# How much does the cost of survival vary between populations?

Lindgren, Mattias

Lund University, Department of Economic History

2015

COMPARATIVE INSTITUTIONAL
ANALYSIS WORKING PAPER 2015:1

Lund University
School of Economics and Management

# The elusive quest for the subsistence line

## How much does the cost of survival vary between populations?

MATTIAS LINDGREN

# The elusive quest for the subsistence line

## How much does the cost of survival vary between populations?

**Mattias Lindgren**[1]

**ABSTRACT**

The subsistence line, defined as the lowest possible income that can sustain a population, depends on several factors that vary between populations. For simplicity, however, the line is typically assigned a fixed dollar value, so that it represents subsistence under average conditions. We explore how much the line may differ across populations if we take relative prices, age composition, heights and climate into account. We estimate the cost of the physical minimum requirements, since this is the quantifiable part of the subsistence line. The variation of the physical minimum can shed light on the variation of the subsistence line, even though the latter is likely to be significantly higher than the physical minimum.

Our physical minimum line, under baseline assumptions, is 0.67$ per day in 2005 international prices. Differences in prices between our cases imply physical minimum lines that vary between 50% and 150% of the baseline. The range of potential heights implies lines between 84% and 115% of the baseline and the range of age compositions implies lines between 97% and 110% of the baseline. The effect of climate is by assumption small, less than 5%. We cautiously suggest that relative prices is the first thing to take into account if we want to improve the subsistence line, whereas differences in the age composition is less of a concern.

We argue that the variation in the subsistence line have implications for how we judge some income estimates, as well as the extraction ratios suggested by Milanovics and others. We suggest that data on nutritional requirements from FAO, data on heights, UN data on age distribution and survey data on the cost of staples could offer short-cuts to fine-tune the subsistence line.

**Key words:** subsistence line, poverty, living standard, income estimate

**JEL classification:** D31, E01, I32, O10, O15

---

[1] Department of Economic History, Lund University. Earlier versions of the paper was presented at "Ekonomisk historiska motet 2013" in Lund October 2013. I am thankful to all inputs along the way, especially from Christer Gunnarson, Robert Allen, Klara Johansson, Hans Rosling, Martin Andersson, Jan Luiten van Zanden and Fernanda Drumond for valuable help, criticism and comments.

**Abbreviations used**

| | |
|---|---|
| PAL | Physical Activity Level (equals TEE/BMR) |
| BMR | Basal metabolic rate (energy at complete rest) |
| TEE | Total energy expenditure |
| PL | Poverty line |
| DLW | Double Labeled Water (the “golden-standard” method to measure TEE) |
| BMI | Body Mass Index (weight in kg / height^2 in meters) |
| CED | Chronic Energy Deprivation (BMI>18.5, body in energy balance) |
| FFM | Fat-free mass |
| AED | Acute Energy Deprivation (energy expenditure > consumption) |

# 1. Introduction

Some years ago Maddison and Wu (2008) argued that the Chinese GDP per capita of the World Bank was unrealistic. One of their arguments was that the data implied a level in 1950 that corresponds to only 326$ per year (or 0.89$ per day)[2]. This level, they claimed, is "well below subsistence". Since the "subsistence line" is supposed to indicate the lowest possible income the World Bank data cannot be accurate.

Dikhanov and Swanson (2010) from the World Bank disagreed. They argued that it is unclear exactly where we should put the subsistence line, but that it must be lower than 326$ since several contemporary countries have experienced incomes below this level. They could also have added that a quarter of a billion people consumed less than *half* a dollar per day in 1984 according to World Bank data (2013D) and people below the suggested subsistence line seem to have a significant non-food consumption (Banerjee & Dufflo, 2006 & 2011). Clearly, if the subsistence line indicates the limit of human survival then 326$ must be well above this line.

Then again, these examples might simply reflect either the under-measurement of consumption, or reflect a large number of individuals that are literally starving to death, which would be an unsustainable situation. In such a case, the figures above does not reflect the real, long-term, income level, and the subsistence line might very well be much higher than 326$ per year.

So who is right? At what level should we put the subsistence line and how should we interpret it? The question is not merely a technical detail in the debate about Chinese GDP data: the subsistence line is a point of reference in a wide range of studies on income, inequality and growth. The line does not only set a floor for the GDP per capita, but it also sets a limit to the size of the economic "surplus" that can be used for non-food consumption, investments and elite extraction.

Authors that use the subsistence line typically assign a fixed dollar value to represent the line. For example, Pritchett (1997) set the line at 1.11 $ per day. Others have suggested a somewhat higher line, e.g. 1.5$ per day. If 1.11$ is taken as the absolute lower limit for income, it would not only give Maddison and Wu right, but it would also imply that a number of the income figures from the World Bank (and others) are implausibly low and misrepresent the real, long-term, income. On the other hand, if the subsistence line is much lower than 1.11$, it would not only mean that a GDP per capita quite below 400$ is possible, it would also imply a much larger room for an economic surplus above the bare necessities than usually assumed.

So does 1.11$ represent the absolute limit to income and human survival or is a different level perhaps more correct? To answer this question we need to remember that Pritchett, who suggested the subsistence line of 1.11$ per day, used it for a very general argument about global inequality, so he only needed an approximate value based on a number of simplified assumptions. One important assumption is that he, and others with him, use the same subsistence line for all populations. However, the cost of survival depends on many factors of

[2] We will consistently express all figures in 2005 international prices per day. Many of the figures we cite are expressed in other units, e.g. 1990 international dollars. However, we want to avoid burdening the text with too many alternative measurements so we recalculate all figures with the GDP deflator for US from World Bank data (2013A). We will also express most figures as dollars *per day*, even when we talk about GDP per capita.

which several vary between populations, such as the relative cost of calories, climate, the average height of the population and the age composition of the population.

Hence, Pritchett's line of 1.11$, as well as most of the other suggested lines, can best be described as the lowest realistic level of consumption under *"average"* conditions. In this paper we explore how much the subsistence line may vary across population if we account for the fact that conditions vary across populations. For example, in some countries the relative prices of calories are very low, which could make the subsistence line lower than the "average" subsistence line, and vice versa. Is this variation large enough to have any practical consequences?

Another important property of the existing subsistence lines is that their main aim is not, strictly speaking, to reflect the physical minimum requirements. Instead, Pritchett and others try to find the lowest level of GDP per capita that we could ever expect to observe for a typical population. It is worth highlighting that this definition is not the same as a physical minimum defined as the cost of the most basic need for nutrition, water and warmth under idealized conditions. Hence, we will differentiate between these two definitions and call the former the minimum consumption line and the latter the physical minimum line.

There are indeed several reasons why the minimum consumption line should be higher than the minimum consumption line. People can die prematurely due to all sorts of poverty related reasons even when they have the theoretical possibility to consume sufficient nutrients. The list of poverty related risk factors can be made long but includes things like poor sanitation, poor health services or simply the difficulty to tackle any unexpected income fluctuations around the long-term mean.

Hence, we need to add a "safety margin" on top of the physical minimum requirements to give room for expenditures that, although not strictly covering basic physical needs, are necessary to keep mortality at a sustainable level. We still know far too little, though, to suggest a figure for such a margin. Whatever it is, it should be very contextual. For example, if the environment is such that hygiene is difficult to maintain, or such that mortal diseases are common even when the population is well fed, or such that unpredictable income fluctuations are common, then the safety margin should probably be quite large. In other, more benevolent environments, the safety margin could probably be relative small.

Because of this we decided that we had too little information to directly explore the variations in the minimum consumption line. However, we know far more about the factors that influence the basic physical requirements of humans, such as nutrition, water and warmth, and these factors can more easily be quantified. For that reason we choose to focus on the physical minimum rather than the minimum consumption.

But why focus on the physical minimum line when no populations could be expected to survive at that level? Life slightly above the physical minimum would be extremely hard, and most people would not manage to survive, although some just might, through a combination of skill, luck and a kind environment. However, below the physical minimum line life is not just difficult, or hard, but literally, physically, impossible. Accordingly, we should not observe any population permanently below this line under *any* circumstances. Hence, the physical minimum is the "hard floor" upon which the subsistence lines stands, so if we know something about how much the physical minimum line varies by conditions, this would also shed light on how the subsistence line varies.

That being said, even though the physical minimum is easier to quantify, there are nevertheless ambiguities as to exactly where to draw this line. There are no fixed cut-off values for things like body weight and food variety under which death is certain and over which mortality is unaffected. Rather, there is a gradual increase of mortality for harsher situations, so we just have to assume exactly where these cut-off points are. However, we also examine how sensitive our results are to these assumptions.

So what we do is to estimate the physical minimum line for populations and explore how it changes when we vary the *conditions*, such as prices, age composition, average height and climate. Furthermore we explore how sensitive the line is to our *assumptions* concerning the requirements for weight for height (BMI), food variety and physical work effort. Conditions are factors that we believe vary between populations in an observable way, whereas assumptions is simply where we set the cutoff for survival. The latter are, in principle, the same for all populations.

It is worth noting that this separation of the underlying factors into conditions and assumptions is a bit arbitrary. For example, the required physical effort could be much lower in some contexts where food production can be done with little physical effort, whereas in other places food production always require heavy physical labor.

It is also important to underline that we are exploring the variation in the physical minimum line for populations, or at least larger groups of people. Individual subsistence lines should vary even more, as the conditions vary across individuals within a population.

Finally, it is also worth highlighting that the subsistence line differ from a number of related concepts, most importantly *the national poverty lines, the international poverty line* of 1.25 international dollars and the so-called *barebones basket* constructed by Robert Allen. All these concepts have different purposes than the subsistence line, and are defined in a different way. In this paper we do not directly focus on these alternative concepts, although we will discuss them briefly.

## 1.1 What we do

So what are the options for calculating a subsistence line? Pritchett (1997) regress infant mortality rate on incomes and use this relationship to find the income level at which infant mortality becomes “unsustainable”. He do a similar exercise with income and nutritional intake. The results from these methods could best be thought of as a minimum consumption line for average conditions since the variation is substantial around the regression line. We could, in principle, add additional variables to the regression and use this model to say something about how the subsistence line vary.

However, we choose to use a “bottom up” approach instead. The first step is to find the relevant values for all the determining factors, including the prices. We then use a model that relate a number of factors to the physical requirements of an individual. We finally use relevant prices to calculate the costs of these requirements.

But how should we determine the range of possible conditions and assumptions? One way could be to somehow select a “representative sample” of all populations, find the values for all conditions for all these populations, and from that calculate a physical minimum line for each of these populations. We could use the distribution of this set of lines to calculate, for example, the mean and variance. However, we have far too little comprehensive data to do such an exercise and we have, in any case, no way to find such a representative sample of populations.

What we do instead is to review the available literature on each of the determinants of the physical requirements, and see what values we can observe for each of them and what other consideration we should take. We then use our model to calculate the physical minimum under the range of plausible assumptions and conditions. Then we use a selection of price datasets, purposefully chosen, to explore the variation caused by differences between the chosen datasets. The restricted number of price datasets is of course a serious limitation, but it is nevertheless interesting to see the variation in costs caused by such a narrow selection.

For each factor (prices are one of them) we set a baseline value, a minimum value and a maximum value. The minimum and maximum values could be seen as the extreme range of possibilities, but they do not represent outliers. We calculate the physical minimum line for each of these scenarios, to see the relative impact of them.

We also combine the scenarios for each of the factors to see the potential extreme range, even though this does not represent directly observed lines. We combine all our baseline conditions which give us something that corresponds to the subsistence line under average conditions. We combine all our minimum conditions which give us what we call the "rock bottom line". We also combine all our maximum conditions which give us a top value for the physical minimum.

## 1.2 Results

Our baseline scenario, i.e. the combination of all baseline conditions and assumptions, is 0.67$ per day. Our selected price datasets imply physical minimum lines that vary between 50% and 150% of the baseline. The range of potential heights imply lines between 84% and 115% of the baseline and the range of age compositions imply lines between 97% and 110% of the baseline. The effect of climate is by assumption small, less than 5%. We cautiously suggest that relative prices is the first thing to take into account if we want to improve the subsistence line, whereas differences in the age composition is less of a concern.

When we combine all the minimum conditions (under baseline assumptions) we get a physical minimum line at 0.27$. This represent what we call the rock bottom line, the lowest possible income under any conditions, supposing our baseline assumptions are correct. When we combine all our maximum conditions (under baseline assumptions) we get a line at 1.28$.

All the figures above is based on our baseline assumptions. How sensitive are the results to these assumptions? The baseline assumption for what to include in the basket was based on a simplified version of the so-called barebones basket of Allen. We could instead use the simplest thinkable basket that includes *nothing* other than the cheapest staple. The price data we examined did not reveal any realistic source of calories much cheaper than this. This extreme and unrealistic assumption cuts the line to about 65% of the baseline.

If we assume that the required physical effort can be cut the line drops to about 77% of the baseline. If we assume that a population can survive even when severely under-nourished the line is cut to 91% of the baseline. If we combine *all* the minimum assumptions, under baseline conditions, we get a line at 0.32$. Hence, there is some room of ambiguity below our baseline assumptions, but we have to make quite harsh assumptions to create any tangible differences to the line, and most of these ambiguities are connected to the composition of the basket, rather than body mass and work requirements.

## 1.3 Implications

Does our results have any implications for the conclusions that so far have been based on the subsistence line? An average subsistence line should be sufficient for general arguments, such as Pritchett's argument about global inequalities. However, if we want to assess an individual income estimate it is worthwhile to look into the specific conditions.

It seems clear that incomes below the average subsistence line are possible under some circumstances. If we know nothing about a population all incomes above 0.27$ *could* be possible, although unlikely. Such low income estimates are rarely, if ever, presented, so this "rock bottom line" is of little use for assessing incomes. However, usually we know at least something of the circumstances of a specific population and we can use that information to raise the lowest possible level of the line. We can illustrate that with the debate about the Chinese income data at the beginning of the paper: is 0.89$ a plausible income level for 1950?

From our results we might say that incomes way below 0.89$ are possible, but given what we know about China in 1950 in terms of income inequality, average heights, age composition of the population and surplus consumption we could say that 0.89$ do not give sufficient room for the basic physical need of the bulk of the population. It hence seems that Maddison and Wu was right on this particular point.

This illustrates that one dollar per day can represent quite different things. It will always represent deep poverty, but in some cases a person at this level can, with some luck, both survive and consume a few things above the bare-necessities. In other cases life at one dollar per day is simply physically impossible to survive, no matter how lucky you are.

The "extraction ratio" suggested by Milanovic and others [3]are based on a fixed, i.e. average, subsistence line. If we take the variation in prices into account the conclusions of Milanovic remains roughly the same, but there are, nevertheless, a few cases where "our" extraction ratios increase over time where Milanovic's ratios decrease.

Nordhaus (1996) has suggested that we should use a "true cost of living index", i.e. an index that take quality improvements into account, when we deflate incomes. Such an index imply a pre-industrial GDP per capita that is far below the fixed subsistence line at 1.11$. However, if we use our approach we should deflate the physical minimum line with the same true cost of living index. This "true cost of living" subsistence line would be below any such "true cost of living income". Hence, our approach would give room for the much higher growth implied by quality improvements over time.

Our exercise obviously have several shortcomings. We look mainly at a maximum range based on selected cases. We do not explicitly account for other nutrients than proteins and calories and we do not take losses in preparation into account. The requirements for warmth and cooking remains vaguely quantified. However, the key point is to illustrate the potential value of this exercise and give some pointers to how the subsistence line could be improved.

Taking relative prices into account when setting a subsistence line have the potential to give a more accurate picture. Population specific energy requirements have some potential to make

[3] E.g. Milanovic etal (2007) and Milanovic (2013).

a difference to. A short-cut to take this into account is to use the country-specific energy requirements produced by FAO, and to use price data for cheapest staple in each country.

The rest of the paper will be organized as the following. In section two we define the line more precisely and in section three we discuss earlier related research. In the following three sections we discuss each determinant of the physical minimum line separately: the composition of the requirements (section five), food requirements (section six) and relative prices (section seven). We put all the pieces together in section eight.

# 2. What exactly is the subsistence line?

We need a more exact definition of the "subsistence line" before we try to put a dollar value on it. First we will explore different ways to define the subsistence line, then we will discuss what variables the subsistence line should be compared with, and finally we describe the model for calculating the physical minimum line.

## 2.1 Alternative definitions of the subsistence line

There are in fact several possible ways to define a subsistence line. Before we go into that we should point out that we choose to focus on subsistence line for a population, rather than for individuals. A subsistence line for a population should be based on the average requirements of that population. However, within each of population the requirements will vary across individuals since the underlying factors such as height, metabolism, physical activity and age vary. Accordingly, some individuals might survive on a consumption level quite a bit below the physical minimum line of the population, and some are unable to survive even at a level above the physical minimum line of the population.

So how could we define a subsistence line for a population? Several different possibilities exist, ranging from very "harsh" definitions to more "generous" ones. Let us discuss each possible definitions in turn, starting with the one that implies the lowest line, up to the one that imply the highest line.

The most extreme definition would be to think of the subsistence line as the level of consumption under which survival is impossible for *any* group, even under the most "ideal" circumstances. We will refer to this line as the *rock bottom line*. It is likely to be extremely low, since some groups, living under very "ideal" circumstances, could manage to survive at extremely little consumption. Hence, most people would not be able to survive at the rock bottom line. This line is not a very useful one, although we can be very confident in discarding consumption estimates below such a line.

Another possible definition is to think of the subsistence line as the lowest level of consumption that in theory fulfills the physical minimum required by a "typical" person under the conditions that prevails for a specific group of people at a specific time and place. The physical needs include the nutrition, water and warmth needed to survive and to produce what is needed to maintain the same consumption in the future. Nothing above those requirements would be included. We will call this line the *physical minimum line*.

A third way to define the subsistence line is to think of it as the lowest level of consumption we would ever expect to actually observe for a given group at a given time. We will call this line the *minimum consumption line*. This line, as pointed out earlier, is likely to be significantly higher than the physical minimum line.

A fourth way to define the subsistence line is to think of it as the lowest GDP per capita we would ever expect to observe. This line would be higher still, since GDP includes more than consumption. We will refer to this line as the *minimum GDP per capita line*.

Finally, we could define a "*Malthusian subsistence line*" as the GDP per capita for which the population growth becomes zero (Persson, 2010). This would probably be the highest line, since not only mortality, but also fertility and migration, could be affected by income in ways that have nothing to do with the physical minimum requirements.

We will focus on the physical minimum line, partly because this is the easiest line to define and calculate. The rock bottom line could simply be thought of as the lowest line in the set of all possible physical lines. The other lines are far more difficult to quantify, but the physical minimum line represents the lowest possible level of these other lines.

## 2.2 What should we compare the subsistence line with?

The subsistence line is of little use in isolation. We want to compare it with the income level of some specific group and see how close it is to the subsistence. It is hence important that we include the same things in the income measure we use, as in the subsistence line we use. Furthermore, it is important that we have deflated the values in the same way. If incomes have been transferred to fixed prices by using a GDP deflator, the costs in the physical minimum line should also be deflated with the same GDP deflator. If incomes have been deflated with a consumer price index, the same should go for the subsistence line. If the income measure intentionally exclude some kinds of food, then we should also set the price of those food to zero, which could, in principle, mean that the physical minimum becomes zero.

