poverty counts, is not included.

[9] In recent years it is the consumption based PPPs that are used in poverty research, as opposed to the overall GDP PPPs. Consumption based PPPs are deemed more appropriate for poverty estimates since they exclude components irrelevant to the household welfare level.

Africa in particular Deaton and Dupriez (2011) also find a small impact. It would be very interesting to have a global investigation using the approach by Dikhanov et al. (2017). One limitation in Dikhanov et al. (2017), as the authors readily acknowledge, is that the prices in their disposal are not those faced by people living in poverty. Here, the use of the price dataset by the International Labour Organization (ILO) partially addresses this limitation, as the ILO explicitly instructs national authorities to report prices that working class families face, and not the average household of the entire economy.[10]

In addition, the PPP rates per se allow only for the calculation of the poverty rates for the benchmark year for which they were produced. To apply the poverty line in other years one needs to use the domestic consumer price index (CPI). It is the case, however, that the CPI index is not constructed to follow the consumption habits of those living around the (applied) poverty line. Antithetically, it typically follows the consumption patterns of the entire population, making the applied CPI particularly plutocratic as seen from the perspective of poverty measurement.[11] If anything the CPI rate applied should be following the consumption patterns of those within the definition of poverty that one aims to trace.

As exemplified elsewhere (Moatsos 2017), the effect of these assumptions is large on the aggregate. Its size depends on the welfare level of the definition of poverty that is operationalized. The key issue here is that it is not a definition of poverty as provided by international organizations such as the United Nations that requires those assumptions. It is only the result of reverse engineering the problem. Instead of operationalizing the poverty definitions deriving from various key treatise, such as the Universal Declaration of Human Rights, the dollar-a-day method circumvents the burden of specifying explicitly what type of poverty traces, by providing a metric based on available NPLs. Even if those NPLs themselves have not been qualified for meeting any set of common standards.

3 Constructing welfare-specific poverty lines

The core of the approach pursued here is a teleological one. Following the spirit of Reddy and Pogge (2010), any two poverty lines are taken as equivalent if they both just suffice to the same end, or "telos". This teleological approach comes with the advantage of clarity in what type of poverty is being monitored by the measurements. It also removes the relative component introduced in any poverty measure simply by the change in the perception of what constitutes poverty. This can be seen as a virtue or as a disadvantage depending on the research question at hand. Having an international comparison in mind, this becomes a welcomed attribute. In any case, the

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[10] See Sect. 4 for details.

[11] Recent research by the World Bank (Dabalen et al. 2016) investigates the problem, and finds the in some occasions poverty is overestimated by the application of the average CPI. Nonetheless, this does not make the average CPI less inaccurate. It merely makes it inaccurate in the opposite direction than what many fear, at least for the cases discussed in the analysis. On the other hand, Wimer et al. (2019) find that accounting for price differences between average CPI and price index of expenses faced those living in poverty increase the number of poor in the USA by 3.2 million in 2018.

results presented here should be interpreted bearing in mind that the social inclusion dimension of poverty is not considered.

Nonetheless, a wide range of elements are considered when constructing a poverty line (PL). Those include anthropometric and demographic information (age/gender distribution, height, and the intensity of physical activity), as well as environmental parameters (food nutrients, temperature and heat energy requirements). Additional socioeconomic data (prices, income distribution data, and aggregate consumption shares) are required to derive a poverty rate. As described in more detail in Sect. 4, in the present approach each one of these elements is introduced with a reasonable (usually uniform) distribution in the Monte Carlo micro-simulations to capture the uncertainty of the data at hand, and to propagate it on the final poverty estimates.

To paint the evolution of poverty for most of the twentieth and the beginning of the twenty-first century, three welfare levels are considered. To pinpoint those welfare levels, the two most fundamental nutrients, calories and proteins, are used.[12] Thus, it is required that each PL allows the consumption of the minimum dietary energy requirement (MDER) as defined by the Food and Agriculture Organization (FAO) which is an agency of the United Nations. For the calculation of the MDER, a number of anthropometric and demographic data are required (FAO 2008).[13] These include the distribution of the population in age-groups and per gender, the average height of the population, the body mass index (BMI), and the physical activity level (PAL) for each age group.

The level of the MDER changes along with the evolution of these characteristics. The reason for including MDER as a dynamic element is that the poverty level within a population should be evaluated based on the characteristics of that population. The end or scope of the PL constructed here is to allow the population in a country on a specific year to be nourished at a well-defined minimum level.[14] The alternative of keeping the MDER constant implies a systematic overestimation (underestimation) when the anthropometric characteristics demonstrate deterioration (improvement).

As shown in Table 1, a number of basic nutrient sources are used in linear programming (LP) to solve the problem of cost minimization of the consumption basket. A main staple is the core source of calories (kcal) and proteins, accompanied by a fixed consumption of meat (or fish if it is cheaper), beans (or peas if cheaper), butter (or ghee if cheaper), and sugar. Beyond the food component, a fixed budget share is dedicated to clothing, and expenses for lamp oil, soap and candles are included. For quick reference, each PL is assigned one of the three basic RGB colors. Red PL contains the most basic elements for scrapping a living, and it is very close to the

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[12] An alternative would be to use all six basic nutrients as stipulated by Kakwani (2003). These six nutrients are: calories, proteins, carbohydrates, fats, vitamins, and minerals. An other approach to expand the nutrients considered would be that of Allen and Khaustova (2017), who concludes that "half the Indian recommended daily allowances (RDA) of iron, folate, thiamine, niacin, and the RDA of vitamins C and B12" should be used on top of the calorific, protein and fat requirements.

[13] Along with the corrections mentioned in Allen (2013) and Moatsos (2015).

[14] Arguably the selection of the minimum energy requirement is not an obvious one. A strong case can be made for tracking the average energy requirement. This energy requirement would be based on the "median of the range of weight-for-height given by the BMI reference tables" (FAO 2008, p. 7). On the contrary the MDER tracks the energy needs of the population with a BMI at the 5th "lowest percentile of the distribution of the BMI" (ibid). Arguably an incredibly low standard.

bare bone baskets used in the real wages literature (Allen [2001], [2013]; de Zwart et al. [2014]). The four basic differences between the consumption basket in Red PL and the bare bone basket in real wages are: the re-configuration of its caloric content (MDER), the removal of the explicit allowance for beans or peas, the method of estimation of the heat energy requirements, and the explicit allowance for cooking fuel. Red PL is also in close alignment with the requirements set by UNESCO, according to which: "[a]bsolute poverty measures poverty in relation to the amount of money necessary to meet basic needs such as food, clothing, and shelter."[15]

The heat energy requirements are included so that the PLs are consistent in evaluating poverty between countries with different prevailing temperatures as well as between years with substantial temperature level differences for the same country. The aforementioned requirements are calculated following the concept of degree-days (Day [2006]). Degree-days give the number of total days equivalents in a year where indoor heating is required.[16] The base (threshold) outside temperature used is the 15.5°C, which corresponds to an indoor temperature of about 18°C. This indoor temperature is recommended by the World Health Organization (WHO) to avoid chronic health deterioration (Collins [1986]). The temperature data come from the Global Historical Climatology Network.[17] The energy required for cooking is included as a function of the caloric content of the food that requires cooking. This is done in accordance with the FAO finding that the food to fuel energy ratio is approximately 3 to 1.[18]

Green PL relaxes one step the assumption that those living in extreme poverty apply LP to consume the cheapest possible nutritional bundle, and thus, it takes the average of the two cheapest bundles. It also doubles the relative allowance of housing, compared to the Red PL, and adds explicit expenses for health, education, and water. In lack of better readily available evidence, the share for those components from the World Bank's Global Consumption database is used throughout. This database provides consumption shares for developing countries in 2010. The Green PL is compatible with the definition found in the Universal Declaration of Human Rights as a person not having the means to achieve "a standard of living adequate for the health and well-being of himself and of his family, including food, clothing, housing and medical care."[19]

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[15] Obtained from UNESCO on February 22nd, 2016. The shortcoming here is that the differences in renting costs, expressed as budget shares, between more and less developed economies is not addressed. Allen ([2017]) approach addresses this issue for a small set of countries in 2011.