We chose to define the subsistence line as the lowest *consumption* possible. The first question is why we focus on *consumption* rather than on gross income, net income, expenditures, or functionalities. The main reason for this is that incomes could be zero, e.g. by drawing on savings. Even expenditures (or acquisitions) could be zero for some time if we draw on stocks built up in the past. Consumption, on the other hand, should in principle include everything we somehow utilize, including the use of capital goods and the drawing down of stocks. Hence, consumption is the only measurement that is constrained by our physical requirements in the short run. In the long run consumption should match some kind of permanent income, though.

We should in principle include publicly provided consumption in our consumption measure. Public consumption might include "survival goods", such as water supply. The GDP per capita would accordingly indicate what is available to fulfill the subsistence needs, including the required investments.

Secondly, we focus on consumption averaged over several years. Low, or even zero consumption, is possible in the short run. If our energy intake is lower than our energy expenditure we can survive by burning body mass, which will supply additional energy. At some point the body mass will be depleted, if we do not reestablish energy balance, and then, if not before, we die.

This situation with a temporary energy imbalance, sustained by falling weight, is referred to as Acute Energy Deprivation (AED). AED ultimately ends when the body mass have been depleted and the person dies. This is different from Chronic Energy Deprivation (CED) that occurs in a situation where energy balance has been achieved at a lower body weight. This lower level of weight depresses the energy expenditure, and can hence, in theory, be sustained in the long run.

A situation with AED can go on for some time. A normal-weight person under total starvation can survive about a month (Lieberson, 2004; Henry, 2001).[4] Semi-starvation, whereby the body mass is slowly depleted, is not well documented so it might well be that a person with a minor energy deficit could survive for a more extended period. However, this situation would not be sustainable in the long run, and it is implausible that anyone could survive any noticeable deficit over several years. Hence, the physical minimum line should account for the possibility of living in a situation with CED, but it should not account for persons with AED.

Short term movements in consumption should be expected, both between years (e.g. due to temporary crop failures or negative life events) and within the year (e.g. seasonal changes or temporary crisis). The Overseas Development Institute (2014) estimates that one third of those living below the international poverty line is chronically poor, meaning that two thirds are not chronically poor. Hence, it is important that we consider long term consumption.

Thirdly, we want to measure consumption and not functionalities. Functionalities include things like being warm, being well fed, tasting good food, surviving etc. The cost to achieve a specific functionality differs with circumstances, e.g. because of variations in relative prices, variations in personal characteristics or because nature provide some functionalities for free.[5] Hence, the same consumption level, measured in fixed dollars, would be able to buy different amounts of functionalities in different time and places. Indeed the physical minimum line could be considered as the cost of the functionality "the possibility to survive", and the variation in this cost is one of the very thing we try to measure.

Fourthly, we are considering a very "inclusive" consumption measurement. In reality we are likely to come across consumption observations that are below the physical minimum simply because they have failed to include all relevant consumption. However, one potential use of subsistence lines is to help identify such observations.

We should in principle compare the physical minimum line with a consumption measurement that *include everything* that can contribute to survival. Real survey typically deviate from this ideal at several levels. First, the standard definition of consumption might exclude some utilities that can help a person to survive, such as some types of famine foods. Second, many surveys exclude, for practical reasons, items that should have been included if the standard definition had been followed. Some types of home production are one example of this. Thirdly, any surveys fail to fully capture even the things they intended to capture. Specifically, what is *actually* measured in a particular survey can fall short of what was intended. Crucially, food intake is systematically underestimated (Goldberg & Black, 1998).

[4] An over-weight persons can survive longer. The record seems to be 382 days, for a person that initially weighted 207 kg (Henry, 2001).

[5] Some measures try to take variations in relative prices into account, such as the real wages calculated with the barebones basket.

If the measured consumption is falling short in any of these ways we could, in principle, expect a figure below the physical minimum line. Consumption could even be zero in extreme cases. Hence, we could use the physical minimum line to track observations that are certain to be underestimated.

The inclusive definition of consumption means that even "famine food" should be included. A common survival strategy for people who slip into extreme poverty is to consume "less preferred food". This includes items that can be called "famine food". But it can also include normal food that are spoiled, or even, in extreme situations, left over from other people as garbage.

These food items obviously constitute a major uncertainty when we try to estimate the limits of survival. It is a reasonable guess that the consumption of famine food is rarely included in surveys, since such food is typically only consumed in very special circumstances. Spoiled "normal food" might, on the other hand, be included without any deduction for the lower quality.

Tanzanian data (National Bureau of Statistics Tanzania, 2002) contains some items that might be less preferred foods, most notably "wild birds & insects", but none of that are cheap calories according to the data (the calories in "wild birds and insects" are five times more expensive than the average cost for calories in the basket.) The bigger problem is that even if we had information on the consumption of such items, there would be no obvious way to price them. We would rarely expect to find any price data on them, since they by their nature would not normally be traded.[6]

Since this type of food by its nature is very undesirable one could argue that the implicit prices should be very low. However, it is not given that such food has a low "production cost". For example, Cliggett (2005) describe how the poorest of the poor in Zambia collected grains from wild grass. This required several hours of work to get just a small bowl. The production cost per calories seems hence to be quite high.

Accordingly, the reason people consume such items is not a low "cost", but rather a lack of alternatives. A famine reflected in a high relative price of food would constitute a higher substance line. Famine foods, with a high, but unchanged, "cost" would help to cut such "peaks" in the subsistence line, but would do nothing to lower the subsistence line in normal years.

Other measures of utter desperation, such as eating food from garbage, might constitute calories that are less labor intensive to acquire. The nature of such desperate food items would reasonably imply a very low implicit price, i.e. lower than the cheapest normal caloric source. On the other hand, left-overs require someone more fortunate that throw away food. Hence, a whole population cannot subsist in this way.

Some famine foods might be "cheap" to acquire because the existing stock is quite large, e.g. the stock of "less-preferred" free-living animals. However, the marginal cost would rise sharply as soon as the initial stock is exhausted, so this does not constitute a long term solution.

One could certainly argue that the concept of consumption breaks down in the extreme situations we are considering here. For example, what is the monetary value of the consumption

[6] Differences in relative prices could particularly problematic for these types of items since part of what make them less desirable is culturally determined. For example, lobsters used to be considered famine food in New England in the 19th century (Luzer, 2013), so modern prices would give a totally wrong impression.

of a prisoner, who survives by eating the occasional insect? In a sense he consumes both "housing" (the cell), and food, but these are things that we do not put monetary values on.

Furthermore, what sense do prices make when nothing of what you consume can be substituted with anything else. An isolated group of hunter and gatherers get what they happen to catch or find, and there is no way they can change a lizard with a bread or a fruit. The best we can do is to make all our underlying assumption as explicit as possible. Furthermore, it could be argued that such extreme situations are so extremely rare, and that they do not constitute the "normal" situation at the border of survival.

The principles we discussed so far are difficult to follow in reality. The consumption measures we usually encounters are likely to exclude or underestimate some items. When we construct our physical minimum line we lack the data to account for whether water is freely available from nature, or entails a cost. However, these principles can help us to explain why a consumption estimate does seem to be below what we assumed to be the physical minimum line.

## 2.3 How we calculate the physical minimum line

We define the physical minimum line as the consumption needed for physical survival, but nothing more. The most basic requirements for physical survival is sufficient quantities of water and nutrition as well as the ability to keep a reasonable temperature. However, we assume that water is always for free, or that it is consumed in sufficient quantities but excluded from the consumption measurement.

There are of course many other basic physical conditions that are important for the chance of survival, such as basic hygiene. However, we cannot set a specific level of lack of hygiene under which survival becomes *impossible*. Basic hygiene is also very context dependent, e.g. it is very difficult to achieve in a crowded environment, and much easier if clean water is naturally available. Hence, we will not include basic hygiene, and similar factors, in the physical minimum line, but assume that they are satisfied in the idealized scenario we consider here.

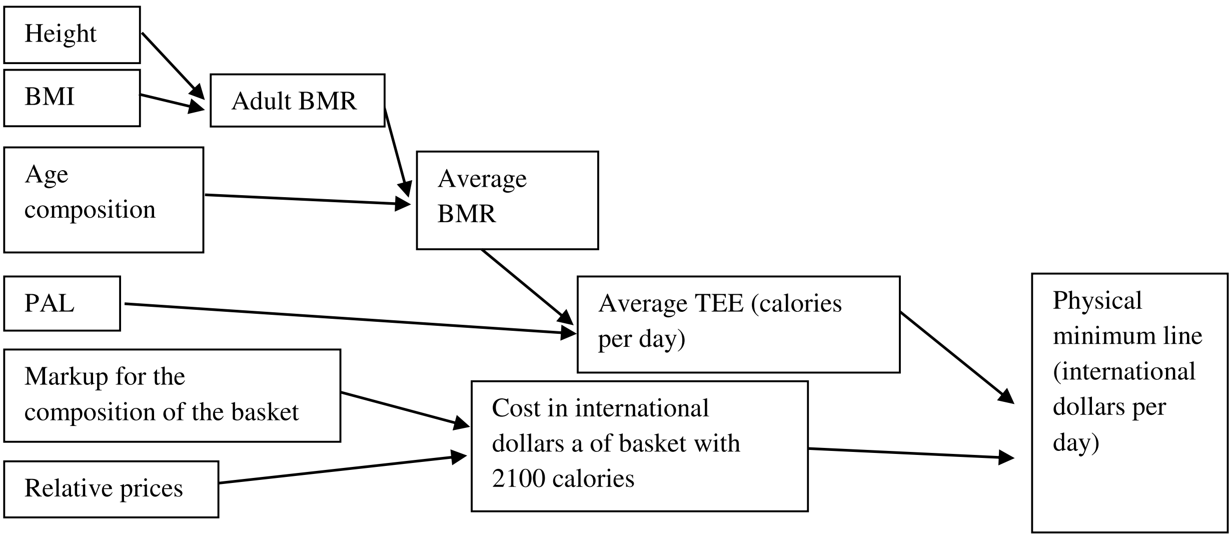
A key part of the physical requirements are food nutrition. Hence, the key part of the physical minimum line is to determine a food basket that supply sufficient of nutrients. We will consider food energy and, indirectly, proteins. Hence, the first step will be to determine how much food energy that constitutes the physical minimum. Then we need to find the cheapest realistic food basket that supply this energy. We will then use available data to put a price on this basket. Next we need to consider which non-food items are necessary to survive. We will try to put a price on these as well, but in most cases we will have to calculate this cost with a mark-up factor applied to the food basket, i.e. we assume that the relative price of the non-food basket to the food-basket is the same across our cases.

Determining the average energy need in a population is central to our calculation. For a weight-stable person the energy intake equals the total energy expenditure (TEE). The TEE is often broken down into energy expenditure at total rest (Basal metabolic rate, BMR) and the energy needed for physical activity (including the energy needed to digest food). Hence, the TEE is often expressed as BMR multiplied by a factor for physical activity (the "physical activity level", PAL). The value for PAL is determined by the average physical activity during the period. FAO (2001) offer values for various specific activities as well as for a number of default "life styles".

The BMR is mainly determined by the body size, age and gender although other factors are important to (both at the individual and the population level). For our purposes it will be useful to break down the body size into height and "skinniness", i.e. weight for height. The latter is measured by the Body Mass Index, BMI.[7]

FAO (2001) and Henry (2005) have estimated equations that describe how height and BMI relates to BMR for specific age groups. We can use them to calculate the BMR for a reference group, in our case "adults 18-30". We can then use age-adjustment factors, determined by the age-composition of the population, to calculate the average BMR for the population. We can then use a PAL value to calculate the average TEE of the population. With the help of this energy requirement we can scale our food basket so it supply the correct amount of calories. We then price the basket and add a markup for the non-food items. The whole exercise is summarized in the figure below.

*Figure 1: Our model for the physical minimum line*




The various measurements of poverty lines, subsistence lines, barebones baskets and under-nutrition are all, in principle, based on the average energy requirements, be it for a population or an average household member. This energy requirement is typically calculated by assuming a typical body mass, age and gender distribution and PAL. We will, in the same way, assume various values for these factors to see what range of values we end up with.

We will begin with a baseline scenario that are based on an average energy requirement of 2100 calories. We choose this as baseline since it is the same energy requirement as in the so-called barebones baskets, introduced by Robert Allen. It is a simple consumption basket designed to allow comparisons of living standards across time and space. It is based on assumptions that replicate the consumption at a very low income level. The barebones basket is hence an important point of reference for any subsistence line. Furthermore, many studies have assumed an energy requirement of 2100 calories, thanks to the barebones basket.

[7] BMI = (mass in kg) / (height in meters)^2

The barebones basket contains four food items that together supply 2100 calories, as well as six non-food items. Table 1 illustrates the barebones basket with the quantities. The quantities are fixed, so the expenditure shares vary with prices.

*Table 1: The barebones basket.*

| | | | | England, 18th century | | US, contemporary | |
|---|---|---|---|---|---|---|---|
| | Item | Quantities | Calories | Percent of expend-itures | Percent within food, and within non-food (approximatly) | Percent of expend-itures | Percent within food, and within non-food |
| Food | oats | 466 (grams per day) | 1657 | 79 | 57 | 78 | 62 |
| | beans/peas | 55 (grams per day) | 187 | | 13 | | 25 |
| | meat | 14 (grams per day) | 34 | | 15 | | 11 |
| | butter/oil/ghi | 8 (grams per day) | 60 | | 15 | | 2 |
| Non-food | soap | 4 (grams per day) | | 21 | 9 | 22 | 7 |
| | cotton/linen | 3 (meters per year) | | | 30 | | 14 |
| | candles | 4 (grams per day) | | | 15 | | 4 |
| | lamp oil | 3 (litres per year) | | | 22 | | 6 |
| | fuel | 5 781 (kilo Joules per day) | | | 19 | | 47 |
| | housing | 5% of the total of the above | | | 6 | | 21 |

*Comments: Oats are used for England. For the US 534 grams of wheat flour have substituted the oats. Quantities and calories are from Allen, 2013A. The expenditure shares for contemporary US are calculated from Allen (2013A), table 7. For England 1750-1800 the expenditure shares were based on the following. The expenditure share of food in the total expenditure is calculated from Schneider (2012), table 3. The expenditure shares within the non-food-category are calculated with prices derived from the respectable basket from Strasbourg, (so they are obviously not comparable). The expenditure shares within food-category is calculated using price data from Clark (2006).*

It is truly a "barebones" basket. Less than 2% of the calories come from meat. This is a somewhat lower share than in many poverty line baskets in contemporary low-income countries. The fuel energy of 5781 kJ is about what is needed to bring about 17 liters of water to boil per day (if there are no heat losses in the process).

The energy content of 2100 calories is set to reflect the energy expenditure of a typical English working class family during the early 19$^{th}$ century. Since we will use this energy requirement as our starting point it is worth going through the underlying assumptions in detail, which is done in the table below.

*Table 2: the assumptions used by Allen (2013A) to motivate the caloric content of the barebones basket*

| Factor | Allen assumption | Based on |
|---|---|---|
| Height | 166 cm for adult men, other heights in proportion to that | Adult men in England in 1841. |
| BMI | 18.66 (which implies a weight of 51.4 kg) | FAO assume this to be the lowest value that is consistent with health.[8] |
| Implied BMR | Adult man: 1463 calories<br>Adult woman: 1182<br>Children: not specified | FAO equations |
| PAL | Adult man: 2.16<br>Adult woman: 1.74<br>Children: not specified | Model based on assumed activities.<br>Adult man: building laborer<br>Adult woman: spinner<br>Children: "strenuous" activity level |
| Household composition (age & gender) | An adult man<br>An adult woman<br>Two children | England 1841 (as far as I understand) |
| Energy requirements (in calories per day): | Adult man: 3160<br>Adult woman: 2057<br>Children[9]: 1602 each<br>Average per household member: 2105 | |

The average PAL for the two adults is 1.95. The implicit age-adjustment factor is 81%, i.e. if we divide the average energy requirement per household member (2105 calories) with the average for the two adults (2609 calories) we get 0.81.

These assumption are based on a relative poor group in an economy with relative low incomes, so it certainly represent a very low living standard. However, it is not intended to represent the physical limits of survival. Hence, we will in subsequent section examine alternative scenarios for these assumptions. First, though, we will go through earlier research in the field.

# 3. Earlier research

In this section we review not only how subsistence lines have been determined so far but also the related concepts of barebones baskets, poverty lines, and under-nutrition. Let us begin with poverty lines. Poverty lines are not set at the lowest limit for mere physical survival. If that were the case, the only way to "qualify" to be poor would be to die of outright starvation. Instead they are based on the caloric requirement needed to maintain a healthy weight (e.g. a BMI higher than 18.5), a reasonable level of physical activity, a height that corresponds to the average in the country, a food basket composition that corresponds to what poor people in the

[8] FAO (1996) actually assume a BMI of 18.5 as their lowest level (which is also the cut-off value for being under-nourished). Perhaps Allen is referring to another version of FAO.
[9] Allen just states "less", but given the average and number of children it had to be like this.

country actually consume, and a mark-up for non-food consumption that is based on the share of non-food consumption of people living close to the poverty line.

Caloric requirements in poverty lines vary between 1700 to 3000 calories per day (Appleton etal, 1999). The international poverty line at 1.25 $per day is the average of a number of these national poverty lines, and so reflect the same considerations, but the internal poverty line is fixed by its dollar value, not by the cost of a specific set of goods. Hence, the international poverty line is based on average conditions.

A substantial number of people live below the international poverty line, 1.2 billion in 2010, and a quarter of a billion people lived on less than *half* a dollar per day in 1984 (World Bank data, 2013D). This can partly reflect the fact that consumption have been underestimated, people in temporary poverty or people who are in the process of starving to death, but it also reflect the fact that the poverty line is not the same as a physical minimum line.

Ravallion (2014) use available household surveys to estimate the lowest level of consumption that occur in the world at a specific year, after accounting for temporary poverty and measurement errors in the data. His estimate is 0.67$ per day, with little change over time. This, he suggests, is probably close to the consumption of essential foods, although it is possible that the existence of social safety nets could raise the floor above the biological minimum.

A more direct poverty concept is undernourishment. The FAO publish data on the prevalence of undernourished in each country. A person is defined as being undernourished if he has a caloric consumption below a specified cut-off level. To calculate this cut-off level the FAO assumes a BMI of 18.5, and a "light" physical activity level (a PAL of 1.55 for men and 1.56 for women). This is combined with country specific data on heights and age-structure to calculate a minimum caloric requirement for each country-year (Svedberg 2002 and Cafiero NA). This generates average caloric requirements per person and day that range from 1615 calories per person (for Yemen 1990-1992) to 2173 calories (for Comoros 2003-2005) (FAO, 2013).

These caloric requirements could be a useful basis for calculating country specific subsistence lines. However, they have two shortcomings if we want to focus on the physical minimum. Firstly, they are based on the absolute minimum needed for a "healthy and active life", not the lowest level someone can survive on. Secondly, it is likely that range of possible values for the subsistence line is quite a bit wider, since the requirements above reflect the known conditions in a relatively limited time period.

Anyways, the number of undernourished in 2010-12 by this definition was 868 million persons (12.5% of the world population). These figures, as the poverty counts, could potentially reflect a mix of people actually starving to death, people in short term stress, measurement errors and people that manage to survive on less than the cut-off point.

Let us now move on to the actual subsistence lines. There are a number of authors that have put a value to the subsistence line, including Maddison, Pritchett (1997), Milanovics etal (2007) and Bairoch. The assumptions they use to set their lines are important points of references for any discussion of the topic, so we reasons to discuss these assumption in some details.

Maddison refers to a subsistence line at 1.50$ per day. This level, as far as I have been able to ascertain, is informally assumed rather than explicitly calculated.[10]

Pritchet (1997), on the other hand, has a more extensive line of arguments.[11] He argues that GDP per capita cannot go much below a level that corresponds to about 1.11$ per day in 2005 prices[12]. He bases this conclusion on several arguments. First, we have never observed a GDP per capita below this level (at least not in the data he had available in 1997). Second, Ravallion etal (1991) puts the "lowest defensible poverty line" at 1.12 per day[13]. This line seems to be based on the very lowest of the available national poverty lines at the time. The GDP per capita has to be significantly higher than this, Pritchett argues, since consumption is always unequally distributed.

Third, he refers to a lower-bound estimate of caloric requirement of 2000 calories. This is based on the assumption that men weigh 50 kg and women 40 kg, a young population (39% is under the age of 15) and an ideal climate.[14] He then regress caloric intake against GDP per capita. The predicted value at 1.11$ is only 1600 calories. Fourth, he regress infant mortality rates (IMR) against GDP per capita. The predicted IMR at 1.11$ is 765 per 1000, which is likely to be too high to achieve a stable population.

The lower bound of GDP per capita allows Pritchett to argue that cross-country incomes must have diverged "big time" in the last 130 years (since there is a limit on how unequal they can have been in the 19th century). The aim of the subsistence line of Pritchett is not to be a physical minimum line. The assumptions he use reflects that. For example, a weight of 50 kg is consistent with a BMI of 18.5 and a height of 164 cm. A BMI below of 18.5 could be dangerous, but it is possible to survive quite a bit below this level.

Bairoch (1993) calculated a subsistence line corresponding to 1.38$ per day. [15] This level "assumes a food intake just sufficient to sustain life with moderate activity and zero consumption of other goods", although it is not entirely clear how this was calculated.[16]

Milanovics etal use the 1.50$ line of Maddison. They argue that this is a reasonable line in light of the international poverty line of the World Bank, as well as the estimate of Bairoch. However, they note that their line is higher than the Bairoch line, and so include items above the bare necessities. They also note that the actual inequality of several poor countries is larger than the inequality frontier implied by the 1.50$ subsistence line. Hence, they suggest that this line might be too high, at least in tropical countries where the need for heating is lower. Accordingly, they also consider a lower line of 1.125$.[17]

Milanovics (2013) has also suggested that the subsistence line for a country should be higher the higher the average income in the country is. Such subsistence lines parallel the idea of relative poverty lines.

---

[10] I have failed to find any details in the reference that Milanovic etal refers to. Maddison & Wu (2008) implicitly mention their subsistence line.

[11] Interestingly, he notes that subsistence lines are a concept that is now "rightly out of favor". I have not managed to find what literature this refers to.

[12] The original figure is 250$ in 1985 PPP $. We deflated this figure with the GDP deflator from World Bank data (2013A).

[13] The original figure is 252$ per year in 1985 PPP $.

[14] This estimate is from a FAO publication from 1957. Hence the estimate might be somewhat different today, since the estimation methods of caloric requirements have been revised since then.

[15] The original figure was 80$ per year, in 1960 prices.

[16] The figure refers back to Bairoch (1979). The corresponding figure there seem to be a guesstimate based on 1900 calories, of bread only, and 15% non-food consumption.

[17] 300$ per year in 1990 prices.

None of the lines above are intended to be physical minimum lines, at least not in the strictest sense of the term. And, indeed, we do observe many people that supposedly consume significantly less than even the lowest of these lines. To what extent does this reflect the existence of a much lower physical minimum line?

Banerjee & Dufflo (2006 & 2011) have calculated a physical minimum line, of a sort. They find, using Philippine prices, that the cheapest basket that supply 2400 calories and sufficient protein only cost 0.21$.[18] However, this diet only contains eggs and bananas, so, as they point out, it is obviously not a realistic diet. This is, in fact, one of their messages: we should not expect people to manage to consume a theoretically optimal basket.

They also discuss the life below the international poverty line by analyzing a set of household surveys. As expected, food is the biggest post in the consumption of the poor. However, non-food consumption ranges between 22% and 44% and some of that consumption, such as the ownership of TVs, cannot be classified as pure "survival goods". This seem to indicate that the physical minimum *can* be quite a bit below the international poverty line, since people to some extent consume other things than just the cheapest nutrients.

But, if that is so, it does not mean that consumption above the physical minimum line is sufficient to get enough nutrients. Indeed, Banerjee and Dufflo point out that a high share of the poor shows clear signs of food deprivation and other forms of stress, even though many of them might have enough resources to acquire sufficient calories if all their consumption were perfectly allocated to calories. Lipton (2012) points out, in a similar discussion, that people differ substantially in their ability to turn a given consumption into outcomes (such as nutritional status). Hence, even though the correlation between the consumption level of a household and nutritional outcomes is clear, much of the variation in outcomes remains unexplained by this factor.

The same pattern emerges if we look at self-reported food-insecurity, which is reported by the World Value Survey (2014). In figure 2 we display the percent of a population that sometimes or often went without enough food, plotted against the GDP per capita of the country (all figures are for 2010).[19] As expected there is a negative correlation between the income and food insecurity. However, the variation at a given income level is quite substantial, and we find at least some food insecure households at all income levels, even in countries where we would expect the poor to live substantially above a physical minimum line.[20]

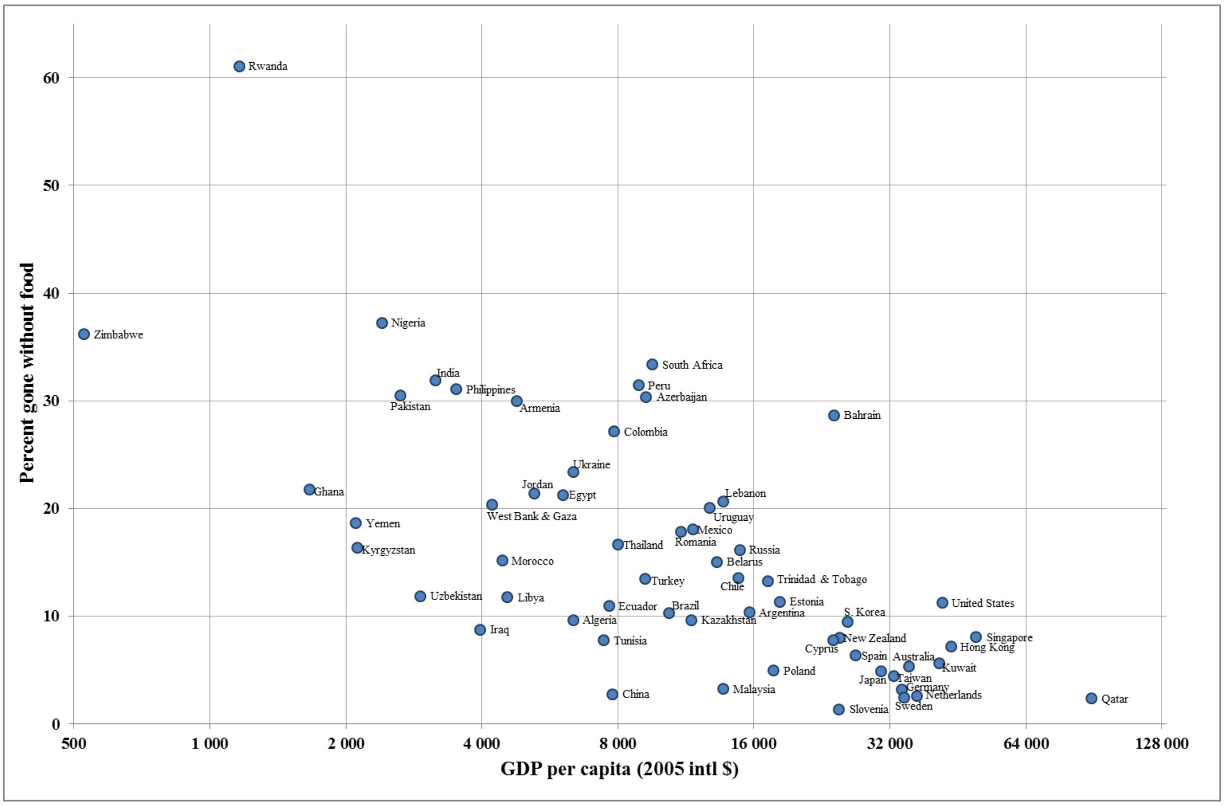
---

[18] In addition, according to Banerjee (2012), when poor people are asked what they need in order to survive they say something like 0.35$ per day.

[19] If we just look at those who answered "often" we get a similar pattern, but at a lower level.

[20]In the US, for example, many food insecure household lives close to the national poverty line, which is much higher than the international one-dollar-per-day line (Coleman-Jensen etal, 2011)

*Figure 2. Percent who went out food and GDP per capita.*




*Notes: "Gone without food" are the sum of those who answered "often" or "sometimes" to the question: "In the last 12 month, how often have you or your family: Gone without enough food to eat". Sources for "Gone without food": World Value Survey (2014). Source for GDP per capita: Lindgren (2014)*

The term "not enough to eat" might be understood differently across countries, so we should interpret this data with some caution. It includes households that experience temporary liquidity problems, perhaps due to some unforeseen economic event that they did not plan for. This is certainly not the same as starvation or long-term under-nutrition[21], but it illustrates that the ability to handle all unforeseen economic chocks can be a challenge far above the physical minimum, even though it gets easier the further above it you are.

What is the relationship between low income and *mortality?* Does mortality increase sharply below a certain low level of income? Bengtson and Poppel (2011), who review evidence on social differences in mortality, point out that the pattern is far from straightforward. Social differences in mortality exist in societies with high incomes, as well as societies with low incomes. More importantly, social differences in mortality are absent in several societies where average incomes arguably were low, such as pre-industrial Sweden. In other cases social differences exist, but not in a way that is consistent with a simple income-mortality link.

[21] In the US the food insecure have a *higher* BMI than the national average Dinour etal (2007). Coleman-Jensen etal reports that 10.8% in US were food insecure in 2010, but only 1.6% had experienced that they were hungry but did not eat for a whole day due to lack of money.

A related strand of literature have examined the effects of food price chocks on mortality (see for example Bengtsson etal) and many of these studies have, indeed, found a clear mortality response to such chocks. However, the effect is not universal, not even in low-income societies, and higher social classes often also exhibit mortality responses.

So even though low income is connected with a higher mortality, we do not see a consistent pattern that help us pinpoint the physical minimum. It is not surprising that we see an income effect on mortality at incomes well above the subsistence line. There are many reasons for why lower incomes pushes up mortality, such as poor sanitation, living condition, education and so forth. Additionally, an economic crisis can force people to migrate or increase the crowding in poorhouses etc, which increase the exposure to infections for everyone.

The fact that we sometimes fail to find a mortality effect in populations that supposedly have low incomes could simply reflect the fact that all the groups under study live sufficiently above the physical minimum. Indeed, the lowest social group included in studies of pre-industrial societies are unskilled laborers whereas paupers and similar groups are generally excluded.

Floud etal (2011) examine various living-standard scenarios, including some at the edge of survival. Based on assumptions for both the distribution and the average of heights and BMIs they arrive at hypothetical historical levels of BMR by income deciles. They then make assumptions for how the caloric consumption is distributed. From these assumption they get how much is left for PAL in each decile. In one scenario the poorest decile in England have a BMI of 16.2 and a PAL of 1.46. This means that they would be slowly starving to death, according to the reference values they use. The second lowest decile (with an implied PAL of 1.66) would have to be inactive during 2/3 of the day. The worst scenario is for France. Under certain assumption the lowest decile would have had a BMI of 14.25 and an implied PAL of less than 1. Hence, several of the lowest deciles would be “starving to death quite rapidly”. Based on this they concluded that the assumptions for this scenario was unrealistic.

They also discuss how a low BMI and a short stature increase the mortality risk, and how this relate to caloric intake and the evolution of mortality over time. However, they do not elaborate on when survival becomes impossible. The main source of mortality data only cover BMI levels larger than 17. Furthermore, they do not discuss directly how the various BMI levels relate to consumption levels expressed in modern PPP dollars.

So how could we sum up the literature so far? Most of the concepts we discussed can be said to be based on some kind of average conditions, conditions which typically include a bit more than the bare physical requirements. The partial exceptions are the barebones baskets which take prices into account, and the national poverty lines which are based on local conditions but not according to a standard definition. Examining the physical minimum line with a fixed definition but under local conditions can hence serve as a step forward. Before we go into that, though, we need to say something about why we should not equate the physical minimum line with the subsistence line, something we do in the next section.

# 4. The other subsistence lines

In this paper we focus on the physical minimum line, but we have suggested four other definitions of a subsistence line: the rock bottom line; the minimum consumption line; the minimum GDP per capita line and the Malthusian subsistence line. The rock bottom line is simply the lowest line in the set of all possible physical minimum lines. The other three lines we believe to be higher than the physical minimum line, at least in a significant number of cases. Why would that be so? To answer that we need to discuss in more detail *why* consumption cannot fall below subsistence. What mechanisms hinders consumption from falling any further?

If we look at the physical minimum line the answer is straightforward. Anyone consuming less than this line will lack even the chance to fulfill their need of nutrition and warmth and will starve, thirst or freeze to death. But should we really ever expect to observe a population that consume at the physical minimum? That requires that everyone manage to use their resources according the optimal composition defined in the physical minimum line, that poverty have no effect on mortality as long as the consumption is above the physical minimum and that an extreme fall in consumption has no other effect on the population or incomes as long the physical minimum is covered.

What other mechanisms could there be, beyond an unavoidable starvation to death? We should of course not consider any chain of events that at some point have stopped the income of a population from falling further. What we will consider is only mechanisms that stop incomes from falling for every population in the same situation.

## 4.1The needs are not same within a population

The physical minimum is meant to fulfill the need of the *average* person in a population. However, this will only work if the needs are exactly the same for all individual in the population, or if the consumption is distributed perfectly according to individual needs. Neither of these assumptions are realistic, so in a population at the physical minimum some individuals are likely to consume more than their individual physical minimum and some less than the physical minimum. Hence, even if the physical minimum is the only source of mortality we would see mortality rise before consumption has dropped to the physical minimum.

## 4.2 Aggravating factors

For the physical minimum line we disregard other physical needs than nutrition and warmth. This could perhaps be true in some very favorable environments. However, in reality a number of aggravating factors, such as a harsh disease environment or natural environment, mean that additional resources, such as care or protection, are needed for the population to survive. For example, a high “normal” mortality mean that even a small cut-back in nutrition could push up the mortality to unsustainable levels. The aggravating factors might be so unfavorable so that survival is only possible at a very high level of consumption.

## 4.3 The difficulty to plan for unforeseen economic chocks

The physical minimum line presumes that all households consume an idealized and fixed theoretical basket, and nothing else. This, as Banerjee and Dufflo argue, require that the household manage to plan their consumption perfectly and manage to prioritize away *all* other needs, including things such as buying medicines for a sick relative. There would be no room for any unexpected complications, such as a delayed wage or a sudden price increase. Furthermore, the individual need to have knowledge of prices, nutritional content and such thing, as well as the necessary resources to make use of this information. Indeed, studies by Collins etal (2009), suggest that the income of the poor is not only low, but alse volatile and unpredictable.[22]

Very few people can be expected to actually turn consumption at the physical minimum into the expected amount of calories, proteins and heating. This is consistent with what we saw in previous sections, i.e. that persons that presumably consume more than the physical minimum nevertheless fail to get sufficient food, at least occasionally. Of course, if an individual's average income are high, well above the physical minimum, then only a long string of unfortunate events can leave him unable to get enough food. A poorer person would only need the tiniest of incident or planning failures to end up without enough food, and this are likely to happen often enough for under-nutrition to occur. At the physical minimum the consumption planning would turn from being extremely difficult to being impossible, and no one would succeed even with the best of luck.

## 4.4 Mortality that is not related to nutrition or warmth

There are obviously many other ways, other than starvation, by which a low income can raise the mortality. Poor sanitation, crowding and the collapse of the order are just a few.

## 4.5 Inequality

The physical minimum line for a population are based on the assumption that there are no inequalities. However, all known societies have at least some inequalities, even including hunter-gatherer societies (Smith etal, 2010). It is possible that there are practical limits on how equal a society can become, and we would need to take that into account.

Hence, we should perhaps assume a "lowest attainable inequality" and set our line on such a level so that a sufficient *share* of the population consume enough to survive.[23] In the most simple model, where insufficient nutrition and warmth is the only source of mortality, the population could reproduce even if a share of the population dip below the physical minimum, as long as the fertility is able to fill the gap.

## 4.6 Effect of population on income

So far we assumed that populations that lives below subsistence simply die out. However, before it goes that far there other things can happen that push the consumption back up again. A shrinking population could mean improved factor ratios, e.g. more land per farmer, which, in turn, could help to pull up the consumption again. Obviously, this requires that there is scope

[22] In addition, research by Mullainathan & Shafir (2013) suggest that the lack of "slack" encountered by the poorest make the *psychological process* of planning more difficult. The stress inherent in the situation simply constrain capacity to look beyond the immediate needs.

[23] Note that we still assume that everyone in the population has the same physical requirements. What we assume is that the distribution "must" be unequal to a certain degree. Hence, we must allow the average consumption to be higher to make sure that a sufficient share of the population is above the physical minimum.

for such improvements. If population densities were low to start with, or if increased abundance of land does not push up incomes, then this effect would be absent.

## 4.7 Migration and fertility

So far we assumed that a too low consumption raises the *mortality*. However, a low consumption can also affect both fertility and migration, which would, in turn affect the population growth.

## 4.8 Relative poverty

Milanovic suggested that the subsistence line should be higher in richer countries. Are there any mechanisms that could motivate such a pattern? Milanovic does not elaborate on what underlying mechanisms he has in mind, but we could think of a couple of arguments for the subsistence line might be moving up when incomes are higher.

Banerjee and Dufflo (2011, page 37) suggest that the availability of new goods can decrease the spending on nutrition. This should not be seen as the poor "choosing" to be less nourished. Rather increased options would make the task of perfect planning and prioritization even harder. The new competing goods could very well be considered as representing very central functionalities. For example, Krishna (2010) document how medical spending, for oneself or for relatives, are a common route into poverty. Much of this medical spending was not available in the past. So when new medical services and goods became available this might very well have increased the spending pressure at a given level of poverty.

## 4.9 Summary

All these mechanisms are obviously very speculative. So while we argue that the minimum consumption line is higher than the physical minimum line, it is clear that much remains to clarify in terms of exactly how much higher it is, and what the underlying mechanisms are that explain this supposed difference.

Whatever we believe the minimum consumption line to be, the physical minimum should be a major component in any such line. Hence, since we argue that the physical minimum line varies according to a number of factors it seems reasonable that the minimum consumption line varies, to some extent at least, according to the same factors.