[16] Moreover, I assume that the house is empty for 8 hours per day, then residents are sleeping for another 8 hours (not requiring heating), and for the remaining 8 hours per day heating is required. For simplicity this is included in the calculations by dividing the total number of degree-days by 3.

[17] Menne, M.J., I. Durre, B. Korzeniewski, S. McNeal, K. Thomas, X. Yin, S. Anthony, R. Ray, R.S. Vose, B.E.Gleason, and T.G. Houston, 2012: Global Historical Climatology Network—Daily (GHCN-Daily), Version 3.22.

[18] At section ''13.5 Do we really need more energy under the pot than in the pot?" from "Energy for sustainable rural development projects—Vol.1: A reader" located at http://www.fao.org/docrep/u2246e/u2246e02.htm. Here as a more cautious first step I consider half the energy required in the pot, and the ratio used is 2.5 ± 0.5. Halving this energy requirement is done in order to roughly account for using the stove also for heating purposes. This way some double counting is avoided. The unwelcome disadvantage is that for regions with limited heating energy requirements the energy needed for cooking is considerably underestimated.

[19] Universal Declaration of Human Rights, G.A. Res. 217 (III)A, art. 25, U.N. Doc. A/RES.217(III) (Dec. 10, 1948).

Table 1 "RGB" poverty lines components

Item	Unit/year	Poverty line short name		
		Red	Green	Blue
Energy target	kcal	MDER	MDER	MDER
Protein target	g	0.75 g/kg of persons weight		
Minimization	–	Cheapest bundle	Mean of 2 cheapest bundles	Mean of 3 cheapest bundles
Main staple	kg	Linear programming based on kcal/protein target		
Beans or peas	kg	LP	20 at minimum	40 at minimum
Meat or fish	kg	3 or 6	6 or 12	12 or 24
Butter or oil or ghee	kg	3	6	12
Sugar	kg	2	4	8
Linen (applied)	Share	8%	8%	8%
Lamp oil	l	The equivalent of 1.3l added as fuel		
Soap	kg	1.3	1.3	–
Candles	kg	1.3	1.3	–
Fuel[a]	mbtu	Calculated on country daily temperature data		
Cooking	mbtu	MDER/2	MDER/2	MDER/2
Housing	Share	5%	10%	15%
Health, education, water	Share	–	WBGC	WBGC
Surplus	Mark-up	–	–	10%

[a] Fuel data are imputed and they can be at maximum half the food component, see Moatsos (2015) for more details

Blue PL builds upon the Green, uses the average of the three cheapest combinations, and doubles again the allowance for meat (or fish), butter, sugar, while including a 50% increase in the housing allowance. Finally, an explicit percentage is added an all-purpose surplus indicating additional implicit choices made possible on this welfare level. Soap and candles are not explicitly included in the Blue PL. This PL comes closer to the definition of absolute poverty found in the Copenhagen Declaration by the United Nations: "[a]bsolute poverty is a condition characterized by severe deprivation of basic human needs, including food, safe drinking water, sanitation facilities, health, shelter, education and information. It depends not only on income but also on access to social services."[20]

As a final note to this methodological section, consider that Table 1 can be readily consulted by anyone to get an idea of what these RGB PLs can provide for in every country for any year needed. It is rather bizarre that this is not available for the dollar-a-day international poverty line standard. Nobody can promptly say what someone can buy in a given country at a given year with that PPP equivalent dollar amount. Or, inversely, if a bundle of goods that would keep a person nourished, clothed, warm and within a residence would be affordable or not.

4 Available data, and accounting for uncertainty

4.1 Key sources of uncertainty

Figure 1 shows the various data sources, and the uncertainty linked to those sources. The left most column contains the data variables in boxes. Starting from the second column, the diamond-shaped elements contain the points that introduce uncertainty over the point estimates with which the data variables are made available in the sources. There are also four main intermediary steps in the process, namely the MDER, the dense price dataset, the heat energy needs, and finally the poverty line. In a final step, the poverty line is combined with the income distribution, and level, to produce the poverty rate.

In principle uncertainty is accounted for by using a uniform distribution within a specified interval around the point estimate in a dataset. For convenience Table 2 summarizes the approach used for each uncertainty source, tagged in the form of MC plus keyword in the previous diagram. The price data are used together with inflation information to produce an imputed, yet complete, dense price dataset. According to the benchmark scenario, the possible value of a price in the dense price dataset will be within uniformly distributed within 15% around the datapoint. This means that for a single poverty estimate the value will be drawn accordingly at random, and together with the random draws for the other sources of uncertainty will produce one poverty rate estimate. This is repeated 10,000 times for each country and year combination, which is also the procedure that produces the confidence intervals in the final estimates. For the consumption shares a 10% interval is used, while for the exact mean of the

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[20] Obtained from UN, Copenhagen Declaration on February 22nd, 2016. Arguably though, it could be thought as the lower possible expression of such a definition in monetary terms.
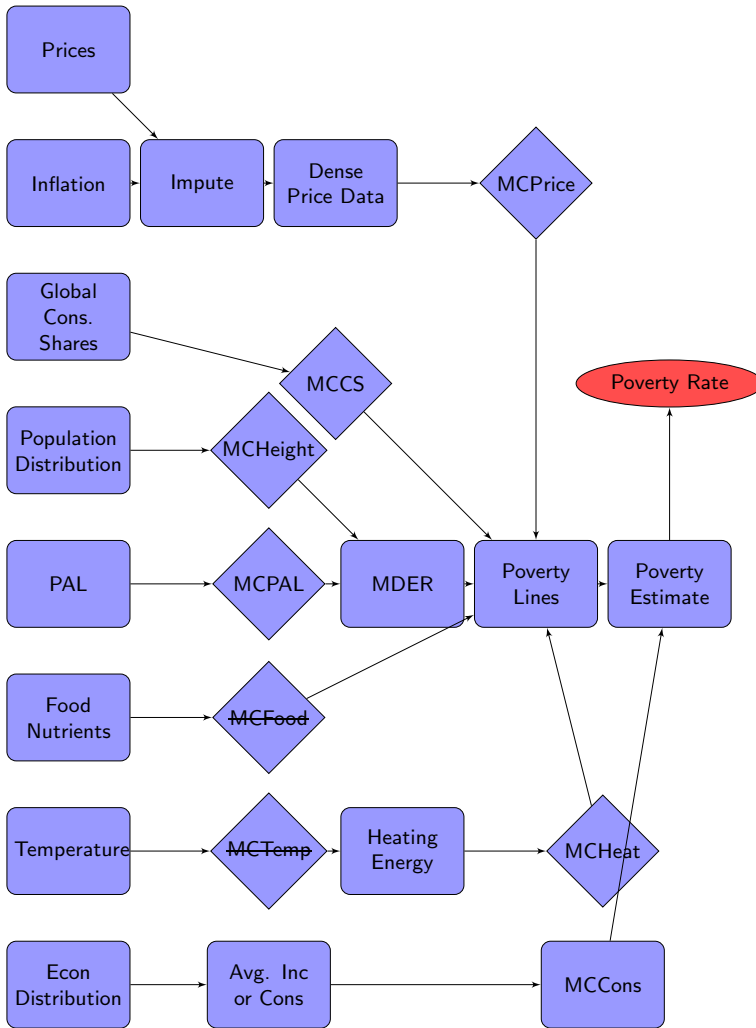
Fig. 1 Architecture of data and Monte Carlo method. *Note* MCFood and MCTemp are ignored, as shown in Table 2

income distribution a 5% is used. These values should be considered as benchmark ball-parked values.