We could simply assume that the subsistence line is proportional to the physical minimum line, i.e. equal to the physical minimum line multiplied by a fixed mark-up. We do not know what that mark-up should be, or if there are any determinants of this mark-up we could add. This is ultimately an empirical question that, as far as we can see, is not yet solved. However, a minimum consumption line surely has some relation to the physical minimum line. That gives us another reason to examine the determinants of the physical minimum, something we will do in the coming sections.

# 5. Composition of the minimum physical requirements

In this section we will discuss *which* food and non-food items we need to survive. We begin with the non-food items. A good starting point is the barebones basket of Allen. However, this basket is primarily constructed to be a bench-mark for comparing living-standards, rather than to represent a physical minimum, so it needs some modifications to fit our purposes.

The barebones basket is directly based on the cost of a specific list of non-food items. In contrast, the authors who calculate the national poverty lines use an indirect method: First, they calculate a food poverty line. Then they look at the households whose *total* expenditure matches this food poverty line and see how much these households spend on non-food items. They assume that this non-food consumption represent the absolute minimum non-food consumption. The total poverty line is the sum of this non-food consumption and the *total* food poverty line.

Hence, the non-food consumption in the national poverty line is typically expressed as a mark-up on the food-poverty-line, without specifying exactly which non-food items are included in this consumption. It is accordingly hard for us to judge to what extent this non-food consumption represent what is needed for survival. The barebones basket, on the other hand, include a specified amount of six non-food items, as given in table 1 above. The best would be to use the same approach for the physical minimum line, i.e. construct a set list of non-food items that we think are necessary for survival. Unfortunately we lack the necessary data to do that, so we have to rely on a fixed mark-up based on the costs given in table 1.

So, let us now look at the specific non-food items in the barebones basket and see if we need to add or subtract something. First, we would argue that a couple of things ought to be added to the basket. Water is not always for free, so it should in principle be included. However, we rarely have any information about the cost of water, so we have to leave that out. The equipment and heat required for cooking should probably be included as well. We will argue below that food generally requires some basic processing, but the food items included in the basket are unprocessed. Hence we should try to account for the basic requirement of food processing.

Soap and lighting, on the other hand, could probably be left out from the basket. Both items satisfy very basic needs, and soap is important for health. However, survival would be possible even for persons that lack these basic items. With these initial remarks we can move on to discuss the remaining items in some detail.

## 5.1 Fire and clothing for warmth

The human body needs a certain temperature to survive. To keep warm we typically use a combination of clothing, housing and heating. In a sufficiently warm climate none of these are, in principle, needed. On the other hand, all known population use fire (Wrangham & Conklin-Brittain, 2002), although some might use it for cooking purposes only.

However, some groups have lived without heating from a fire, even in temperatures below zero, but that would require sufficient clothing and other isolation. In most climates some basic form of clothing would be a minimum necessity for survival.

The barebones basket supply three meters “unprocessed” cloth per year. It is difficult to judge how much “clothing consumption” this corresponds to. The clothing from this cloth could probably last for many years, but we need to factor in at least some processing. It is hard to know if it would be enough to survive with this in a cold climate without any other source of warmth, or whether it would be possible to survive on even less. We assume that three meters is about what is needed in a cold climate. In a warmer climate much less would be needed, and in some rare cases we could dispense it altogether.

## 5.2 Housing

The cost for housing is the only consumption item that is not directly priced in the barebones basket. Instead it is assumed to equal 5% of all the other consumption.[24] It is hard to know what type of dwelling this corresponds to. The barebones basket is based on working class Europeans at the time of the industrial revolution so we would guess that the housing item corresponds to some kind of fixed structure, although a relative small and primitive one.

Some populations consume little, or no, housing. In warmer climates some mobile hunter and gatherers have no dwellings at all, except perhaps a simple windshield, e.g. the Batek in Malaysia (Endicott, 1999). Some extremely poor people live in very basic shacks, quickly set up by left-overs etc. Even in colder climates some groups survive in quite simple dwellings, such as the tents used by pre-industrial nomads. In addition, there was an estimated 100 million homeless in the world in 2005 (Kothari, 2005), of which many lived in colder climates. Hence, the most conservative physical minimum excludes housing altogether.

## 5.3 Fire for cooking

Wrangham & Conklin-Brittain (2002) and Carmody & Wrangham (2009) cite several reasons for why cooking is essential for human survival. For example, cooking break down molecules so that the energy is more accessible for absorption. This is especially important for cereals since they are rich in starch that the human digestion system is bad in breaking down. Some foods, such as meat or nuts, should be easier to digest raw, but these are rarely a cheap source of calories.

All known populations, including all known hunter and gatherers, cook food (Wrangham & Conklin-Brittain). The notable exception to this universal pattern is the modern "rawfoodists", of which some supposedly have lived on raw food for three years or more. They do show signs of malnutrition, even if they had constant access to the full range of food available in a high income society. This made Wrangham & Conklin-Brittain conclude that it would be unrealistic to survive on a pure raw food diet under more primitive conditions. On the other hand, the raw-foodists were, after all, alive, so the possibility of surviving without cooking cannot entirely be ruled out.

Be as it may, in almost all relevant situations it seems safe to assume that at least some minimum of food preparation is required. We did a very crude attempt to estimate the wood energy required (including heat losses) to boil 460 gram of oats into porridge (see Annex B for details). This works out to be about 3100 kilojoules, i.e. about half the daily allowance in the barebones basket.

[24] This implicitly assumes that the relative price of housing is the same across time and place.

## 5.4 Food items

The four food items of the barebones basket are intended to supply sufficient calories and proteins for bare survival, as well as providing some minimal variation. We will use the food content of the barebones basket as our baseline assumption for food. However, it is quite possible that this composition will be insufficient in several other nutrients. On the other hand, it is not clear to what extent such shortcomings imply a *certain* death.

We will return to these issues further on, so here it is sufficient to say that we also will consider other more complex food baskets, as well as the simplest possible basket in which all calories are supplied by the cheapest staple.

## 5.5 Summary

We have argued that there are a couple of non-food items that are likely to be necessary for survival, even in the most restricted interpretation. These items are some heating for cooking, some other basic cooking equipment and some basic clothing (at least in most climates). Hence, the main basket we consider contain the food content of the barebones basket, plus a minimal addition for cooking and clothing. We call this the *minimalistic barebones basket*. We assume a slightly more expensive basket for cold climates since the need for clothing is larger. We will also consider the full barebones basket and briefly discuss a few more complex baskets. Finally, to get a lower bound for the physical minimum we also consider a basket that only contain food.

*Table 3. Assumptions for the composition of requirements.*

| Description | Assumptions | Markup |
|---|---|---|
| The full barebones basket | As specified above | 1.28 |
| A minimalistic barebones basket for cold climates | This would include enough clothing to maintain warmth, and enough fuel to boil the staple for a household once a day. Housing, and all the other items, would be set to zero. If we arbitrarily assume that this require all the clothing and half the fuel of the barebones basket, and use the prices implied by table 1, we get a basket that is about 11% higher than the food-only basket. If we add some minor margin for cooking, we could assume a mark-up of 15%.[25] | 1.15 |
| A minimalistic barebones basket for very favorable climates | This would only include the fuel for cooking. If we use the prices implied by table 1 this cost about 5% more than the food-only basket.[26] With some margins we could set this to 10% (i.e. not much different from the cold climate case). | 1.10 |
| The "food only" basket, including the four food items of the barebones basket. | This corresponds to an implausible situation where there is a cheap staple that can be eaten raw, without losing any of the nutritional content. However, it is a useful point of reference, since case (2) and (3) should be somewhere between case (1) and (4) and we often lack the necessary data to calculate case (2) & (3). | 1.00 |

[25] England prices: (19*0,5 + 30)*0,21 / 79 = 10,5%. US prices: (47*0,5 + 14) * 0,22 /78 = 10,6%

[26] England prices: (19*0,5)*0,21 / 79 = 2,5%. US prices: (47*0,5) * 0,22 /78 = 6,6%

The price dataset we look at unfortunately lack non-food items, although some other studies we refer to have calculated baskets that utilize prices for non-food items. Hence, we can only calculate the cost of the food items of the barebones basket. For the other baskets we have to assume a constant add-up based on the non-food cost we have from table 1 above. The relative costs in 19th century England and contemporary US is actually quite close. We use the English prices. All our assumptions, and the markups we use, are summarized in table 3 above.

# 6. Energy requirements

The barebones basket match an energy requirement of 2100 calories per day, a level that reflects the heights, BMI, age composition and physical activity level of the English working class in the 19th century. These underlying factors could of course be quite different in other contexts, which, in turn, would imply quite different levels of energy requirements. In this section we discuss the range of likely values for each of these four underlying factors. Once we have established these ranges we will move on and see what levels of energy requirements this imply.

There are a number of additional factors that can affect the BMR. For example, pregnancy increases a woman's recommended caloric need by 211 calories per day on a yearly basis. Other factors that can increase the energy requirements includes being sick, being too cold, being too warm or living at high altitudes. We will not take these additional factors into account in our scenarios, but focus on the four main factors we mentioned. The first underlying factor we discuss is heights.

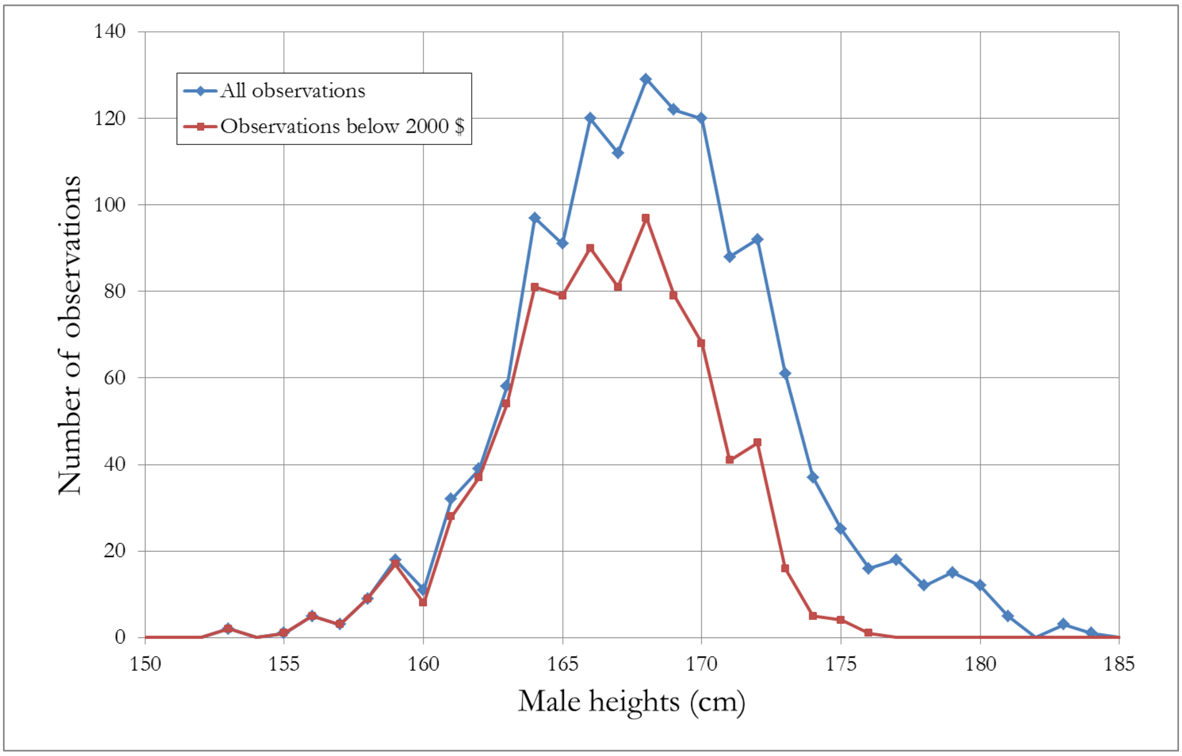
## 6.1 Heights

Allen assumed an average adult male height of 166 cm which is based on the situation in England in 1866. But what is the range of heights have been observed throughout history? Baten & Blum (2012) offer (unbalanced) panel data of adult male heights for 154 countries from 1810 to 2000. The observations range from 152.4 cm (Papua New Guinea in 1880) to 183.2 cm (Denmark in 1980).

Heights are, at least to some extent, a function of the past living standard of the population. Hence, a very tall population is unlikely in a population that lives close to the subsistence line. We accordingly restrict the height observations to county-years for which the GDP per capita is below 2000 international $ per year. The observations in this restricted sample is now 152.4 cm to 175.3 cm. [27] The average is 166.0 cm so Allen's assumption is spot-on for a low-income population. We have plotted a histogram of all the observations and all the low income observations in the figure below, although we should remember that it is based on an unbalanced panel.

[27] The height observation concerns Estonia in 1900. The low-income status of the observation is not entirely certain, given the very low quality of the GDP data. However, there are several height observations from West Africa that are close to 175 cm. In these cases the low income status is certain.

*Figure 3. Distribution of male heights across populations.*




*Notes: based on the comprehensive dataset from Baten & Blum (2012). Average adult heights, by birth decade and country. Low income status based on GDP per capita data from Gapminder (Lindgren 2014) in 2005 international $.*

Even shorter sub-populations exist. The shortest on record is the "Eastern Pygmy" with an adult male height of only 144 cm, and a female adult height of 136 cm. Several other small sub-populations exist that are almost as short (Walker etal, 2006). All these populations are small, and represent quite special circumstances, but their existence motivate us to set our minimum height value below 155 cm. There probably also exist some low-income populations that are slightly taller than 175.3 cm. Hence, we will assume that low-income populations can range in male heights from 150 to 180 cm.

We have not found any similar dataset for female heights. However, Baten (2006) offer the following formula, based on country-years with both male and female heights (expressed in cm):

(1) Male heights = 24.9879 + 0.9175 female heights

We will assume that female heights relate to male heights in accordance with the formula above.

## 6.2 Weight for height – how thin can we be?

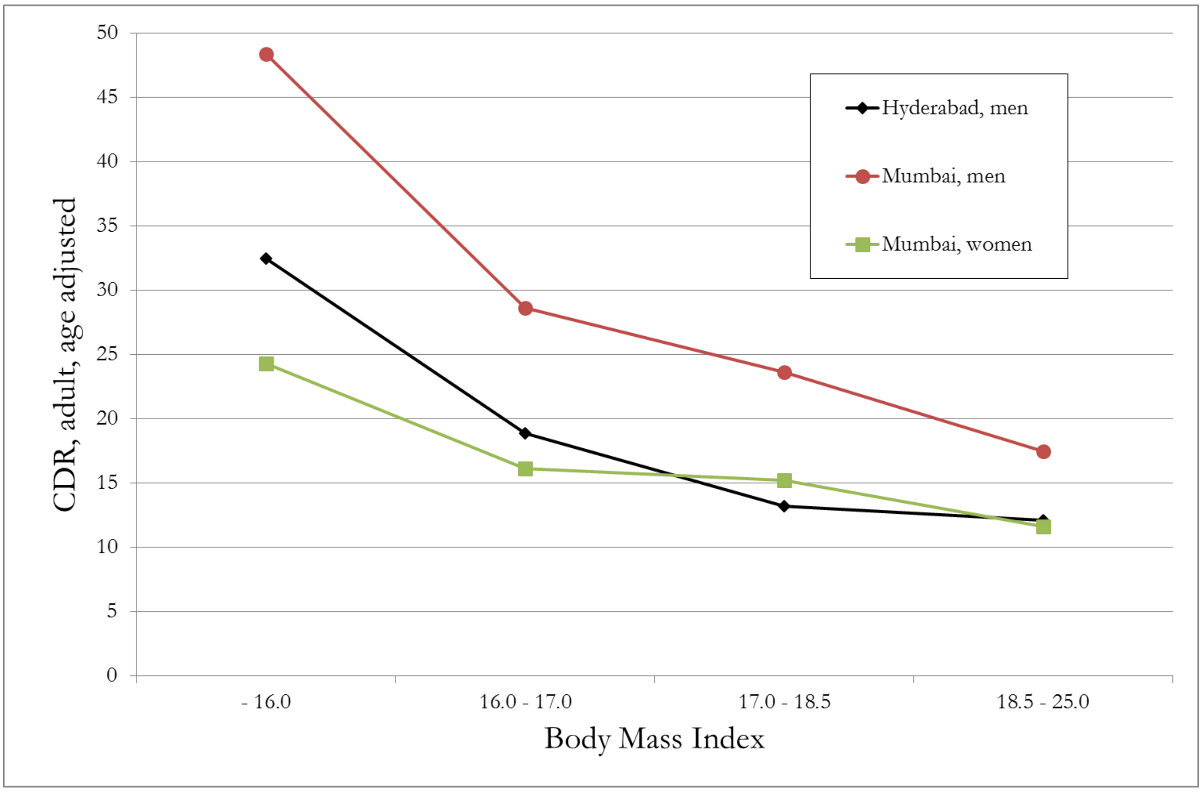
When the energy intake is insufficient the body will burn body mass, and cause the weight, and hence the BMI, to drop. A lower BMI implies a reduced energy need, and a new equilibrium between intake and expenditure can be reached at a lower level of energy consumption. Hence, losing weight is a way for the body to "adjust" to insufficient consumption.[28]

There are obvious physical limitations on how far BMI can fall, and, accordingly, on how low the energy equilibrium can be. But what are the lower limits to BMI, and hence to the energy savings? A person is usually defined as being under-nourished when his BMI is below 18.5. However, people have survived with a substantially lower BMI, and, hence, with a lower energy equilibrium.

A number of studies have looked at the link between BMI and mortality. As Kurpad etal point out, the *causal* link between a low BMI and mortality should be treated with great caution. For example, illness might both increase the mortality risk and lead to weight-loss. However, this is less of a problem if we just want to show that survival is *possible* at a certain BMI level.

In a quick review we found two studies that both measured crude death rates for adults by BMI, and also included data for BMI<16. One study is for adult men in Hyderabad in India (from a study cited in Shetty & James, 1994), but no further details are given in our reference. The second study is for men and women in Mumbai (Pednekar etal, 2008). It is based on data on more than 148.000 adults aged over 35 years. The age-adjusted CDRs are presented in the figure below. The Mumbai males have the highest relative risk for extreme under-nutrition, as measured by the CDR for BMI<16 divided by the CDR for BMI > 18.5. Other studies only provide relative risks, and they all display lower relative risks than the Mumbai men (Rotimi etal, 1999 for Nigeria, and Sauvaget etal, 2008 for Trivandrum, India).

*Figure 4. Adult crude death rates by BMI category. Sources: see text.*




[28] It was earlier believed that under-nutrition could "stimulate" an improved metabolic efficiency, i.e. the energy consumption per body mass is lowered. However, later evidence has put this into question, at least for CED (Henry 2005)

Can a population reproduce itself if it has the CDRs displayed by the BMI <16 categories? The available information does not allow us to do any proper assessment of that. However, we did a rough attempt to see what fertility rate (TFR) we need for the population to have a zero growth, given the CDRs. This is based on a number of bold assumptions, but we choose conservative assumptions that would tend to overestimate the required TFR.

We assumed the CDRs represent the average death rates between the age of 20 and 40 years. This overestimate the mortality since the Mumbai data was based on those aged 35 or older, i.e. an age group that is likely to display a higher mortality than the 20 to 40 year olds. The CDR in Mumbai is below 10 per 1000 for the normal-weight group.

This mortality risk was matched to a model life table (we used the model "UN general, female", as extended by the World Population prospects 2010A, with additional interpolations by the author). The chosen mortality level in the life table is then used to find the survival rate to age 25 (which is assumed to be mean age of child bearing). The reverse of this rate, times two, is assumed to be the TFR needed for a constant population.[29]

The required TFR was 4.6 children per women for the CDR of Mumbai women (with BMI<16), 6.0 children for the CDR of Hyderabad men, and 11.7 for the CDR of Mumbai men. The first two estimates are TFR levels that have been observed. Hence, a BMI below 16 does not have to mean that a population will diminish (assuming that the BMI does not also affect the fertility). The figure also illustrate that the effect of a low BMI depends on the situation, so it is quite possible that a more modest drop in BMI in some context is sufficient to turn population growth below zero.

We do not know what happen to the mortality rates below the open-ended BMI<16 category, but it is possible that the mortality rates accelerate below this level. To find the extreme physical limits of survival we must turn to smaller scale studies of extreme situations, such as famines and sufferers of anorexia.

From studies of anorectics and others Henry (2001) concludes that there is a quite apparent cut-off in the survival chances for males at a BMI of 13. Women seem to be able to survive even lower levels, although there was no clear cut-off level for them. Henry points out, though, that anorexia patients are hardly equivalent with CED sufferers.

However, Collins (1995) observed BMIs as low as 10.1 during a famine in Somalia.[30] 65% of those with BMI below 11 survived. Collins speculates that previous experiences in CED and the warm climate contributed to the survival. High stature was probably not an explanation. In an emergency in South Sudan Irena etal (2013) observed BMIs as low as 8, but in this case the tallness of the population was a likely contributing factor. However, in neither of the cases have we observed persons living like this for sustained periods of time, so this hardly represent a situation we should expect for a population over any sustained period.

So far we just discussed the risk of death, but for a population to survive they need to be able to work. The patients in the emergency centers above were definitely not in good shape, many were unable to stand up unaided. Any productive work at these exceptionally low BMIs can certainly be ruled out.

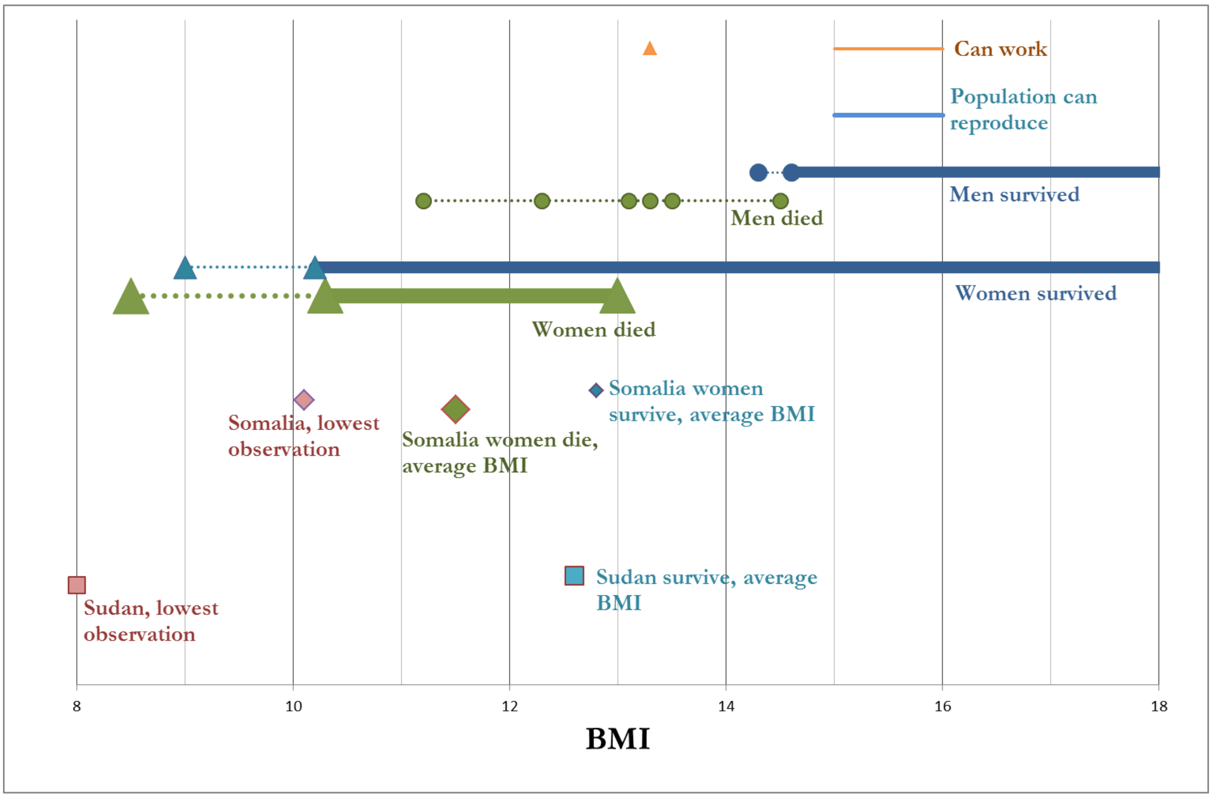
[29] Livi-Bacci (2007), figure 1.8, display a model that relate TFRs to Life expectancy at zero growth. His TFRs are lower for a given life expectancy than what our model imply. This also indicates that our TFRs probably are on the high side.
[30] The famine occurred in 1992. They documented 573 patients in an emergency center.

Anorectics with extremely low BMI can be hyperactive and appear well. However, they are often prone to infections and other health problems and it seems unlikely that they could perform heavy tasks required for food production in a low-income setting (Shetty & James, 1994).

Payne & Lipton (1994) refer to a study in which poor Indian adult male workers with BMI between 15 and 16 were able to work and did well on physiological tests. BMI close to 13 was observed in a group of free-living females from south India. “It was claimed that they were physically active and carrying out their normal daily chores” (cited in Shetty & James, 1994).

Durnin (1992) suggested that there would, in most cases be no effect on physical capability until BMI drop below at least 17. However, he pointed out, the effect of low BMI depends on the type of task. A task that includes heavy lifting is more affected by a low BMI than other physical tasks. All the information discussed so far has been summarized in figure 5 (inspired by Henry 2001).

*Figure 5. Outcomes at different BMI levels.*




*Notes: The figure show observations of persons who have either survived (blue) or died (green) with a given BMI, or simply the lowest observed level. The observations concern the men and women summarized by Henry, or the ones observed in emergency condition in Somalia or South Sudan. The thick line indicates that there were several observations, and the dotted line indicates that the markers we see are the only observations. The orange triangle is the south Indian women who allegedly managed to work. The orange line is the Indian workers who were able to work and perform well on physical tests.*

So far we discussed the possibility of survival with a low BMI, and the potential for work, but how common is a very low BMI in the available data? Bangladeshi women had the lowest national average BMI we observed since 1980: in 1980 they had an average BMI of 18.5.[31] In the available data women in India in the 1970s displayed the highest share of extreme-low BMI (Naidu & Rao, 1992; WHO, 2013): 27% had a BMI below 17; 12.7% had a BMI below 16; 4.7% had a BMI of 14 or lower and 1.4% had a BMI of 13.

How many die *directly* from under-nutrition in India?[32] IHME (2013) estimates that the death rate directly attributed to "protein-energy malnutrition" was about 8.5 per 100 000 for women, aged 15-49 years, in India in 2005. In the same year about 15.8% of Indian women had a BMI < 17 (WHO 2013). It is not entirely clear what this implies for the deadliness of under-nutrition since the exact definition of protein-malnutrition mortality is not clearly stated.

However, in a protocol for verbal autopsy for child morality (Baqui etal, 1998) the requirement for the diagnosis are (a) failed to diagnose a number of specific causes of death (b) child was "very thin when the final illness started" or "feet swollen". This could mean that the dead in this category had exceptionally low BMI, but it could just as well mean that the very thin failed to catch one of the specified diseases.

We have so far only focused on *adult* mortality, although most of the literature focuses on *child* mortality. Our focus on the adults is motived by the fact that the adult consumes a high share of the nutrition, so their energy requirements should have a large impact on the total energy requirements. However, that focus indirectly assumes that a drop in energy intake is disproportionally born by the adult, something that is not certain.

Children (infants excluded) are much affected by under-nutrition. Svedberg (2002) noted that "(y)oung children with only about 60-70 per cent of the norm weight have been estimated to face a mortality risk that is five to six times the average in African and South Asian child populations, which means that the risk approaches unity."

So where does all this leave us? A BMI of about 15 seem extreme but possible: we have observed non-famine populations with this BMI, for which some work seem possible, and for which mortality is below "unsustainable" levels. A BMI of 10 is the extreme bottom that we only can expect to see during extreme famines, and not over any extended period. Hence we could argue that whatever the correct cut-off for BMI is, it must be significantly higher than 10.

## 6.3 Age and gender

The BMR vary with age and gender not only because of differences in body size, but also because of, for example, body composition and the energy need of growing. Hence, FAO (2001) offers 12 different equations to calculate the Basal Metabolic Rate, one for each gender and age-group. This mean that the BMR per kg varies by age-group and gender. Other publications that offer alternative equations offer, in a similar way, a set of equations.

If we would like to calculate an average BMR for a population with these equations we need to do separate calculations for each gender and age-group, and then weigh these BMRs together according to the relative size of each group. However, a crude short-cut is to use so-called equivalence scales. Equivalence scales give us a factor that can help us transfer the caloric need

[31] Data from The Global Burden of Metabolic Risk Factors of Chronic Diseases Collaborating Group
[32] Most deaths from under-nutrition are *indirect*.

of a reference group, say males aged between 18 and 30, to that of some other group. If we assume a BMR for men between 18 and 30 we can then multiply this BMR with a group-specific factor to get the BMR of any of the other groups. This calculation is based on the assumption that any changes in heights, BMI and so forth affect all gender and age-groups proportionally, which is certainly a serious simplification.

The group-specific adjustment factors for each gender and age-group can be combined to calculate an adjustment factor for a population. To do this we calculate an average of all gender and age-specific factors, weighted by each groups share in the population. The result is a population-specific adjustment factor. If we multiply the assumed BMR of our reference group with this factor we get the average BMR of the population.[33] Hence, the age-composition of a population imply a population-specific adjustment factor.

What is the range of possible values for this adjustment factor? In order to examine that, we calculate population-specific adjustment factors for all populations for which we have age-composition data, and see what range of values we actually observe. Our reference group will be "adults", i.e. a group that consist of 50% men and 50% women, all aged between 20 and 39 years. "Adult men" are often used as a reference group, but when we later calculate the BMR we will do so for *adults*.

To get a set of age adjustment factors we need as much data on population composition as possible. Luckily the World Population Prospects (2010B) supply age-distribution data for 196 countries for each five-year period after 1950. [34] We combine this with gender and age-specific adjustment factors for each relevant age group taken from Floud etal (2011), which we recalculated so that the reference group is *adults* and not *adult males*. [35]

*Table 4. The BMR adjustment factor, in percent of adult BMR*

| **Population composition** | **BMR, percent of adult BMR** |
|---|---|
| Children under five | 51% |
| The household used in the barebones basket | 81% |
| The lowest ”observed” factor for a population (Grenada, 1960) | 84% |
| Our ”baseline” assumption | 87% |
| France in 1806 | 89% |
| The highest ”observed” factor for a population (Qatar, 2010) | 95% |
| Adults aged 20 to 39 years (reference group) | 100% |
| Males aged 15-19 | 117% |

So what range of adjustment factors do we get in actual populations? We have summed up a number of adjustment factors, both for age-groups and for populations, in table 4. We start by noting the theoretical boundaries. The lowest *group-specific* adjustment factor, 51%, is for

[33] This procedure is often used when calculating poverty rates. However, it is typically done in "the other direction", i.e. to transform the average consumption of a household to consumption per adult equivalent.
[34] This gives us an adjustment ratio for 196 countries for 13 five-year periods. If we include the projections we get eight additional five-year periods. Doing that changes nothing.
[35] Floud etal (2011), table 2.2, which cited a FAO/WHO publication from 1971. Appleton etal provide a breakdown for individual years for the first five years (they cite a WHO publication from 1985). The equivalence scale has since been revised, but the differences do not seem to be too large

children under five, i.e. a population that is entirely made up of children would have about half the BMR compared to a population that is entirely made up of adults. The highest group-specific factor is for men aged 15 to 19, which has an expected BMR that is 117% of the reference group. Hence, any population adjustment factor must be somewhere well within 51% and 117%.

The range of values based on observed population distributions are actually quite narrow, from 84% (for Grenada in 1960) to 95% (for Qatar in 2010). Neither of these observations are extreme outliers. We do not know whether we could find any lower values before 1950, but we suspect that this is not the case given that the highest population growth rates we know of occurred in the 1960s (a high population growth implies a young population). Furthermore, all historical data we found points in the same direction. The adjustment factor for France in 1806 offered by Floud etal (2011) imply a higher factor than the Grenada value above. Historical values for England also show similar values (Allen, 2013A). We also checked the age composition for Sweden from 1750 and on (with data from the Human Mortality Database, 2013). At no time during this period did Sweden have a population as "young" as Grenada in 1960.

Allen implicitly assumes an adjustment factor of 81% when he calculates the energy need for the barebones basket. This adjustment factor is below the 84% for Grenada. However, his factor is used to calculate the average for a *household* of two adults and two children. We, on the other hand, are trying to calculate the average for a *population*. The age distribution of a population is unlikely to display the same age structure as the typical household of the barebones basket.

The available data only allowed us to use quite broad age categories, due to the available data. To get some sense whether this have a large effect we can compare our results with Appleton etal. They calculate an equivalence factor with finer age categories (and their age distribution is taken directly from their survey). They get an adjustment factor that is slightly higher than we get if we apply our model, so this strengthen the case for using 0.84 to 0.95 as a maximum range for plausible values.

We have no idea how these equivalence factors behave under more extreme circumstances, e.g. when the population is undernourished. FAO (2001) suggests that BMR is lower amongst the older partly because of composition changes (e.g. a reduction in FFM). Hence, if BMI was generally low then, it could be argued, the BMR of older would not be lower, since there would be little "excess mass" that could change its composition. However, they also cite studies that found a 5% reduction in BMR amongst older persons, even after controlling for FFM.

With all of this in mind we decide to consider 84% to 95% as a reasonable range of age adjustment factors. We will also consider a baseline assumption somewhere in the middle. We choose, quite arbitrarily, 87% as our baseline assumption. The reason for this choice is simply that 87%, together with all our other baseline assumptions, yield a total energy requirement of 2100 calories, i.e. the same as in the barebones basket. [36]

[36] If we use all the assumptions made in the barebones basket, i.e. including an age adjustment for 81%, we get an energy requirement below 2100 calories. The reason for this discrepancy is probably that we use a different set of energy equations than Allen, for reasons that will be explained later.

## 6.4 Physical activity

So far we have discussed the main factors behind the BMR, but to get the total energy expenditure we need to multiply the BMR with a factor that depends on the level of physical activity. This factor is referred to as the physical activity ratio (PAR). The FAO (2001) offers estimates PARs for a range of specific activities. They range from 1 for sleeping and 1.2 for sitting to 9.654 for "loading a 16 kg sack on a truck".

If we take the average of the physical activity ratios during a longer period we get the Physical Activity Level, PAL. If we multiply the BMR with the PAL we get the energy requirement of the individual. We can estimate a PAL by adding up the PAR for every activity, weighted by the average time spent on each activity. So, to take an unrealistic example, an individual that sleeps 8 hours per day, and sits 16 hours, would have a PAL of (8/24)*1+(16/24)*1.2=1.13.

Allen assumed an average adult PAL of 1.95 (2.16 for adult men and 1.74 for adult women). This figure is based on a set of specific assumption about working class condition in 19$^{th}$ century England. In this section we will discuss what the range of values this figure could be expected to have in a low income setting.

Several factors should be kept in mind. First, the physical activities required for production will vary with the type of economy, even across low-income economies. Second, there is evidence that extreme poverty will push people to save on their physical activities, so that PAL will be somewhat lower than normally assumed. Thirdly, the discussion tends to focus on the PAL of adults, but we need to consider all age groups if we want to get the average energy need for a population. Fourthly, PAL will vary substantially across individuals in a population.

We will briefly discuss the assumptions normally made for PAL, and in what ways extreme poverty might push down the PAL. However, we know too little to assign hypothetical activities and PARs to estimate a range of PALs. Instead we briefly review the range of PALs actually observed in low-income settings. Finally, we discuss how the PAL varies with age.

So what are the ranges of PALs that are normally used? Many studies, such as Allen's, assume a set of typical individual activities, and use the PARs to estimate a PAL. However, as a shortcut, FAO offers PAL ranges for thee default life-styles. These are displayed in the three last rows in table 5 below.

Allen's assumption of a PAL of 1.99 is accordingly in the in the upper range of the "active-lifestyle" category. However, even across low-income economies we would expect a variation in the physical requirements of work, e.g. some settings might require very little land preparation and food processing, whereas other might require very heavy digging and cutting, as well as a lot of food preparation.

Low-income economies, which are the focus of our attention, are normally dominated by various sort of manual labor, so the "light-lifestyle" category seem unrealistic in this setting. Indeed, Floud et al argued that a low-income population with a PAL of 1.66 would have to be inactive during 2/3 of the day. A preliminary guess, then, would be that PAL values vary between 1.70 and 2.40.

*Table 5. Cut-off values for Physical Activity Levels.*

| **Lifestyle** | **PAL value** |
|---|---|
| FAO suggestion as a mean for short-term survival of a totally inactive population | 1.21 |
| Floud etal use this as a lowest base-line, which is enough for eating, digesting and the essential hygiene, But it does not allow for cooking, working etc. This was the lowest baseline energy requirement in an earlier FAO-report. | 1.27 |
| Lowest value suggested as possible to sustain for long periods in free-living adults. This is also the lowest recommended cut-off to use in short term emergencies. | 1.40 |
| Light-lifestyle (FAO) For example, a rural woman that works with selling things or doing light housework, and that have access to piped water, electricity and roads. | 1.40-1.69 |
| Active-lifestyle (FAO). Examples include a mason, a construction worker or a rural woman who participates in the work in the field, or who has to walk long distances to fetch water. | 1.70-1.99 |
| Vigorous-lifestyle (FAO). Examples include, farm worker who work with hand tools to dig or cut down things, or a person who has to walk with loads in rugged terrains. | 2.00-2.40 |

*Sources: based on FAO (2001) & Floud etal (2011)*

However, we could argue for a minimum value below 1.70 for a number of reasons. First, there is, as already pointed out, evidence that the extremely poor find ways to save on their physical activities. Secondly, there are, indeed, some PAL-observations that are lower than what we would have expected from the recommendations above. Furthermore, when FAO calculates a cut-off value for under-nutrition they assume a PAL of 1.55 for men and 1.56 for women. Even though the context for these assumptions differs a bit from ours, they do indicate that assumptions below 1.70 could be plausible.