With respect to the other sources of uncertainty, the population distribution statistics, the temperature data and the food nutrients are taken at face value. While the height data are used with a ±3 cm interval in case, there is a datapoint provided for a country, and a ±5cm interval in case a country is solely using imputed data from its geographic region (see below). As explained in more details below, the PAL is estimated as a random draw of possible activities within a day; thus, the uncertainty derives from the variation in physical intensity of the randomly selected activities. The resulting normal distribution has a standard deviation for this is 0.19 with a mean of 2.26. This value

Table 2 Intervals used in uncertainty accounting as random draws

Data variable	Keyword	Calculation
Prices	MCPrice	± 15%
Consumption shares	MCCS	± 10%
Mean of economic distribution	MCCons	± 5%
Temperature	MCTemp	± 0%
Population distribution	–	± 0%
Food nutrients	MCFood	± 0%
Height	MCHeight	± 3 cm (±5cm when regionally imputed)
PAL	MCPAL	Normal distribution 2.26 ± 0.19
Heat energy	MCHeat	People per household 2.5–5

places the PAL derived here within the area of vigorous lifestyle 2.00-2.40 (FAO 2001, p. 38, table 5.3). Heat energy is produced by the energy requirement to heat a small standardized room[21] to the target temperature, divided by the number of people in the room or household. It is assumed that this follows a uniform distribution between 2.5 and 5 persons per household.

4.2 Price datasets

The prices used in the calculations come from the ILO October inquiry. They include data from 1925 up until 2008, when ILO stopped collecting them. The price catalog consists of a wide range of necessities, and the exact number of products varies with the country-year combination. Information on average inflation rates was used to impute missing prices taken from de Zwart (2015).[22] When imputation concerned a point between two available datapoints from the ILO dataset, then the average of two imputations was used. The first imputation used the earliest year observation—among the two years with data that are closest to the missing datapoint—and used the inflation to go forward in time and estimate the missing observation. The second imputation used the latest year observation, and used inflation to go back in time and estimate the missing observation. Then, the average of the two is taken as the imputed value for the missing observation.

Regarding items included in the ILO October inquiry, those vary for different years. The earliest documents contain information for 15 products some of which had additional subcategories depending on specific type and quality: bread, flour, butter (fresh and salted), margarine, beef (ribs and thin flank, home produce and chilled or frozen), mutton (leg and breast, home produced or frozen), bacon, potatoes, sugar, coffee, tea, cheese, rice, eggs, and unskimmed milk. Those covered 16 capital cities: Amsterdam, Berlin, Brussels, Christiania (Copenhagen), Lisbon, London, Madrid, Milan, Ottawa, Paris, Philadelphia, Prague, Rome, Stockholm, Vienna, and Warsaw. By 1931, several

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[21] The size of the room following Moatsos (2017) is: $10 \times 10 \times 8$ ft.

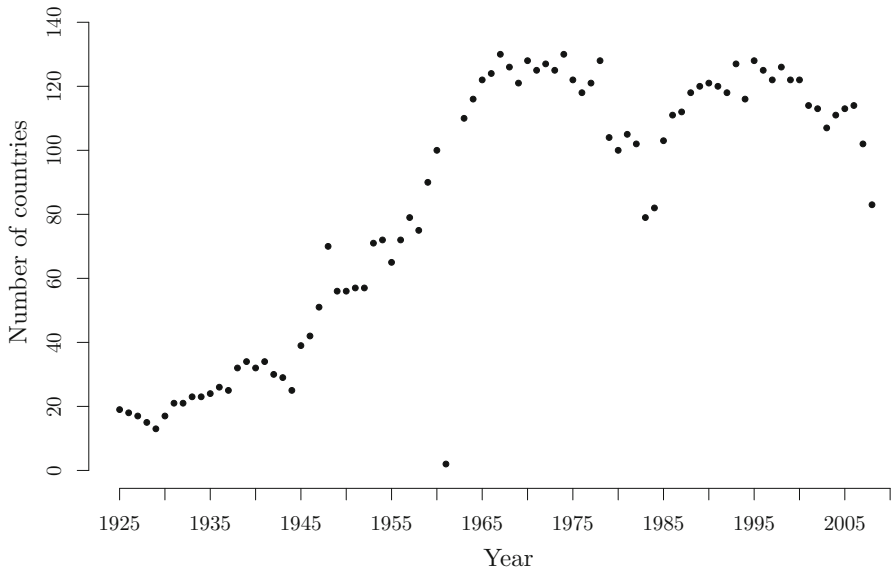[22] For USA 1929, the implied inflation from https://www.bls.gov/data/inflation_calculator.htm is used.

Fig. 2 ILO October inquiry country coverage, 1925–2008

new items were introduced including: rye and white bread, oatmeal, lard, pork, veal, cocoa, pasta, peas, beans, prunes, olive oil, firewood, bituminous coal, coke, electricity, gas and paraffin oil.[23] The geographical coverage also expanded to 19 countries with an average of about 4 cities for which the average price was reported. The USA covered 10 cities; Great Britain 7; Germany, Canada, France, Italy, 6; Spain, Netherlands, and Poland 4; Austria, the Irish Free State, Sweden, Czechoslovakia, and Yugoslavia 3; Estonia, 2; and Belgium, Denmark, Latvia and Portugal 1.

By 1933 Australia (Sydney), Finland (Helsinki), Hungary (Budapest), Switzerland (3) are added. By 1940 many Latin American along with a few African, Asian and European countries and territories are added: Egypt (Cairo), Union of South Africa (2 towns), Argentina (Buenos Aires, and 3 other towns), Brazil (Rio de Janeiro, Sao Paolo, and 5 other towns), Chile (Santiago), Colombia (Bogota), Cuba (La Havana), Guatemala (ibid), Mexico (Fed. Distr.), Peru (Lima), Salvador (San Salvador), Uruguay (Montevideo), Venezuela (Caracas), China (Shanghai), Bulgaria (Sofia), Romania (2), and New Zealand (Wellington). In the following years, more countries are added and by 1967 the list includes 130 as shown in Fig. 2.[24] Until 1983, the number of countries reporting drops gradually to 79, to later increase again to about 120 countries. In 2008, 83 countries are included in total, and it is then that ILO stops reporting global price data.

The last update in the product list takes place in 1984. It then includes in addition to the aforementioned items: corn, couscous, sorghum, tortillas, specific types of fish, three types of cheese, and other less important items for the purpose at hand.

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[23] With a few changes this list of products remains the largely same until 1983.

[24] The dip in 1961 is due to incomplete transcription of the original data.

Table 3 Original ILO price data coverage

Country ISO3 code	Years covered
KEN	1948–1954, 1956–1960, 1963–1967, 1971–1972, 1974–1978,
	1983–1984, 1986, 1989–1993, 2005–2006
NGA	1949, 1951–1954, 1956, 1958–1960, 1963–1975,
	1977–1978, 1981, 1983–2006
EGY	1940–1941, 1945–1946, 1948–1952, 1955–1957, 1959–1960,
	1963–1967, 1969, 1972–1982, 1986–1989, 1990–2006
SWE	1925–1960, 1963–2008
NLD	1925–1941, 1945–1959, 1963–2002
ITA	1925–1928, 1930–1935, 1938–1939, 1947–1960, 1963–1978, 1981–1982, 1985–2008
USA	1925–1960, 1963–1978, 1980–2008
CAN	1925–1928, 1930–1960, 1963–2008

For the countries investigated here, namely Kenya, Nigeria, Egypt, Sweden, the Netherlands, Italy, USA and Canada, the data coverage is relatively high as shown in Table 3. Naturally, in every year with available data not all covered commodities are reported. However, in the substantial majority of the years covered there are prices available from most groups of commodities which are used in the construction of the poverty lines here.

Finally, when prices for soap are not available, I follow de Zwart et al. (2014) in imputing soap using the value of butter or ghee with the same weight. The same procedure I follow for candles as well. A short hand for the fuel calculations is that I follow Moatsos (2015) and impute the fuel price per mbtu with the average per mbtu budget share from the de Zwart et al. (2014) data (4% $\pm$ 2%).