Let us begin with discussing the various ways by which poor people could economize on their physical activities. Both adults and children decrease their physical effort when malnourished according to Lipton & Payne (1994).[37]

There are several ways to save on physical efforts: First, the poor might limit or avoid all non-necessary physical activities; secondly, they might find ways to economize the energy in the remaining physical activities; thirdly, they might lower their PAL through their low weight; and, fourthly, they might reduce their work.

The first way to reduce the PAL is to reduce non-work activities, e.g. social activities. This would not affect production. Studies cited by Gray (1995) and Shetty (2005) give examples of this. For example, rural Guatemalan workers did their normal work, but in their spare time they were almost completely inactive. Children can reduce their activity at play (Lipton & Payne). Kurpad etal cite studies of Indian and Ethiopian women with unexpectedly low PAL. Their

[37] However, according to Norgan & Ferro-Luzzi (1996) it is not clear that physical activity is lower on average in areas with a higher degree of undernourishment. This does not have to contradict the notion that some severely undernourished persons reduce their effort.

spare-time activities were very limited. Norgan & Ferro-Luzzi, however, maintains that evidence of reduced spare-time activities remains largely anecdotal.

Minor activities unrelated to work, such as fidgeting, can consume energy corresponding to as much as 30% of BMR and 10% of total energy expenditure. Undernourished persons seem to avoid such "unnecessary" movements, perhaps unconsciously (Kurpad etal and Norgan & Ferro-Luzzi).

The second way to reduce the PAL is to do specific work activities in a more "energy efficient" way. This would also, in principle, leave the production intact. For example, a person might sit and work whenever that is possible. The Indian and Ethiopian women discussed by Kurpad etal above did precisely that. A person that does a task slower reduces the total energy expended, and there is indeed evidence that small persons work slower (Shetty 2005 & Lipton & Payne, 1994). The rural Guatemalan workers mentioned above took a longer time to complete their tasks and they walked home very slowly. Lighter persons in a study had a lower PAL than heavier persons, for the same tasks (Kurpad etal).

It has been suggested that undernourishment can push a person to somehow do the same task (such as walking or carrying things) in a more energy efficient way. Norgan & Ferro-Luzzi (1996) cite some evidence for such an improved mechanical efficiency, but argues that the evidence remains inconclusive.

The third way to reduce the PAL is simply to work less which would correspond to assuming a lighter life-style category. However, this would obviously reduce production, so this is really not an option for a whole population, if we believe that their incomes were at subsistence already with a normal PAL.[38]

Now that we have pointed out some reasons for why the PAL could be lower than we initially assumed, we can move on and review the PALs we actually have observed in low-income settings.[39] Can we find examples of average PAL below the 1.95 figure used by Allen? Many PAL values from low-income countries are in fact higher than the ones used by Allen. For example, male Gambian farm-workers had a PAL of 2.4 while working (Kurpad etal 2005) and Hadza hunter-gatherers had, on average, a PAL of 2.26 for the men and 1.78 for the women (Pontzer etal, 2012). On the other hand, the average PAL in a number of low income settings was estimated to be 1.8 (Norgan & Ferro-Luzzi), i.e. slightly lower than the Allen assumptions.

Several individual studies find PAL values below 1.70. Borgonha etal (2000) estimated the PAL of six male Indian slum-dwellers, with chronic energy deficiency (their average BMI was 17.0). Their average PAL was only1.54, despite the fact that they were manual laborers.[40] Kurpad etal suggest that the low PAL could be due to long rest periods during work, or a low level of activity during spare time, including less fidgeting.

A study cited in Shetty & James (1994) found that PAL was below 1.40 among both Indian and Ethiopian women. The women performed manual work up to 4.5 hours per day. However,

[38] Specific groups within a populations could very well survive with a lower PAL, e.g. if they earn their income by begging.
[39] Observations of the PAL-level is typically based on data on the total energy expenditure, the TEE, and estimates of the BMR. The TEE could be estimated either by the so-called DLW method or by a so-called caliometric method. Food intake studies could in theory also be used (assuming that the person is in energy balance). These sometimes indicate extremely low intakes. However, DLW studies have shown that food intake studies, even well designed ones, underestimate the energy intake (Goldberg & Black, 1998). DLW-studies, on the other hand, are considered the golden-standard for measuring energy expenditure. They have the advantage that they do not interfere with the daily life of the subject. The method is based on an analysis of urine samples (Abrahamson etal, 2006).
[40] The PAL was based on the DLW-method.

they did much of the work sitting down, and they had little leisure activities. A study cited in WHO (1995) found that undernourished Rwandan women (with a BMI<17) had a significantly lower average PAL than normal weight women (BMI 18.7-23.8). The yearly average PAL for the latter was 1.65, but it was only 1.50 for the former.

Dugas etal (2011) did a meta-analysis of PAL studies.[41] The included estimates for men in low-income settings range from 1.70 ("Nigeria, average") to 2.40 (Gambia), and the corresponding estimates for women range between 1.62 (Guatemala, urban, poor) to 1.98 (Gambia, rural).[42] The average BMIs in these studies were generally quite high, so the ultra-poor are probably not well represented in them.

Dufour & Piperata (2008) reviewed PAL-estimates for farmers in developing countries.[43] For women, the lowest value was 1.47 and came from a study of Ethiopian female subsistence farmers. The women were only engaged in agricultural work about 50 minutes per day and were said to have a "relatively leisurely /…/activity profile".

The second lowest female PAL, 1.53, was found for a group of female subsistence farmers, laborers and traders from India. They were reported to be physically active during the peak season. Their average BMI was only 16.7, indicating undernourishment. A third study, of Brazilian women, also displayed a female PAL value in the light-lifestyle category (1.55). The lowest value for men was 1.67 and came from study of Indian subsistence farmers, laborers and traders. Their average BMI was 18.6.

The low PAL levels above is not necessarily in conflict with the cut-offs for the FAO life-style categories. The PAL levels from FAO can be seen as recommendations. FAO could not recommend levels that imply great suffering if followed, even if survival is still possible. Indeed, the FAO report refer to observed PALs as low as 1.2, but they feel that this is too low, even too low to use as a recommendation during short term disasters. A number of studies of white-collar workers do include a significant number of observations below the lower cut-off 1.40 (Prentice etal, 1985; Shetty, 2005). Individual values as low as 1.13 have been observed in free-living individuals, but these are bed bound older individuals (Westerterp, 2013; Speakman & Westerterp, 2010)

So where does all of this leave us? PAL values below 1.70 for an adult population do seem possible. To have a point of reference we will consider a PAL of 1.50 as the minimum value for a low-income population dependent on manual labor. We will use this value, as well as the Allen assumption of 1.95. In some settings the minimum requirement for physical activity might be higher than 1.95, but we assume that this is relatively rare, since the Allen assumption was not set to be a *minimum* requirement.

So far we only discussed the PAL of adults. Children and senior persons typically have lower PAL-levels. Westerterp (2013) report that PAL in high income countries are about 1.4 for children aged 1, between 1.7 and 1.8 for adults and about 1.4 for the really old. However, in low income settings we might expect that a broader set of age groups participate in the physical labor. And it might be that the need to support those unable to work, such as the very old and the very young, raises the required physical activity levels for the age-groups that do work.

[41] All studies were based on the DLW-method.
[42] Their categories "countries with low or medium HDI values" contained a few estimates that were even lower, but we felt that the populations in questions did not fit the criteria for low-income settings (e.g. Russia or students).
[43] The majority of the included studies did not use the DLW-method. Some studies looked at different seasons separately, but in the following discussion we only consider studies that measure the PAL for a full year.

Hence, it is unclear how the inclusion of other age-groups affect the average PAL for the population. We will not make any adjustments to our reference levels above (1.50 and 1.95), although we should keep in mind that the PAL of non-adults might be a source of bias.

## 6.5 What does this mean in terms of caloric requirements?

We have now discussed the range of likely values for four of the main factors that influence the caloric need of a population. We examined two conditions that affects the average caloric need in a population: the average height of the population and the age composition of the population. We also examined two of the assumptions we make for physical survival: the BMI needed for survival and the physical activity level required for survival.

We can now put these pieces together to see what the variation in these four factors actually mean for the average energy requirements of a population. We combine our low and high values for each of the underlying factors to see what range of energy requirements this implies.

The first step to calculate an average energy requirement is to estimate a BMR based on a chosen value for heights and BMI. The BMR is calculated for an adult "genderless" person. The second step to calculate an average energy requirement is to multiply the BMR with a choosen PAL-level, to get the *total energy* requirement for the average adult. The third step is to multiply the adult total energy requirement with a choosen age adjustment factor, to get the total energy requirement for the average *population member*.

To calculate the adult BMR we use the equations suggested by Henry (2005 & 2012) that estimates the BMR for a given age-group and gender. These equations differ somewhat from the equations traditionally used to calculate BMR, i.e. the equations provided by FAO (2001)[44]. The reason for choosing the Henry equations is that a number of reviews had pointed out some potential biases in the FAO equations, which, in most cases, implied an overestimation of the BMR.[45] Henry re-estimated the FAO equation based on a newer dataset, and excluded a large number of problematic older observations (from Italy) that were suspiciously high.

The FAO etc (2001) do discuss the Henry equations[46] and conclude that they have some merits, but that more analysis was needed before the FAO can switch to the new equations. The Henry equations generally predict lower BMRs than the FAO-equations, although exception exists for a few age-groups and weight categories. El Ghoch etal (2012) indicate that the standard FAO equations are likely to somewhat overestimate the energy requirements at the extremely low levels of BMI typically observed amongst anorexia patients.

We will look at the energy need of adult (18-30 years) men and women using the Henry equations below, where *H* is heights in meters:

(2) $$BMR_{men} = +113 + 310 * H_{men} + 14.4 * H_{men}^2 * BMI$$

(3) $$BMR_{women} = -282 + 620 * H_{women} + 10.4 * H_{women}^2 * BMI$$

[44] The full reference is FAO/WHO/UNU, but we use FAO for brevity.
[45] It was originally believed that this overestimation was mainly relevant for specific tropical populations, but more recently studies tended to show that the overestimation was more general. There has been an extensive discussion about potential biases in the available equations. See, for example, Henry (2005)
[46] FAO (2001) refer to an older version of Henry's paper, but the equations are as in Henry (2005).

We assume the same BMI for both men and women, i.e. if we assume that the required BMI is 15 for women, then we assume it is 15 for men as well. We assume that women have heights in proportion to men according to equations suggested by Baten, i.e. equation (1) displayed earlier. If we recalculate equation (1) we get:

$$(4) \qquad H_{women} = -0.27235 + 1.08992 * H_{men}$$

We then take the average of the BMR of men and women to get an estimate of average *adult* BMR. This figure is then multiplied with our choosen age adjustment factor and PAL. Hence we calculate:

$$(5) \qquad Average\ energy = Age\ adjustm. * PAL * \frac{(BMR_{men} + BMR_{women})}{2}$$

We have now summed up the calculations we will do. Let us, before we go on, repeat what values we discussed for heights, BMI, PAL and age adjustment. Our baseline scenario for *heights* is 166 cm for men, i.e. the same assumption used for the barebones basket. According to the equation of Baten the corresponding female height is 154 cm. We assume that the male heights vary from a low of 150 cm to a high of 180 cm.

Our baseline scenario for *BMI* is 18.5, i.e. approximatley the same assumption used in the barebones basket and the FAO estimates of undernutrition. Our low scenario for BMI is 15, a value that supposedly has been observed in some poor sub-populations. Under this scenario we assume that it is indeed possible for such a population to both survive and do the physical work need to survive. We also consider a BMI of 10 as a kind of "line of certain death". We do not consider any scenario with a BMI above 18.5, so this BMI represent both the baseline and the high scenario.

Our baseline scenario for *PAL* is 1.95, i.e. the same that Allen implicitly used for adults. Our low scenario is a PAL value of 1.50. Under this scenario we assume that it is indeed possible, as some of the litterature have suggested, to economise on the physical effort, even in an economy heavily dependent on manual labour. We do not consider any scenario with a PAL value above 1.95, so this PAL represent both the baseline and the high scenario.

Our baseline scenario for the age composition assumes a *population age adjustment factor* of 0.87. This assumption is, for reasons already explained, different from the assumption implicitly made for the barebones basket. Instead we choose this figure because it implies, together with our other baseline assumptions an energy need of 2100 calories per day, i.e. the energy content of the barebones basket. In our low scenario we assume an age adjustment factor of 0.84 and in our high scenario we assume 0.95. [47]

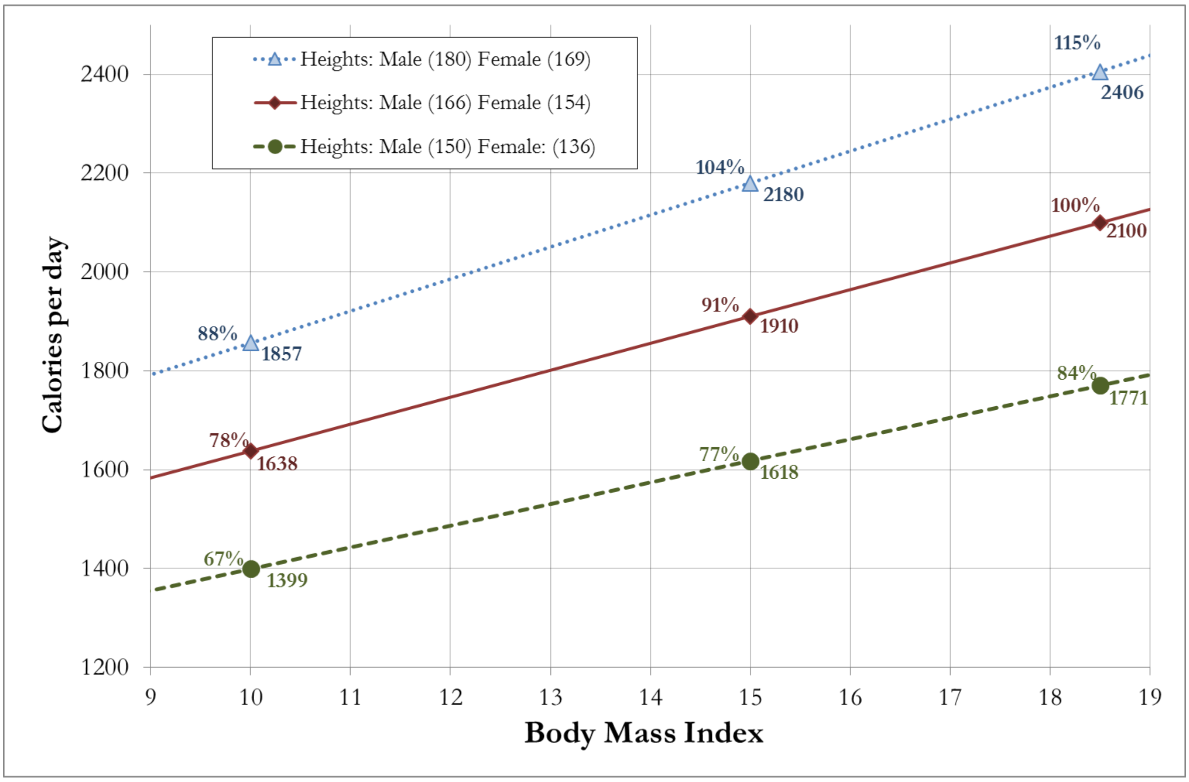
So, let us now see what caloric requirements all of these scenarios yield. In figure 6 below we display the results under the baseline scenarios for PAL and age adjustment and for various scenarios for heights and BMI. Under the baseline scenario of heights and BMI we get the "barebones basket" level of 2100 calories.[48] This is simply reflecting the fact that we choose

[47] There is a certain discrepancy here, since the reference group for the age adjustment factors were adults aged 20 to 39 years, whereas our unadjusted BMR was calculated for adults aged 18 to 30 years.

[48] If we use all the assumptions of the barebones basket, i.e. all our baseline assumption except for an age adjustment of 0.81, we get an energy requirement of only 1948 calories, which is about 7% lower than the 2100 calories Allen got from the same

the baseline age adjustment just to get this standard value. The interesting thing is how much the result varies under the other scenarios.

*Figure 6. Average total energy requirements for a population with an age adjustment of 0.87, a PAL of 1.95, and various assumptions for BMI and heights.*




*Notes: The labels below the lines are calories, and the labels above the lines are percent of 2100 calories. Sources: calculations in text.*

Assuming the lowest height, 150 cm, rather than 166 cm, cuts energy requirements to 84% of the reference value. Assuming a BMI of 15, rather than of 18.5, cuts energy requirements to 91% of the reference value. We do not know exactly how low the BMI in a population could be, but a BMI of 10 represents a certain death, which would cut energy requirement to 78% of 2100. Hence, saving more than 20% from losing weight seem totally out of question.

We should, in principle, not multiply the effects of variations in heights and of the BMIs, but the error of doing so is negligible within the ranges we are considering here. Hence, we can summarize the effects of changing each factor. We do that in table 5 below by showing the energy requirement, as a percent of the baseline of 2100 calories, as we change one factor at the time. For example, the low scenario for age adjustment would cut the energy requirement to 97% of the baseline.

set of assumptions. This discrepancy is likely due to the fact that we use of the Henry equations, whereas Allen use the FAO-equations. Using a BMI of 18.66 as he does not take away the discrepancy.

*Table 5. Adjustment factors for caloric requirement.*

| | Description | Scenario | Adjustment factor (percent of 2100 calories) |
|---|---|---|---|
| **Conditions** | The "youngest" population (adjustment factor 0.84) | Low | 97% |
| | The "medium young" population (adjustment factor 0.87) | Baseline | 100% |
| | The "oldest" population (adjustment factor 0.95) | High | 110% |
| | Shortest population (male heights 150 cm) | Low | 84% |
| | Medium short population (male heights 166 cm) | Baseline | 100% |
| | Tallest population (male heights 180 cm) | High | 115% |
| **Assumptions** | "Reduced" PAL (a factor of 1.50) | Low | 77% |
| | "Standard" PAL (a factor of 1.95) | Baseline & high | 100% |
| | "Extreme" thin (a BMI of 15.0) | Low | 91% |
| | "Normal" thin (a BMI of 18.5) | Baseline & high | 100% |

*Sources: see text*

If we combine all the low scenarios we get an energy requirement of only 1206 calories, or 57% of the baseline of 2100 calories.[49] If we combine all the high scenarios we get an energy requirement of 2406 calories, or 126% of the baseline of 2100 calories. So our range of possible values varies with more than a factor of two.

The country-specific cut-off values for undernourishment (by FAO) varied much less: they were all in the range of 1615 calories to 2173 calories per day. This is what we should expect since we used more extreme assumptions, and combined all the extreme assumptions into one scenario.

Our low scenario of 1206 calories is, indeed, a very low energy level. Has such low energy expenditure ever been observed at all? To answer that question we reviewed a number of studies that have measured energy expenditure in extreme situations. The lowest individual TEE we found was 1147 calories, and the lowest individual BMR we found was 652 calories.[50] These TEE and BMR observations concerns adults. Our population value for 1206 corresponds to an adult value of 1436[51], so this is a bit higher than the extreme observations we cited. These observations concerned extreme situations, but they were not obvious outliers within each dataset. However, they still reflect individual circumstances (including any individual measurement errors). On the other hand, this was just from a handful of studies, generally from high income societies.