4.3 Nutrients

For the values of the various nutrients in the food items the USDA database was used, https://ndb.nal.usda.gov/ndb/. Since food processing (cooking) results in a change in the amount of nutrients preserved, the retention rate needs to be applied in the calculations (see Table 4). Specifically, to the values of kcal a retention rate is applied as pointed out and provided by Appleton et al. (1999). A retention rate is not applied for proteins.

4.4 Income distributions and their mean

Data on the gross income distributions are taken from Zanden van et al. (2013) and are shown in Table 5, since the more appropriate consumption distributions are not available for the long run character of this investigation. When for a given year no distribution is available, linear interpolation is applied, and the last-value rule is applied

Table 4 Main food items retention rates. . Adapted from Appleton et al. (1999)

Food item	Retention rate (%)	Food item	Retention rate (%)
matooke	50	Sweet potatoes	70
Cassava	89	Maize (grain)	90
Irish potatoes	85	Rice	100
Maize (flour)	100	Bread	100
Millet	65	Sorghum	90
Beef	80	Other meat	75
Chicken	61	Fresh fish	60
Smoked fish	70	Eggs	88
Cooking oil/ghee	100	Beans (fresh)	75
Beans (dry)	75	Sugar	100

in case of extrapolation. A limitation here is that the dataset ends in 2000. Thus, the post-2000 poverty estimates are based on the gross income inequality Gini value in 2000.

Unfortunately the income distributions in this dataset do not come with an average, since the idea behind the dataset was to produce global income distributions based on the GDP per capita as average. However, for poverty measurement the use of the average total household consumption can serve as the mean of the gross income distributions. Thus, the mean of the distribution is fixed on the national consumption per capita. Consumption data come from the World Bank,[25] the UC Davis Nominal GDP historical series, and the Jordà–Schularick–Taylor macrohistory database (Jordà et al. 2016). For missing years linear interpolation was used on the basis of GDP per capita evolution (Bolt and van Zanden 2015). A short coming of this source is that it stops in 2000.[26]

4.5 World Bank consumption shares

This dataset contains consumption shares for about 80 developing countries in 2010. The consumption shares are reported per income group or consumption segment. The four consumption segments are defined around three thresholds at $2.97, $8.44 and $23.03 consumption per capita per day (in 2005 PPP dollars). The data provide information about various expenses: food, energy, clothing, housing, health, education, water, personal care, ICT, financial services and others. Here I only use the expense share for health, education, and water. The shares for the countries discussed in the results are shown in Table 6. In lack of a readily available and comparable dataset for developed countries I use the average consumption share of the highest consump-

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[25] GDP and "Household final consumption expenditure, etc" (both in current LCU), accessed December 9th 2016.

[26] The aforementioned treatment ignores the fact that national account statistics and household surveys diverge with respect to the estimated average income or consumption (Deaton 2001).

Table 5 Gross income Gini data from Zanden van et al. (2013); an asterisk marks historical estimates using indirect methods

Year	KEN	NGA	EGY	SWE	NLD	ITA	USA	CAN
1929	55.1*	–	46.0*	50.7*	41.7*	51.3*	54.3	41.9*
1950	55.8*	–	38.8*	40.5*	35.9*	42.9	39.4	36.3*
1955	–	–	38.1*	38.5*	46.4	42.6	38.0	35.2*
1960	68.0	51.0	42.9*	40.1*	44.9	44.4	38.0	34.6
1965	–	–	42.3*	38.1*	41.3	40.8	38.0	33.6
1970	50.5*	38.3*	43.4	37.0	35.9	39.0	36.1	33.8
1975	54.3	–	–	31.2	31.5	39.8	36.1	33.8
1980	57.3	35.2	49.9	29.0	29.8	39.0	36.8	33.5
1985	–	40.4	–	30.7	29.2	39.0	38.6	34.8
1990	48.7	44.1	54.3	30.7	32.2	32.7	39.7	31.9
1995	45.9	45.4	49.1	30.9	31.6	37.6	41.8	36.1
2000	51.1	51.2	53.8	34.6	32.1	36.7	43.9	41.1

Table 6 World Bank consumption shares in 2010

Country	Consumption share (%)
Kenya	7.6
Nigeria	39.5
Egypt	23.7
Developed	24.3

tion segment. For developing countries the segment share of the lowest consumption segment is used.

4.6 Population distributions

As noted times over in the report of the Commission on Global Poverty Atkinson (2016), the population data should not be taken at face value. This relates to both the coverage of total population throughout the world, and in terms of accuracy in the estimates between population surveys. The population statistics that are required here go far beyond the simple total.

The specification of the MDER requires population age and gender distributions which come from Mitchell (2007) (sparse observations for pre-1950 years) and United Nations (2015) (yearly observations for post-1950). Those data provide information in age bins—per gender—that vary in size (Table 7). Since the MDER estimation requires yearly age population shares by gender, an assumption is required to account

Table 7 Population distributions data coverage

Country ISO3 code	Years covered
KEN	1950–2015
NGA	1950–2015
EGY	1917, 1927, 1937, 1947, 1950–2015
SWE	1920, 1930, 1940, 1950–2015
NLD	1920, 1930, 1937, 1950–2015
ITA	1921, 1931, 1936, 1950–2015
USA	1920, 1930, 1940, 1950–2015
CAN	1911, 1921, 1931, 1941, 1950–2015

for the mismatch.[27] This is performed by taking the per year simple average in each population bin.

4.7 Height

Height data are also necessary in calculating the MDER as for each age/gender group in the population a corresponding height is required. The most complete global height dataset is available in Baten and Blum (2015).[28] It covers 165 countries from mid-nineteenth century until 2000, and Table 8 shows the coverage for the countries investigated here.[29] Not all the countries in the world are covered; thus for countries with missing data, the regional average is used. To account for uncertainty, 3-cm interval is used for known locations and 5 cm for locations without data. For years between datapoints a linear interpolation is used, while for extrapolation the last known value is maintained.

Figure 3 shows the population weighted maximum attainable height at each year. This value expresses the weighted average of the maximum attainable height for all age cohorts. So even for a one year old the full estimated height attained when that one year old becomes an adult is used. In principle this average lags the average height in the original height dataset as usually previous generations were shorter than the following ones. The population weighted maximum attainable height is the metric that captures the effective average height used in the MDER calculation.

4.8 Physical activity levels

The exact PAL level of people living in extreme poverty is far from certain or exact. One argument favoring the use of a high PAL level is that those living in extreme poverty

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[27] The entries in Mitchell that were tagged as unknown were discarded. A potential improvement would be to use this as an additional piece of information to ball-park the level of data uncertainty, although the expected difference, based on the relatively few cases marked as unknown, would be marginal.

[28] The average values are converted to corresponding heights for each age/gender group following the model in FAO (2008).

[29] More details regarding the use of height data in estimating the MDER can be found in Moatsos (2017).

Table 8 Height data coverage; data-points available at decade round years only

Country ISO3 code	Years covered
KEN	1880–1920, 1950–1980
NGA	1790–1820, 1870–1880, 1910–1980
EGY	1850–1880, 1900–1920, 1940–2000
SWE	1730–1800, 1830–1980
NLD	1760–1790, 1810–1980
ITA	1730–1980
USA	1710, 1730, 1750, 1770–1790, 1820–1990
CAN	1810–1980

are depending on their physical labor to earn a living. The competing argument is that in these conditions a person cannot acquire enough energy from food that would allow a highly active—in terms of labor—lifestyle. However, such dire conditions appear binding for people far below the PL, and not around it. The physical activity levels (PAL) are composed at random during the Monte Carlo phase of the calculations from various activity elements as listed in (FAO 2001, pp. 92–96). Activity items from sports and recreation categories were excluded. From the remaining, only one hour of extremely demanding activity is allowed (with PAR≥4).[30] The requirements are that a person sleeps 8 h a day, devotes 1 to 3 h in taking care of the household, 1 to 2 h to transportation, 8 to 10 h to work, and the remaining time to personal care. This composition results in PAL values that form a normal distribution. The random draws follow a normal distribution with mean of 2.26 and a standard deviation of 0.19.