What this show is that our extreme low scenario really represent a situation that might occur in some very extreme situations, but is likely to be exceedingly rare, if it happens at all. With these conclusion we can move on to discuss how the cost of a standard basket might vary.

[49] We calculated this by multiplying all the adjustment factors for the low scenario i.e. 0.97*0.84*0.77*0.91=0.57.

[50] The studies were El-Ghosh etal (2012); Henry (2005); Polito etal (2000); Ferro-Luzzi etal (1997); Westerterp (2013); Prentice etal (1985). See the annex for details.

[51] That is: 1206/0.84=1436

# 7. Relative prices

In this section we use price data from a variety of sources to put a dollar values to the assumptions we examined. We will examine both how variations in relative prices affect the cost of the physical minimum as well as how much cheaper a more meager basket can become. The former can be considered as variation in the conditions, and the latter as variation in the assumption.

First, we assess how much the variation in relative prices affects the subsistence line. One dollar per day in fixed prices can imply a range of living standards, depending on the relative prices. A low price of oats can push down the GDP-deflator as much as a low price of luxury goods. If the price of oats is low, and the price of luxuries is high, then the physical minimum line would be low. And if the opposite relation exists we would have a high physical minimum line. But how much would such variation in relative prices matter? We examine this by comparing the same basket across data sets.

Second, how much cheaper can the basket get if we strip it down to increasingly unrealistic versions? We will examine this by comparing a number of different baskets using a given set of prices. The basket will range from a basket that is more inclusive than the barebones basket ("the Stigler diet"), the full barebones basket, the "stripped down" barebones basket, the barebones basket with food only, a basket with only the cheapest staple, and a basket with only the cheapest source of calories.

## 7.1 Data

We would like to have a large number of price datasets that each contains price information on all available food items at a specific time and place. In that way we could be certain that we really have identified the cheapest sources of calories (and other nutrients). A large number of such datasets would allow us to really get a sense how much the cost of the cheapest calories can vary by circumstances, and how cheap it is in the most extreme situation on record. However, what we have been able to find so far is far from this.

The first data source we use to assess the cost of the physical minimum is six price datasets that cover a larger number of food items, each for a specific country and year. These datasets concern contemporary Uganda (Appleton etal, 1999), contemporary Tanzania (NBES, 2002), Sweden in 1931 and 1954 (Kungliga socialstyrelsen, 1961) and the US for 1939 and 1944 (Stigler, 1945). These were comprehensive enough to allow us calculate most of the baskets we wanted.

The second data source we use to assess the cost of the physical minimum is the historical price data for England (Clark, 2006). The dataset we looked at just covered a few items, so we were only able to calculate the cost of a fixed barebones food basket, as well as the cost of a "oats only" basket. However, rather than covering only one country year, it had data for several hundreds of years. So although this dataset did not allow us to compare many different types of baskets, it allowed us to examine how the cost of a specific basket changes over a large number of years. These prices are well examined already, but they are useful for examining how much changes in relative prices changes the evolvement of the English extraction ratios.

The final data source we use to assess the cost of the physical minimum is the values for baskets calculated by other authors. Allen (2013) has calculated barebones baskets for rural India for 2005 and for urban US for 1980 to 2011. We also use data for US for 1989 for a sort of food poverty line (Garille & Gass, 1999). We also include the poverty line for Senegal, since this represents the lowest poverty line in Ravallion etal (2008).[52] We also include the "egg and banana" diet that Banerjee and Duflo (2011) calculated for the Philippines.

We transform all the figures to 2005 international dollars by using the relevant GDP deflator, and the PPP rate for GDP from ICP.[53] We adjust all the baskets so they all supply 2100 calories per day. This is done by simply scaling the total cost up or down with the ratio between the original calories content and 2100 calories. Ideally we should consider the composition as well. If we should re-estimate the non-food share with a different food line we would probably get a somewhat different share. We described the details of the calculations in the appendix.

The baskets calculated for Uganda and Tanzania are likely to represent the low-cost end of the range of baskets. This is so for two reasons. First, the food items in both these datasets are based on the consumption of the poorest half of the population in a low-income country. Hence, we are less likely to miss the cheapest sources of calories in these cases.

Secondly, we choose these two countries since their poverty lines were amongst the lowest in the world, based on the comparison of poverty lines in Ravallion etal (2008). Secondly, Tanzania had the second lowest national-poverty line in the comparison of poverty lines in Ravallion etal.[54] The poverty line of Uganda was not exceptionally low, but it was based on a quite high caloric requirement (3000 calories per day). Neither of the underlying baskets stands out as exceptionally simple, so composition cannot explain the low cost. A more realistic explanation is a low relative price of calories.

## 7.2 Potential biases

Suspected upward biases exist for the US data, since it were based on urban data. Also, the observation for US prices in 1989 was based entirely on price data from a single food chain, rather than a representative sample. Suspected downward biases exists for the Indian barebones basket, which were based on rural prices. Possible downward biases also exist for the Senegal poverty line, which was based on prices from the harvest season. This means that the prices might be lower than the all-year average.[55]

[52] Ravallion etal (2008) have collected data on a number of national poverty lines in low income countries. These poverty lines have been constructed in a variety of ways, but generally with the ambition to find a very basic minimum needed for survival. Ravallion etal have transferred all these lines to 2005 international dollars (with CPI and PPP for private consumption). The international poverty line of the World Bank (1.25$ per day) is based on the average of these national poverty lines (in the poorest countries). We identified the countries with the lowest national poverty lines and tried to find the publications that documented these lines. In some cases we were unable to find the publications, in other cases the publication contained too little information to be useful. In the end we only really found price data for Tanzania, plus for Uganda that did not have an exceptionally low national poverty line.

[53] There are many other options for doing this transformation. Povcal, for example, use private consumption PPP and the CPIs when they calculate their poverty lines and poverty headcounts (they use the same transformation "in both directions", i.e. both when they set their own poverty line, as well as when they transfer their poverty line back to the local currencies). Our transformation is relevant for when we want to relate the subsistence line to consumption measures that is anchored to the national accounts, such as the income distribution data of van Zanden etal (2013).

[54] Only Senegal had a lower poverty line.

[55] Furthermore, it is not entirely clear to what extent they have adjusted for auto consumption, even though they had information about this.

## 7.3 Results

With the data discussed above we were able to get the cost of six different types of baskets across a number of price data sets, although some of the baskets are lacking for each dataset. We have included all the figures in the table below, where each row corresponds to a price data-set and each column corresponds to a specific basket.[56] The various price datasets can be considered as representing different conditions, and the various basket can be considered as representing different assumptions.

*Table 7: cost per day to consume the various baskets.*

| | Only the cheapest staple | Barebones basket, food only | Barebones basket, food plus mark-up for minimalistic non-food | Barebones basket, full (based on mark-up for non-food) | Barebones basket, full (based on price data) | Food poverty lines | Poverty lines, full |
|---|---|---|---|---|---|---|---|
| Phillipines (egg & bananas) | 0.18 | | | | | | |
| Senegal 1992 | | | | | | | 0.60 |
| Tanzania 2000 | 0.23 | 0.30 | 0.33 | 0.38 | | 0.63 | 0.87 |
| India 2005 | | | | | 0.53 | | |
| Uganda 1993 | 0.36 | 0.43 | 0.47 | 0.55 | | 0.59 | 0.85 |
| UK history lowest | 0.19 | 0.49 | 0.56 | 0.63 | | | |
| UK history mean | 0.33 | 0.59 | 0.68 | 0.75 | | | |
| UK history highest | 0.55 | 0.85 | 0.98 | 1.09 | | | |
| Sweden 1931 | 0.53 | 0.61 | 0.70 | 0.78 | | | |
| Sweden 1959 | 0.71 | 0.88 | 1.02 | 1.13 | | | |
| US 1939 (Stigler price data) | 0.54 | 0.63 | 0.72 | 0.80 | | 0.90 | |
| US 1944 (Stigler price data) | 0.74 | | | | | 1.06 | |
| US 1980 (Allen) | | | | | 1.02 | | |
| US 1989 (stigler price data) | | | | | | 1.33 | |
| US 1990 (Allen) | | | | | 0.77 | | |
| US 2000 (Allen) | | | | | 0.73 | | |
| US 2005 (Allen) | | | | | 0.80 | | |
| US 2008 (Allen) | | | | | 1.06 | | |
| US 2011 (Allen) | | 0.84 | 0.97 | 1.08 | 1.10 | | |

*Notes: No adjustment for caloric losses (not even in Uganda). All baskets supply 2100 calories. All have been transformed to 2005 international dollars with the GDP deflator and PPP-rate for the GDP. Sources: see the text and the annex.*

[56] In the case of UK history the rows represent the average, lowest and highest for several hundred of yearly observations

The simplest basket consist of only 2100 calories all coming from the cheapest staple (we include the “egg & banana” diet in this category to). Next we have a basket that only consist of the food content of the barebones basket, which is based on the price data for each of the four food items. However, we will not discuss this basket so much in itself, but rather use it to get figures for the next two baskets. The next basket is similar, but we added some stripped down costs for keeping warm and cooking. As discussed in section 5 we use a standard mark-up: 1.15 for cold climates (Sweden, UK and the US) and 1.10 for warm climates (the rest). We call this basket the minimalistic barebones basket.

The next basket is the full barebones basket. Some of the figures are calculated (by others) from price data for almost all items. Other figures are just based on the cost for the food items, multiplied with the markup 1.28, as discussed in section 5.

Finally we have included available figures for food poverty lines and full poverty lines, all scaled to correspond to 2100 calories. These are included mainly as a point of reference, but the so-called “Stigler diet” will be discussed in some details later on.

## 7.4 Is the food content of the barebones basket sufficient?

There are two main reasons why the food of the barebones basket could be insufficient: losses in preparation and the need for nutrients other than calories. The energy density figures used in the baskets does usually not account for calories lost in food preparation etc. However, Appleton etal (1999) cite figures on such losses for 28 food items. These “loss rates” goes from 50% (for Matoke) to 0% for a number of items (including several staples such maize and rice).[57] The cost of the Ugandan barebones basket increases with 11% if these losses are taken into account. The Ugandan food poverty line increases with 36%.[58] This, then, could be a source of substantial downward bias.

The bare bone baskets only consider calories and protein. How much more would a basket costs that considers the needs of other nutrients as well? The so called “Stigler diet” can shed some light on that. It was constructed to be the cheapest diets that fulfill the minimum requirement for a quite wide range of nutrients. The original diet supplied 3000 calories per day, plus the recommended daily amount of eight other nutrients.[59] Stigler (1945) calculated the diet for the US for 1939 and 1944. Garille & Gass (1999) revisited the Stigler diet for 1989, using updated estimates of nutrition requirements, nutrition content and prices.

We scaled down his diet to 2100 calories. For 1939 we were also able to calculate a barebones food basket, using the same price dataset as Stigler. The Stigler diet was 42% more expensive than the barebones food basket. The available information for 1989 did not allow us to calculate a barebones food basket, but the Stigler diet was much higher than the barebones basket for US available from Allen for 1980 & 1990 (see table 6 for all the figures).[60]

[57] I have not been able to find the primary source for these figures, so it is unclear exactly what they represent and how they have been calculated.
[58] See the annex for details.
[59] The eight other nutrients were proteins, calcium, iron, vitamin A, thiamin, riboflavin, niacin and ascorbic acid. The requirements, as understood in the 1940s, has since then been revised.
[60] The Stigler diet has been calculated with urban prices, which is likely to create an upward bias in the cost. However, the Barebones basket were either calculated with the same price set (as for 1939), or with other urban data (the Allen data), so the relation between the two basket would still hold.

These results indicate that the barebones basket is likely to be insufficient in several of the nutrients other than calories and proteins. The Stigler diet is supposed to be the cheapest way of getting the nine nutrients, so anything cheaper than that would have to be insufficient in at least one of the nutrients.

The Stigler diet has been harshly criticized from a number of perspectives. Stigler only considered the costs and minimum requirements. No account was taken for whether the combination of items was consistent with culturally accepted dishes.[61] Hence, a more realistic diet would cost even more, and the gap to the barebones food basket would be even larger.[62]

The relative short price list (77 items for 1939) raises the possibility that we missed cheaper sources of nutrients (Stigler himself point at the exclusion of fish). Furthermore, even though it seems relatively clear that the barebones basket falls short for some nutrients, it is not clear that the large cost gap found for US can be generalized to other contexts.[63]

It is also unclear how serious the shortcomings of the barebones food basket are. Specifically, it is unclear to what extent the requirements of the various nutrients are dependent on things like body size and the physical activity level (James, 1992).[64]

## 7.5 How much lower could we go below the barebones basket?

Let us assume that the caveats above can be disregarded. How much lower would we get if we assume that it is possible to survive on an *even simpler* diet than in the barebones basket. We could replace some of the meat, fat and beans with the cheapest staple. The cost of that basket would be somewhere the original barebones food basket and a basket that supply all of the calories in the form of the cheapest staple.

In our data such a basket costs between 13% less to 38% less than the food-only barebones basket. The former ratio is found in US in 1939 and the latter is the highest ratio found for any year for England.[65]

Is the cheapest *staple* the cheapest source of calories or are there any candidate for a cheaper "famine food"? Our price data is, unfortunately, far from comprehensive enough to give a conclusive answer to that. However, for Sweden (1931 & 1959) and for US in 1939 the cheapest sources of calories are, indeed, a staple. [66] For US in 1944 the calories from sugar were slightly cheaper than the cheapest staple, but that is hardly a realistic alternative.

In Uganda the cheapest staple was Sorghum. The calories of Sweet banana was 26% cheaper than Sorghum, and the calories of Sim-sim was 35% cheaper than the cheapest staple, Sorghum.

[61] Critics have pointed out that no person would eat the combination of items he proposed. Indeed, the main application of the techniques he introduced is in animal feeding. It is also used as a typical exercise in courses in linear programming.

[62] Garille & Gass also constructed a diet that took into account that some nutrients have a recommended highest intake. Such consideration increased the cost with about 30% from the original Stigler diet. This raises the possibility that some nutrients are consumed in excess with a barebones basket. However, with a diet scaled down to 2100 calories this risk seems to be smaller.

[63] The food poverty lines we have for Uganda and Tanzania (scaled to 2100 calories) cannot shed so much light on this, since they are based on the actual consumption pattern of the poorest half of the population. The actual food habits might both be insufficient or have an "in optimal" composition. Anyways, the Ugandan line is 37% more expensive than the barebones food basket, and the Tanzanian line is 110% more expensive.

[64] Scaling down the Stigler diet depends is reasonable if the requirements for all nutrients change in a similar way as calories does.

[65] The average ratio for England is 35%, ranging between 29% and 38%.

[66] We did not calculate the cost of all the food items in the Swedish dataset. However, the excluded items are unlikely candidates for cheap calories. They are either various forms of meats, or items with a low energy density (like vegetables). The cheapest calories were flour ("råg" or "vete"), which could reasonably be classified as staples.

None of these seems like a very realistic alternative as a main source of calories (although the sweet bananas could perhaps be a complement that pushes down the cost). In Tanzania, finally, calories from Maize were 13% cheaper than calories from Sorghum, and only the latter was consumed in any larger quantities. In some sense, then, maize could be considered as a cheaper non-staple, but the difference to Sorghum is not large. Hence, our limited data includes no examples of a *realistic* source of calories that are *much* cheaper than the cheapest staple.

## 7.6 How much does the cost of a given basket vary?

How much does the cost of a specific basket vary between our country-years? To get a sense of the maximum range of variation we display the highest and lowest cost for three key baskets in table 8. As a "baseline" scenario we simply use the average of the highest and lowest cost for each basket. This is quite arbitrary, but give a sense of a relative typical value for the basket.

Our baseline scenario assumes that the minimalistic barebones basket is sufficient for survival.[67] Our low scenario assumes that the "only the cheapest staple basket" [68] is sufficient and our high scenario assume that the full barebones basket is needed. The highest cost is about three times as high as the lowest cost for all three baskets. Accordingly, relative prices have the potential to cause a substantial variation in the subsistence line.

*Table 8: the cost of a basket with 2100 calories*

| | | | **Assumptions about the basket** | | |
|---|---|---|---|---|---|
| | | | Low scenario | Baseline scenario | High scenario |
| | | | Only the cheapest staple | The food content of the barebones basket plus a minimalistic non-food basket | The full barebones basket |
| **Conditions (relative prices)** | Low scenario | The lowest cost | 0.19 $ *(lowest English)* | 0.33 $ *(Tanzania 2000)* | 0.38 $ *(Tanzania 2000)* |
| | Baseline scenario | Average of highest and lowest cost | 0.45 $ | 0.67 $ | 0.76 $ |
| | High scenario | The highest prices | 0.71 $ *(Sweden 1959)* | 1.02 $ *(Sweden 1959)* | 1.13 $ *(Sweden 1959)* |

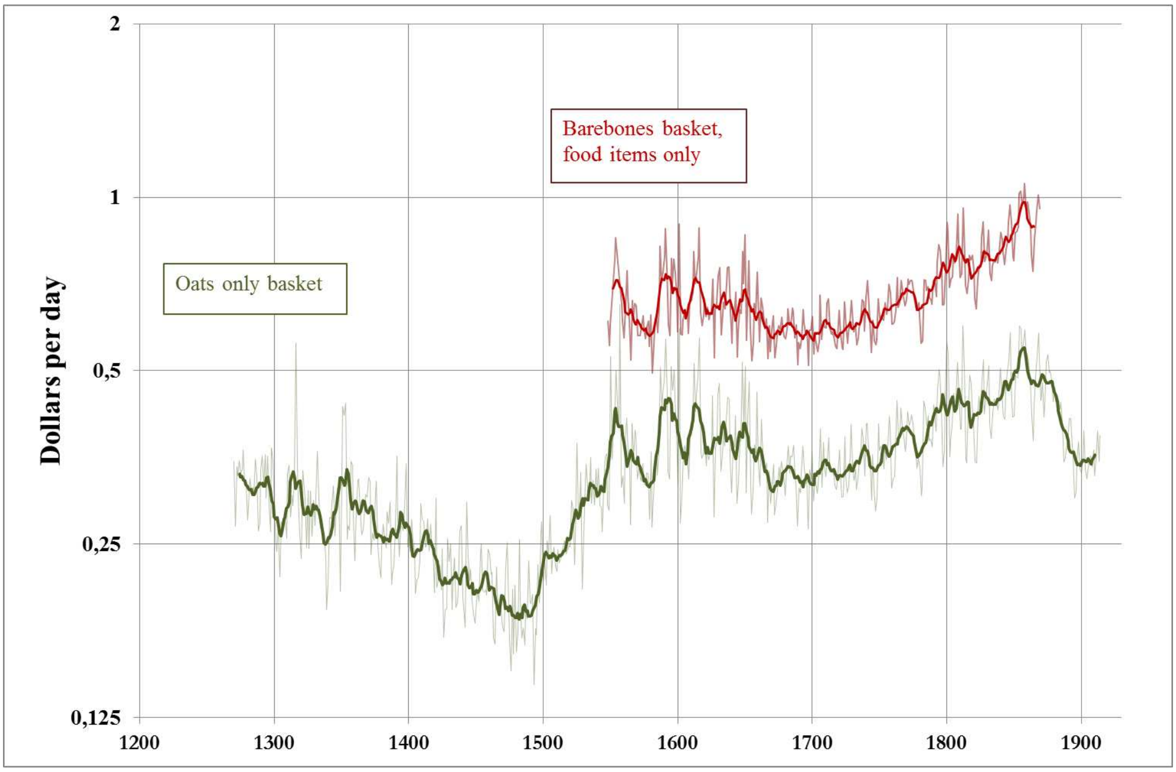
To get a sense of how the subsistence line can vary over time we plot the cost in England for both the staple-only basket and the minimalistic barebones basket. We do that in figure 7 below. Our main focus is the nines year moving average of this cost, since we are mainly interested in the "long term consumption".