4.9 Heat energy requirements

NOAA[31] daily data provide the maximum and minimum temperatures in a given (Table 9). In total more than 100,000 stations are included. These two temperature data alone allow the calculation of the heating degree day using the standard "Meteorological Office" equations (Day 2006, p. 17, table 2.1) When specific days were missing from a station linear interpolation is applied. As inputs in the above equations the simple average of daily minimum and maximum temperatures of weather stations located below 1500 m altitude and less than 65 degrees north and south of the meridian in a given country.[32,33]

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[30] Physical activity ratio (PAR) is the ratio of energy requirement of a certain activity over the energy requirement when at rest (this last energy requirement is also referred to as basal metabolic rate or BMR). See more information at http://www.fao.org/3/y5686e/y5686e07.htm

[31] Menne, M.J., I. Durre, B. Korzeniewski, S. McNeal, K. Thomas, X. Yin, S. Anthony, R. Ray, R.S. Vose, B.E.Gleason, and T.G. Houston, 2012: Global Historical Climatology Network—Daily (GHCN-Daily), Version 3.22.

[32] For the USA, due to the very large number of weather stations a randomly selected subset was used. The sample was about 14,000 out of the 54,211 available weather stations in the USA.

[33] This method has also been adopted by Allen (2017) in his work on constructing cost of basic needs based poverty lines for 2011.
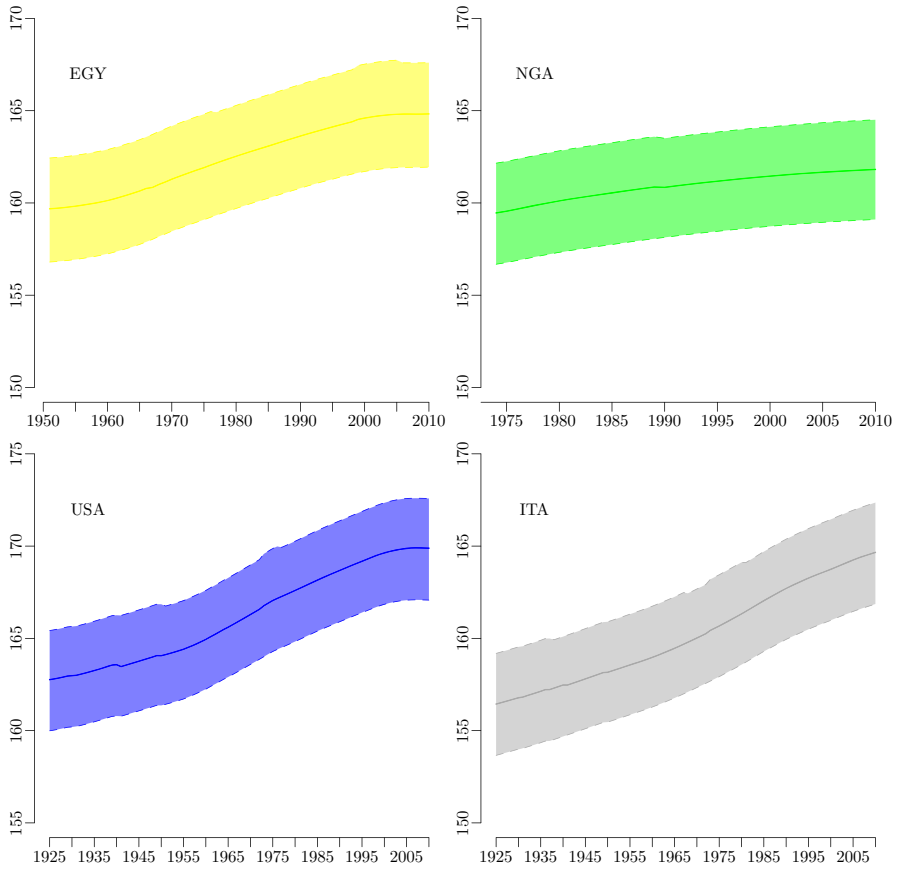
Fig. 3 Evolution of population weighted maximum attainable height for Egypt, Nigeria, USA and Italy

Table 9 Weather data coverage

Country ISO3 code	Years covered
KEN	1957–2016
NGA	1974–2016
EGY	1884–2016
SWE	1918–2016
NLD	1901–2016
ITA	1763–2016
USA	1868–2016
CAN	1866–2016

4.10 MDER

The elements of population distribution, and height and the PAL, all play a role in setting the MDER for a country in a specific year. The final element is that of the body mass index (BMI), which is defined as the weight over the square of ones height (measured in kg/m^2). Its value until the age of 10 is taken by FAO (2001) and FAO (2008) to be that of the 50th percentile in the population distributions provided by the World Health Organization. After that year the value of the 5th percentile is used, which is the way to capture the minimum in Minimum Dietary Energy Requirement.[34] It is informing at this point to have an overview of the evolution in MDER as captured by the FAO methodology and the data available. Figure 4 shows the evolution for the countries presented in the results section.

5 Results

A few countries, which are selected based on their relative data availability, are shown in the figures that follow. The first three countries are from the economically developing world, followed by five economically developed countries. Every graph shows each of the three poverty lines in its respective color as defined in Table 1, accompanied by the 95% confidence interval. In addition, the change of poverty is marked with a point and a vertical line between years that the distributions of the poverty rate estimates overlap by less than or equal to 5%.[35] The idea here is to mark great changes in the poverty profile of a country.[36]

5.1 Kenya

All RGB lines paint the very intense picture of the poverty evolution in Kenya (Fig. 5). Despite the substantial improvements in the early years of the period covered by the data (1955–1970), poverty intensity has since then increased overall. However, after two distinguishable episodes in 1993/4 and in 2003/4, in the recent years some improvement is identified. Nonetheless, Red PL poverty has never dropped lower than 20%, Green poverty below 35%, and Blue below 50%. All minima are reached by late 80s, however they are not very different from those of the early 70s, demonstrating stagnation and reversal. Using the poverty evolution markers it is clear that for some 1968 until 1994 the Red line poverty profile does not change decisively. And when it does in 1995, it is in the wrong direction. Overall the poverty rates are worse or similar at best when compared to the pre-1990 period. What is striking about Kenya is the unprecedented Red line poverty during the late 50s. It ranges at the level of 60% that is by far the highest we observe for more than a couple of years in this

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[34] Arguably taking ADER, which would be the equivalent of MDER for the 50th percentile of BMI, would provide a more reasonable target for poverty alleviation than taking the minimum standard.

[35] This investigation starts from the first available year in each country as the initial reference year, and continues with each new year that satisfies the above requirement as a new reference year.

[36] Naturally, the markers have this meaning only when the poverty rates are substantially above zero. However, these markers are still visible in near zero poverty rates as seen in the figures below. Still, their importance to people actually living in these conditions is far from negligible.
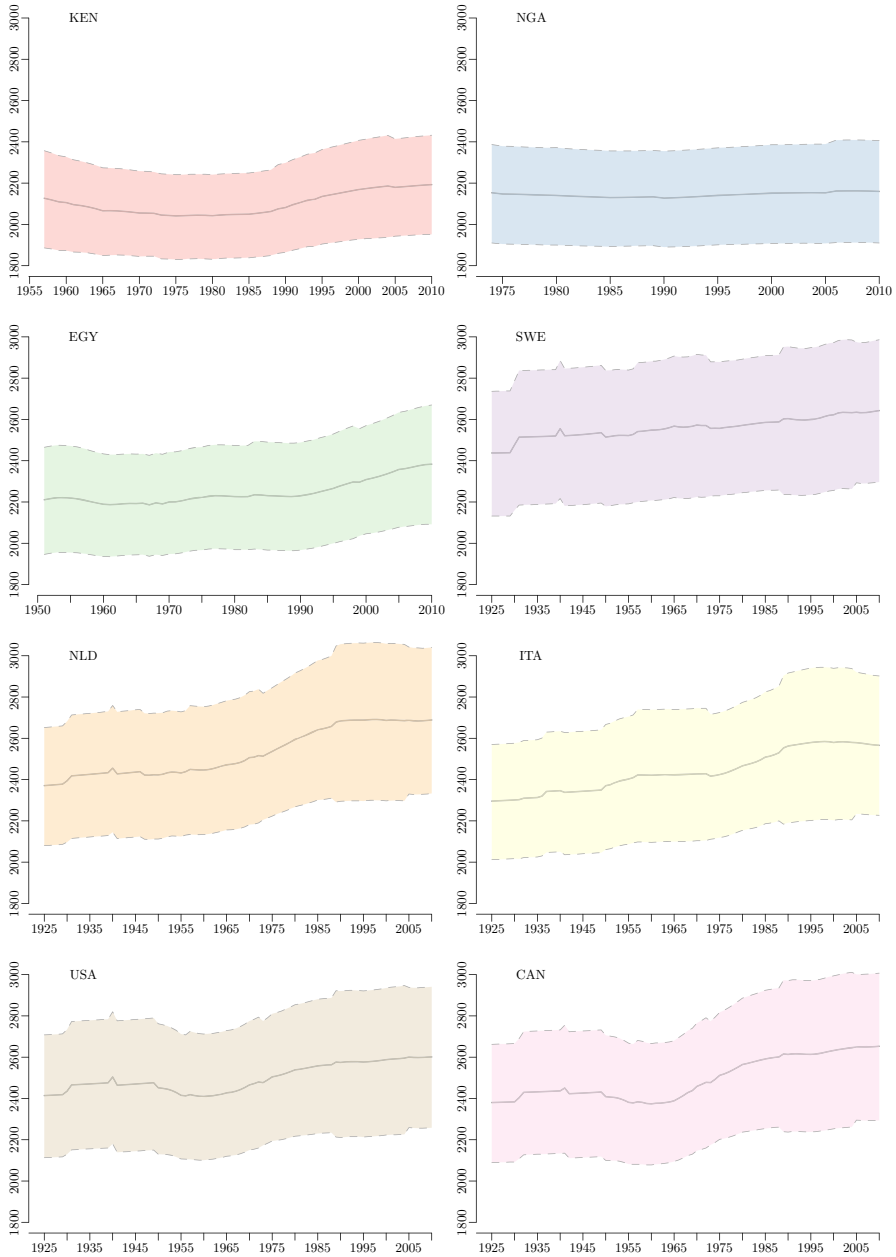
Fig. 4 Evolution of MDER (measured in kcal) for Kenya, Nigeria, Egypt, Sweden, the Netherlands, Italy, USA and Canada

small set of countries. It is only surpassed by a devastated Italy in 1944/5 at the end of WWII. Kenya overall demonstrates the worse poverty profile among the countries investigated here.
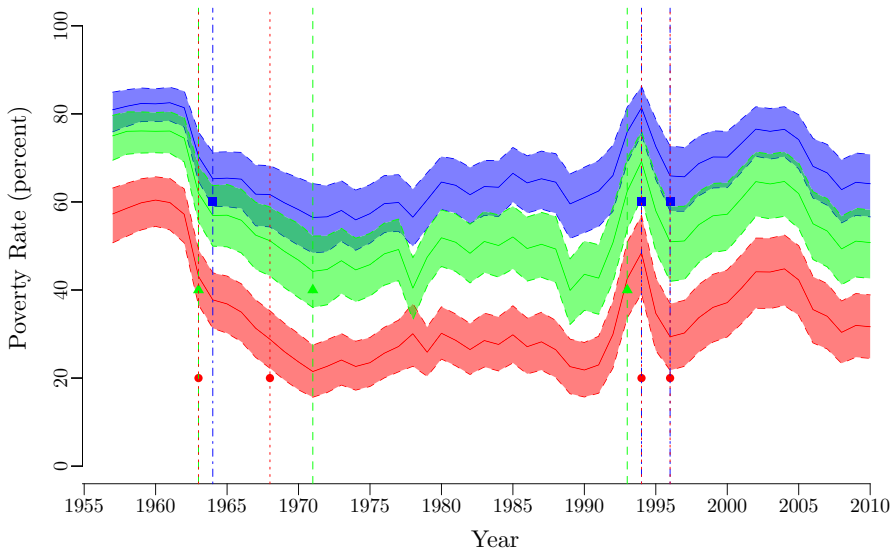
Fig. 5 Evolution of poverty in Kenya using global poverty lines

5.2 Nigeria

The overall RGB poverty trends in Nigeria, for the 1973–2010 period, generally follow an inverted U shape (Fig. 6). An upward trend is operating up until the mid-1980s. Then the trend flattens considerably, before a strong downward trend appears in 2000. For more than a decade during the 70s and 80s, Blue line poverty is hovering at the neighborhood of an astonishing 90%. It is only by 1993 that the situation changes substantially. Focusing on the blue and green poverty lines, the two other important timestamps are 2004/5 and 2010 that both witnessed substantial improvement. With respect to the red poverty line, since 1983 a period of volatile un-improvement manifests until it phases out by 2003. This overall improvement in the late period is in contrast with what is observed in the case of Kenya. Although the poverty profile of Nigeria with respect to both Blue and Green poverty lines is worse than in Kenya, the country manages to demonstrate considerable improvement by the end of the period. In comparison to Kenya, one can observe that Nigeria starts from a worse position in 1973 and ends up with a relatively much better poverty profile by 2010 despite the inverted U-shape form of its poverty evolution. In broader international perspective, the overall RGB profile in Nigeria in 2010 closely approximates Sweden's profile back in 1925, as it will be evident in the section on Sweden below.

5.3 Egypt

The observation period for Egypt is 1950–2010 as shown in Fig. 7. Egypt starts at substantially high poverty rates, which, however, stand very close to the minimum values achieved by Kenya throughout. Despite some volatility, the downward trend is
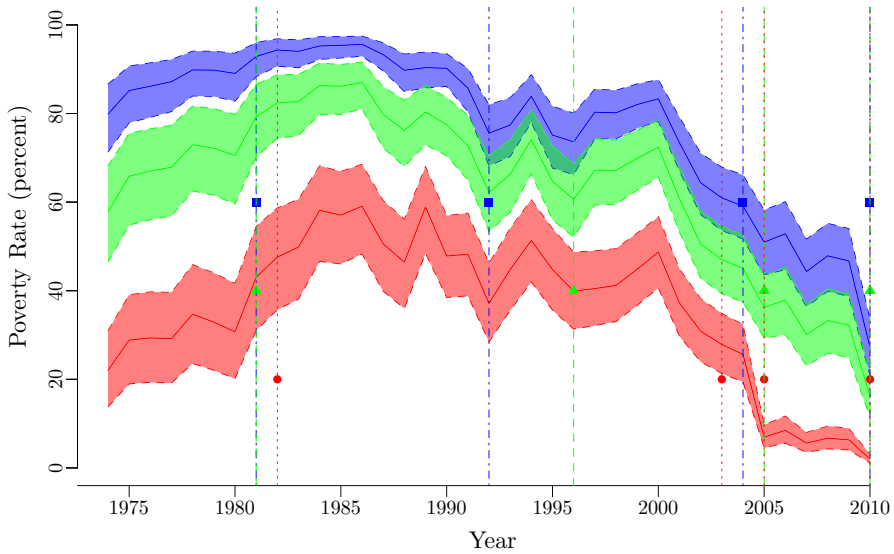
Fig. 6 Evolution of poverty in Nigeria using global poverty lines

present in the entire period. One can notice a series of inverted u-shapes in the depicted lines. Those are between 1965–1979, 1980–1998, and 1999–2010. As we will see next, the poverty rates in 1950 track closely those in 1925 Italy, and by 2010 they closely resemble those in 1925 Netherlands. In 1979 the first considerable reduction in poverty takes place for all RGB lines in sync, as the markers show. By 2010 only the blue type of poverty shows equally considerable reduction. Egypt's RGB poverty profile by the end of the period resembles that of Nigeria, despite the fact that it has a relatively better position in 1973 (the first year of observation for Nigeria).

5.4 Sweden

Sweden is the first of the five "western" countries that this section presents results for (Fig. 8). The observation period here starts in 1925 and lasts until 2010. The poverty profile in Sweden in 1925 strongly resembles the situation prevailing in 1991 Egypt. Within 7–8 years from the beginning of the period the first considerable improvement takes place. And the second wave of major improvement comes at the end of WWII. In contrast to the Netherlands and Italy that follow, the impact of WWII in Sweden's poverty profile is much more modes, although still quite visible. By 1974 all RGB poverty types are too close to zero or exactly zero. Still Green type poverty shows some near zero volatility as captured by the markers. It is worth noting though that the Blue poverty line is non-zero even in the post-2000 period, it even shows some relative reduction as late as 2006, and remains at non-zero levels until 2010. Despite the major success in poverty reduction that Sweden had throughout the period of observation, the speed of poverty reduction is rather slow compared to what the Netherlands and Italy
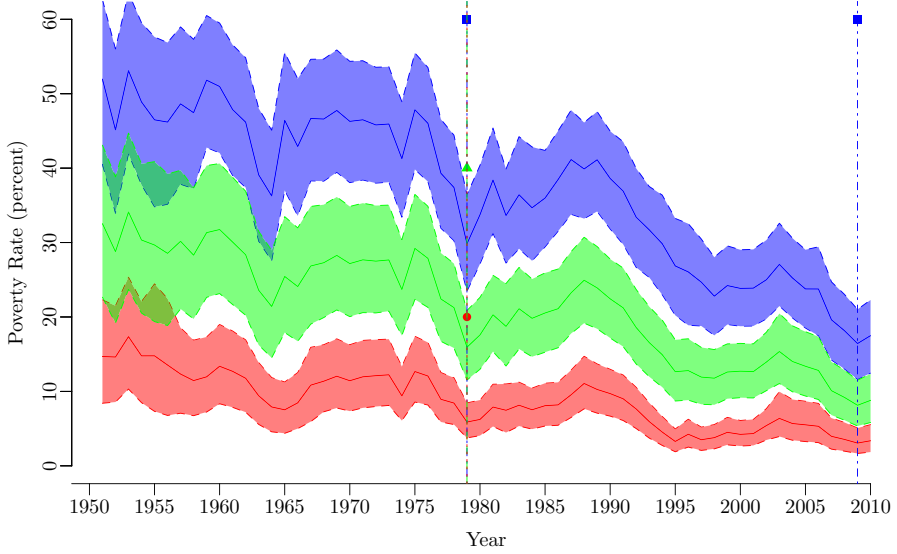
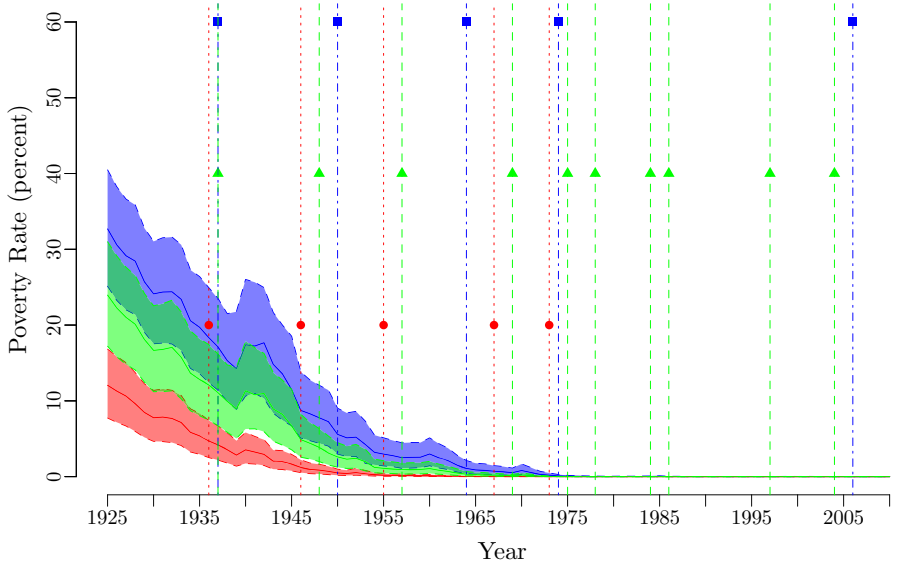**Fig. 7** Evolution of poverty in Egypt using global poverty lines

Fig. 8 Evolution of poverty in Sweden using global poverty lines

show next. On the other hand, in comparison with the same two countries, Sweden has a much smoother poverty reduction trajectory throughout the period.

5.5 The Netherlands

Although the initial profile is slightly better than in Sweden, it is indeed the effect of the WWII in the Netherlands that dominates Fig. 9. Following a strong increasing trend after 1940, the "hunger winter" of 1944 is the spike that shoots all PLs in tandem. During the first period, of 1925–1940 the prevalence of even the most austere Red PL, is non negligible, while Blue level poverty hovers around a substantial 20%. In comparison with Sweden, however, it starts of from a relatively better level in all RGB lines. After the 1944/5 extreme spike, another sudden event takes place in 1952 that considerably raises red poverty line estimates, after the major improvements that took place until 1950. The post-1952 period shows successive considerable improvements at all RGB poverty line levels, as it is shown by the markers. By early 70s all poverty lines become near zero, although as in the case of Sweden, the blue line still shows some improvement as late as 1987. From 1987 onward all RGB lines are at zero level.

5.6 Italy

Compared to the Netherlands and Sweden, Italy starts with much more substantial—near double—poverty figures at all levels (Fig. 10). The slow downward trend that started after 1929, is interrupted by the advent WWII in 1939. Poverty increases massively by the end of the war, at levels clearly beyond 70% for all types of PLs. This situation is—in negative terms—second to none among the countries presented here. The recovery period takes about as much time as in the Netherlands, but the recovery rate is not as sharp. However, the post-WWII years are densely populated with evolution markers for all RGB lines. Since early 80s RGB lines are near zero. From 2000 onward Italy flats out all RGB lines at zero level.

5.7 USA

Poverty rates for the USA start at similar levels as in the Netherlands (Fig. 11). However, the crash of 1929 considerably amplifies the prevalence of poverty at all PL types, though within the 5% overlap requirement. The first marked improvement with respect to the start of the period takes place in 1939, the year where for European countries a positive trend takes place, sometimes severely. Poverty reduction of all traced types of poverty is only briefly and rather "lightly" interrupted in the aftermath of WWII. Thus, in the period before the end of WWII where poverty was claiming a strong foot in the both Netherlands and Italy, the USA demonstrate sharp reduction. In the subsequent period, they have achieved near zero poverty rates by 1970. It is striking however that Red poverty line markers appear even in 2009, implying that all RGB poverty types remain above zero for all but the last year of observation. In 2010, both Green and Blue poverty types are non-zero. This is worrisome finding is unique among all the western countries presented so far.
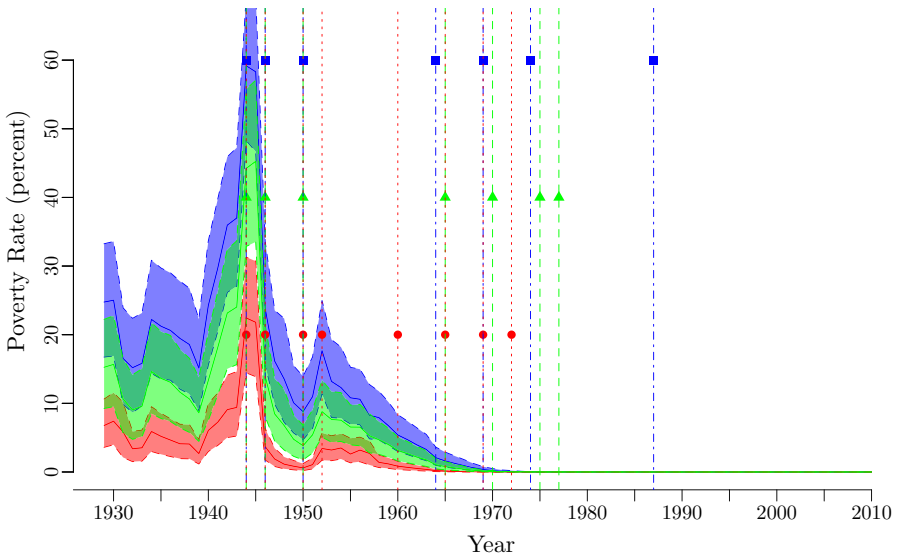
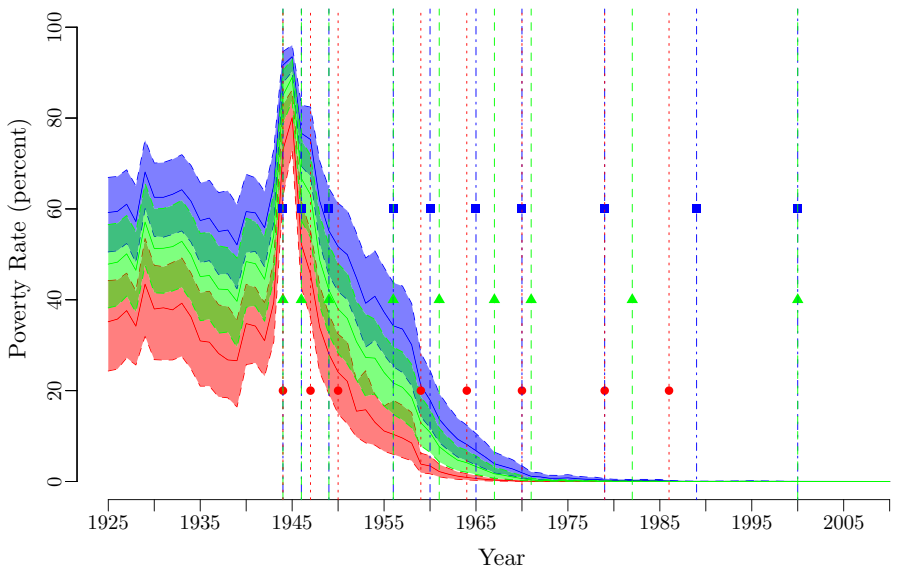**Fig. 9** Evolution of poverty in the Netherlands using global poverty lines

Fig. 10 Evolution of poverty in Italy using global poverty lines

5.8 Canada

Overall Canada shows the best RGB poverty profile (Fig. 12). In the beginning of the period Blue type poverty is at the level were Red type poverty stands in other western countries, save Italy. After a rise starting in 1929, as in the USA, the poverty profile
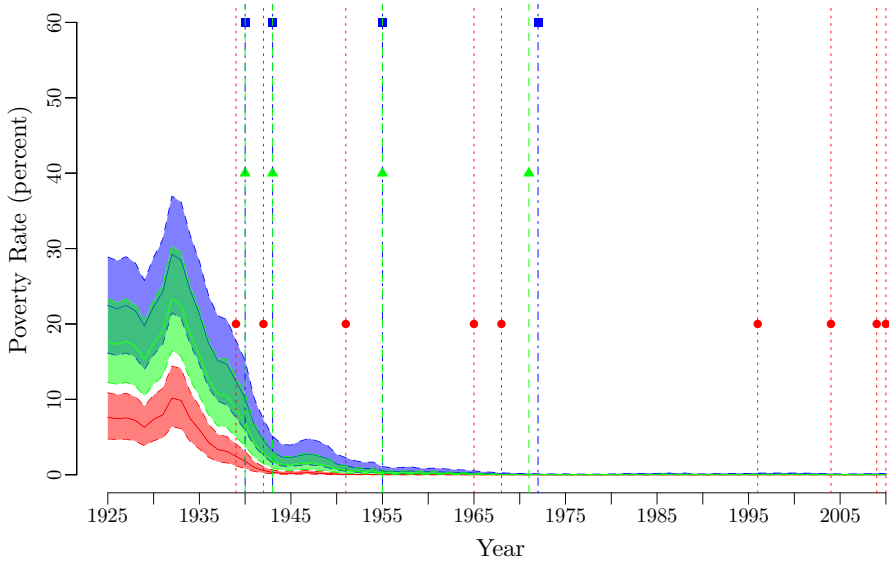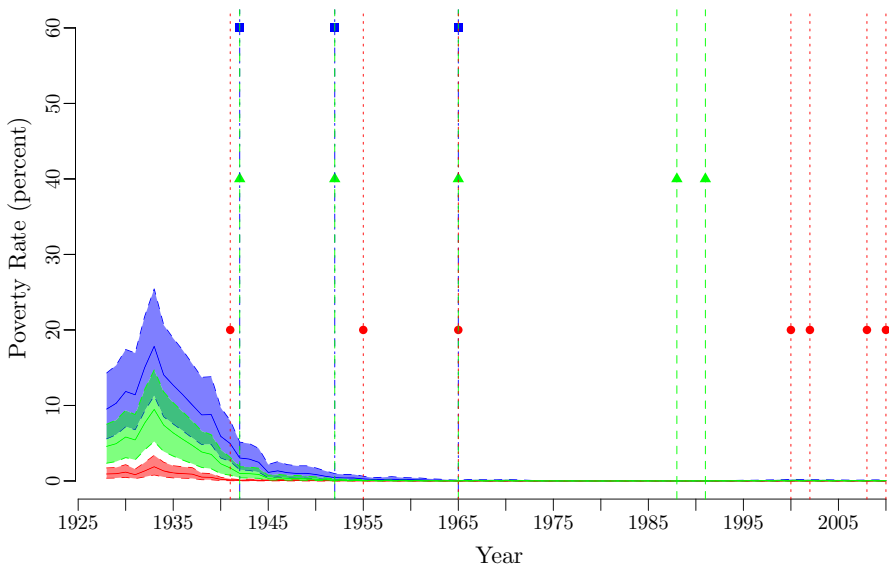
Fig. 11 Evolution of poverty in the USA using global poverty lines

Fig. 12 Evolution of poverty in Canada using global poverty lines

drops faster to the lower levels among all countries for the period up to 1965. Similar to the USA though the RGB lines do not become flat zero. This is also noted by the Green and Red markers in the 80s, 90s and 00s. Canada, thus, resembles the USA in this worrisome way. It is only in 2010 that Red poverty type becomes zero while Green and Blue remain slightly above that.

6 Conclusions, limitations and future research

A first attempt to consistently trace the evolution of global poverty paths throughout the twentieth and early twenty-first centuries is presented here for a small set of countries. The method and the data used have certain limitations that must be acknowledged. First, the methodological focus is entirely in a unidimensional (material) poverty, and this method excludes multidimensional poverty considerations. Second, a number of methodological improvements, too numerous to mention here in detail, can be implemented to provide a more solid framework for drawing conclusions. One example is to use population weighted temperatures to calculate more accurately the relevant degree-days.[37] Third, the data utilized, e.g., the gross income distributions, are not the most appropriate ones for the purpose of poverty measurements; further work and research is needed to pinpoint the margin of error against more appropriate data.

Nonetheless, this research has demonstrated the feasibility to construct standardized poverty lines for historical research implemented in such a way that basic statistical comparisons (e.g., statistical significance) can be performed. Moreover, the identified trajectories in poverty levels provide an in depth glance at the development stages at well-defined welfare levels within a country, that are—with certain data limitations— comparable across the globe. Expanding the set of countries, and the time period covered, as well as improving methodological operations, must be considered next in this line of research.

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[37] Or implementing the idea that where population density is low, then energy expenses for heating and cooking resemble shadow prices.

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