[67] The low poverty line in Senegal hints at an even lower barebones food line. The poverty line contains a wide range of food items, although no meat. Hence, a barebones food line would probably be cheaper than the 0.60$ poverty line.

[68] Not included here are the Phillipines "egg and bananas" basket and the US 1944 basket (based on urban prices). If we include those baskets the price would vary with a factor of four instead.

Much have already been made of these data. However, it will be useful when we consider the implications of relative prices for the extraction ratio, something that we return to in the last section. One thing that is worth noting here already is that the barebones food basket seem to move largely in parallel to oats only basket, at least judged by the period for which we have data. This is not surprising since the staple is the largest post in the barebones food basket. Hence, we could perhaps use the cost of staples together with a fixed mark-up to get the cost of minimalistic barebones basket. Hence, we could perhaps also assume that the cost of bare survival was relative low in the 15th-century.

*Figure 7. Cost of two baskets in England, over time.*




*Notes: Yearly observations, and nine year-moving average. Sources: see text*

So, in summary, we found that the potential range of both prices and composition of baskets have a substantial impact on the physical minimum line. Furthermore, we found no realistic source of calories that are much cheaper than the cheapest staple. The time has now come to combine this information with the conclusions from the previous sections. This we do in the next section.

# 8. Implications

In the previous chapters we discussed the food needs of an individual, as well as the non-food needs, and the prices of a range of baskets. In each case we examined the variation implied by changes in both conditions and assumptions we use. Let us now put all these pieces together to get an overview of our results.

We combine our baseline scenarios into one picture to get a baseline value for the physical minimum, expressed in international dollars per day for an average individual. This baseline value is not intended to be our “preferred estimate” for the physical minimum line, but rather to be just a reference value to compare the other estimates with. That being said, our baseline assumptions and conditions yield a physical minimum line at 0.67$, which is almost exactly the same as Ravallion’s (2014) estimate of the consumption floor.

So how much does the conditions matter? Our selected price datasets imply physical minimum lines that vary between 50% and 150% of the baseline. The range of potential heights imply lines between 84% and 115% of the baseline and the range of potential age compositions imply lines between 97% and 110% of the baseline. The effect of climate is by assumption small, less than 5%. We could cautiously suggest that relative prices is the first thing to take into account if we want to improve the subsistence line, whereas differences in the age composition is less of a concern.

All the levels above were based on our baseline assumptions. How much do these assumptions matter? If we use the simplest thinkable basket that includes *nothing* other than the cheapest staple. The price data we examined did not reveal any realistic source of calories much cheaper than this. This extreme and unrealistic assumption cuts the line to about 65% of the baseline. If we assume that the required physical effort can be cut the line drops to about 77% of the baseline. If we assume that a population can survive at an average BMI of 15 the line is cut to 91% of the baseline.

In table 8 below, we combine all our minimum conditions to get a lower bound estimate, as well as all maximum conditions. We do the same with the minimum and maximum assumptions. The lower bound for conditions is more extreme than any of those actual cases we included, since we combine the lowest observed values from different countries and periods. For example, we combine the “youngest” population we encountered (Grenada in 1960) with the shortest populations we encountered (various hunter-gatherer societies) and so forth.

*Table 8: summary of scenarios*

| | A combination of all "low" assumptions (only the cheapest staple, a BMI of 15.0, PAL reduced to 1.50) | A combination of all "baseline" assumptions (a slimmed barebones basket, a BMI of 18.5, a PAL of 1.95) | A combination of all "high" assumptions (a full barebones basket, a BMI of 18.5, a PAL of 1.95) |
|---|---|---|---|
| A combination of all "low" conditions (lowest prices, an age adjustment of 0.84, male heights 150 cm) | 0.11$ | 0.27$ | 0.31$ |
| A combination of all "baseline" conditions (mid prices, an age adjustment of 0.87, male heights 166 cm) | 0.32$ | 0.67$ | 0.76$ |
| A combination of all "high" conditions (highest prices, an age adjustment of 0.95, male heights 180 cm) | 0.63$ | 1.28$ | 1.42$ |

When we combine all the minimum conditions (under baseline assumptions) we get a physical minimum line at 0.27$. This represent what we call the rock bottom line, the lowest possible income under any conditions, supposing our baseline assumptions are correct.

The assumptions can potentially give rise to a variation in costs of a factor of about two and a half. The conditions can give rise to a variation of a factor of about five. Our highest case (1.42$) is more than ten times as high as our lowest case (0.11$). The biggest source of variation is the relative prices, which varies with a factor of about three.

The maximum physical minimum line could be even higher if we consider extra caloric needs from things like diseases, altitudes, extreme temperature and pregnancies. The lowest value of 0.11$ represent a very extreme situation that we are unlikely to encounter in reality, but we could say that this represent the rock bottom line. The exact BMI value of 15 and PAL value of 1.50 are a bit arbitrarily chosen. However, it is not possible to save much more on these factors, even if we pushed these assumption to the extreme. For example, even if we assumed a BMI of only 10, which would represent a scenario where death is certain and work impossible, we would only lower the cost with 14%, compared to a scenario with a BMI of 15.

## 8.1 Assessing income estimates

Does our results have any implications for the various strands of literature that refer to the subsistence line? An average subsistence line should be sufficient for general arguments, such as Pritchett's argument about global inequalities. However, if we want to assess an individual income estimate it is worthwhile to look into the specific conditions.

Subsistence lines are used to asses GDP per capita estimates. It seems clear that incomes below the average subsistence line are possible under some circumstances. Indeed, if we know nothing about a population then all incomes above 0.27$ *could* be possible, although unlikely. Such low income estimates are rarely, if ever, presented, so this "rock bottom line" is of little use for assessing incomes. However, usually we know at least something on the circumstances for a population and we can use that information to raise the lowest possible level of incomes.

The income inequality is obviously relevant if we want to consider the plausibility of a GDP per capita estimate. We should include a mark-up for inequality, so that we assure that a sufficient large share of the population ends up above the line. Sometimes we have some information on the inequality of the population, or we know something about elite consumption. We can use that information to see how high the average income has to be to keep the bulk of the population above the physical minimum.

Even if we know nothing about the income distribution it would still be inappropriate to use zero inequality as the lower bound estimate. All known societies display at least some inequality, even hunter-gatherer societies, although many of them have quite small inequalities (Smith etal, 2010).

We often have other pieces of information for a given population, even if we do not have all the factors we used in our model. This information can be used to raise the lower bound level of incomes, above the rock bottom line of 0.27$. To illustrate that let us return to our initial question about China.

Is 0.89$ per day a plausible level for GDP per capita for China in 1950? Well, if the only thing we knew about China in 1950 was the suggested level of GDP per capita we would have to say that, yes, we can imagine an economy with this, or even lower, incomes. An impoverished, egalitarian, hunter-gatherer society, with virtually no consumption of clothing, housing or any other non-food items, and a very monotonous vegetarian diet, where everyone was short and undernourished, could in theory have a GDP per capita below 0.89$ per day.

However, we *do* know several things about China in 1950. First of all, income inequalities were certainly not zero. The gini coefficient was about 32 according to Zanden etal (2013). We do not have a social table for this year, but Milanovics etal offer a social table for 1880 that imply a gini of 24. As a "back of the envelope" calculation we assume that the distribution in 1950 were similar to 1880, which probably underestimate the inequalities.

The gentry made up 2% of population and earned about 26$ per day.[69] Milanovic etal also provide income for the commoners (the rest), but that is calculated as a residual, so if we used that it would be circular reasoning. Instead we see how much is left over for the commoners if we accept all our other assumptions. So we assume that the gentry had the same real total income in 1950, 26$ per day, and still made up 2% of the population, whereas 0.89$ is the average for the total population. Under these assumptions 0.38$ per day are left for the commoners that make up 98% of the population.

We have two more figures: the male average heights were 169 cm (Baten & Blum) and the age adjustment factor was 0.77 (calculated by us from World Population Prospect 2010B data). Both of these figures are slightly higher than our baseline. So the only condition that can make a difference is prices, and for that we have no data (although it would probably be attainable).

We start with our baseline assumptions i.e. a BMI of 18.5, a PAL of 1.95, and a slimmed down barebones basket for cold climates. The costs for these assumption range from 0.33 to 1.02. Hence, an income of 0.38$ per day is only 5 cents from the lowest cost of calories we encountered. Remember that this scenario suppose *no surplus consumption at all* beyond the elite consumption, allow *no mistakes* in terms of planning and prioritization, and there exists several other factors that are likely to underestimate the physical minimum. Under these assumptions 0.89$ per day seem like implausible low.

What if we squeeze the assumptions to a PAL of 1.50 and a BMI of 15? That would push back the physical minimum to between 0.23$ to 0.71$. The income of 0.38$ per day would still be in the lower half of this distribution, although the distance to the rock bottom would be larger. However, these assumptions seems unlikely for China in 1950: an average BMI of 15 for a large population has never been observed, and if it happened it would probably be noticed, even by a casual observer. We do not know what the physical labor requirements are for Chinese food production, but a casual look at paddy farming does not strike us as "physically light". Our best guess is hence that Maddison and Wu was right on China in 1950.

All in all, we would have to bring in quite implausible assumption to make the Chinese case possible. These conclusions are obviously very tentative and a firmer results could probably be made by digging deeper. However, this exercise mainly intend to illustrate that we can fine tune the lowest plausible income by adding whatever information we have on the specific population.

This illustrates that one dollar per day can represent quite different things. It will always represent deep poverty, of course. However, in some cases a person at this level can, with some

[69] The ratio between Taels and dollar (in 1990 prices) were implicitly given in the paper. We then transferred 1990 international dollars to 2005 international dollars.

luck, not only survive but also consume a few things above the bare-necessities. However, if the relative prices (and climate) are as in Sweden in the 1950s, the heights are as in Western Africa and age composition are as in Qatar, then life at one dollar per day would simply be physically impossible to survive, no matter how lucky and skilled you are. Furthermore, a subsistence line that sometimes are significantly below one dollar per day allow a larger room for surplus consumption than usually assumed.

## 8.2 Implications for extraction ratios

Milanovic and others use the subsistence line to calculate what they call extraction ratios. The extraction ratio is based on the notion that a certain share of the total production must be set aside so that everyone gets a subsistence income. The highest possible inequality is the society where all of what remains is allocated to a very small elite. We can under these assumptions calculate a "maximum attainable inequality", as measured by gini coefficient, given the mean income of the population and the subsistence line. If we divide this gini with the actual gini we get the extraction ratio.

Milanovic used a fixed subsistence line set either to 1.50$ or to 1.125$. From that he calculates extraction ratios for a number of countries over time, and these give a partially different picture from just looking at ginis. Would our approach change any of the conclusions drawn by Milanovic? We were only able to test our approach for England (the long time series), Tanzania and Uganda, and our data only allowed us to take prices into account (i.e. we assumed that the calorie requirements were the same). We assumed that 1.125$ was a reasonable assumption for the minimum consumption line under average conditions. Additionally we assumed that the minimum consumption line moved in proportion to the physical minimum line, i.e. we multiplied the physical minimum line with a constant to get the minimum consumption line.[70]

The overall patterns from Milanovics remains roughly the same, but there are still some important deviations. In England in the 15th century and in contemporary Tanzania the relative prices of "survival" were unusually low. This mean that extraction was significantly lower in England in the 16th century, and increased substantially in the 16th century, a pattern that the Milanovic assumption does not display. The Milanovics assumption imply extreme levels of extraction in Uganda and Tanzania. But with our assumption the extraction in Tanzania is lower and quite comparable to the pre-industrial experience of England.

## 8.3 True cost of living

Nordhaus (1996) proposed a "true cost of living index" that take quality improvements into account. He takes the cost of lighting as an example. The nominal price of lights, as specified in a traditional consumer price index, increased by a factor of about four since 1800 in the US. However, that does not fully take into account that a modern lamp deliver something very different than a lamp did in 1800. Hence, Nordhaus found that the nominal cost to get a specified amount of illumination, 1000 lumen hours, has *dropped* with 99% since 1800.

He also guesstimates a true cost of living index with similar corrections for all consumer goods. He founds that the "true cost of living index" in 1800 would be about ten times as high

[70] The details of this exercise is not included here, but can be supplied by the author upon request.

compared to an ordinary cost of living index. That mean that the GDP per capita in 1800 should be 90% lower if we deflate them with such an index, rather than with a traditional deflator. Accordingly, even the richest countries in 1800 would have had a GDP per capita below 0.5$ per day, and if we go further back in history it would be even lower.

Applying a traditional fixed subsistence line at 1.1$ per day would not make much sense for such a "true cost of living" income. All historical populations would live way below that subsistence line. However, a subsistence line linked to prices face no such problems. If we deflate the incomes with a true cost of living index, we should do the same with the cost of the survival goods. The "true cost of living subsistence line" would accordingly also be 90% lower with this approach.

For example, a laborer in Babylon would have had an extremely low income in terms of illumination, transport, access to books etc. But the price of nutrition relative to the price of all these things would be extremely low, so he would still have a fair chance of buying the bare necessities. Hence, our approach give room for the much higher growth implied by quality improvements over time.

## 8.4 The way forward

So how should we move forward if we believe a population specific subsistence line is worthwhile? A pragmatic first step could be to use the barebones basket, or at least the food part of it, to price the cost of survival. This basket has the additional advantage that much work has already been done with it in other contexts. The data for the four food items should be generally obtainable, since it was available in all the consumption surveys we looked at.

However, in our experience it was relatively time consuming to identify the surveys and the appropriate data in the surveys. An even easier short cut would be to concentrate on just the cost of calories through the cheapest staple and add a uniform mark-up to that. Our results tentatively suggest that differences in the price of calories can have a major impact on the subsistence line, more than the other factors, so it should be worthwhile to take this cost into considerations.

Variations in the required amount of calories have perhaps a somewhat smaller impact. However, there are a number of data sources that should be easy to use. FAO offers estimates for average energy requirements for many countries from 1990 and onwards. The estimates are based on data on average heights and age compositions, and used to assess the prevalence of under-nutrition in the world. For earlier times we have to construct our own measures, but height data and data on the age composition exists for many countries for long periods. With some work we could hopefully fine tune the subsistence line so that we in the future can more easily settle disputes similar to the debate about Chinese income data.

# Reference list

Abrahamsson, Andersson, Becker & Nilsson (2006), 'Näringslära för Högskolan'

A'hearn, Peracchi & Vecchi (2009), 'Height and the normal distribution: evidence from italian military data', Demography, volume 46, number 1

Allen (2009), 'The British Industrial revolution in Global perspective', Cambridge

Allen (2013A), 'Poverty lines in history, theory, and current international practice', Working Paper

Allen (2013B), "The high wage economy and the industrial revolution: a restatement", Discussion paper in economic and social history, number 115

Appleton, Emwanu, Kagugube & Muwonge (1999), 'Changes in povery in Uganda, 1992-1997', Paper provided by Centre for the Study of African Economies, University of Oxford in its series CSAE Working Paper Series with number 1999-22.

Bairoch (1979), 'Écarts internationaux des niveaux de vie avant la Révolution industrielle ', In: Annales. Économies, Soiétés, Civilisations. 34e année, N. 1. pp 145-171.

Bairoch (1993), 'Economics & World History. Myths and Paradoxes.', The university of Chicago press

Banerjee (2012), 'Transcript: The surprising truth about life on less than 1$ a day', Talk at Chatham House

Banerjee & Dufflo (2006), 'The economic lives of the poor', Working paper october 2006.

Banerjee & Dufflo (2011), 'Poor economics. A radical rethinking of the way to fight global poverty.'

Baqui, Black, Arifeen, Hill, Mitra & Sabir (1998), 'Causes pf childhood deaths in Bangladesh: results of a nationwide verbal autopsy study', Bulletin of the World health organization 76 (2): 161-171

Baten (2006), 'Global height trends in industrial and devloping countries, 1810-1984: an overview', Paper presented at XIV International economic history congress, 21-25, August, 2006, Helsinki

Baten & Blum (2012), 'Growing Taller, but Unequal: Biological Well-Being in World Regions and Its Determinants, 1810-1989." ', Economic History of Developing Regions. The data was downloaded from the Clio-Infra site in 2013.

Bengtsson & Poppel (2011), 'Socioeconomic inequalities in death from past to present: an introduction', Explorations in Economic History 48; 343-356

Bengtsson, Campbell, Lee, etal (2004), 'Life under pressure. Mortality and living standards in Europe and Asia, 1700-1900.', MIT

Blum (2011), 'Worldwide inequality, living standards and its determinants during the 19th and 20th centuries', Dissertation, university of Tübingen

Bolt & Hillbom (2013), 'Social structures and income distribution in colonial sub-saharan africa: the case of bechuanaland protectorate 1936-1964', Paper presented at the swedish economic history meeting, 4-5 october 2013, Lund

Borgonha, Shetty & Kurpad (2000), 'Total energy expenditure & physical activity level in chronically energy deficient Indian males measured by the doubly labelled water technique', Indian Journal of Medical Research 111; 138-46

Broadberry, Campbell, Klein, Overton, Leeuwen (2011), 'British economic growth, 1270-1870: an output based approach', Working paper, 18 december 2011

Cafiero (NA), 'Advances in hunger measurement. Traditional FAO methods and recent innovations',

Carlson-Kanyama & Boström-Carlsson (2001), 'Energy use for cooking and other stages in the life cycle of food. A study of wheat, spaghetti, pasta, barley, rice, potatoes, couscous and mashed potatoes', Forskningsgruppen för miljöstrategiska studier, report no 160

Carmody & Wrangham (2009), "The energetic significance of cooking", Journal of human evolution 57, 379-391

Clark (2006), 'The file "England prices and wages since 13th (Clark)", downloaded 2013 from Global price and income history group, available at: http://gpih.ucdavis.edu/Datafilelist.htm',

Cliggett (2005), 'Grains from Grass: Aging, Gender, and Famine in Rural Africa',

Coleman-Jensen, Nord, Andrews & Carlson (2011), "Household food security in the United States in 2010", USDA Economic Research Report Number 125.

Collins (1995), 'The limit to human adaption to starvation', Nature medicine, volume 1, number 8

Collins, Morduch, Rutherford and Ruthven (2009), "Portfolios of the poor. How the wolrd's poor live on $2 a day"

Dikhanov and Swanson (2010), "Comment: Maddison and Wu: 'Measuring China's economic performance'", World Economics 11 (1)

Dinour, Bergen & Yeh (2007), "The food insecurity-obesity paradox: a review of the literature and the role food stamps may play.", J Am Diet Assoc. 2007 Nov; 107(11): 1952-61.

Dufour & Piperata (2008), 'Energy expenditure among farmers in developing countries: what do we know?', American journal of Human Biology 20: 249-258

Dugas, Harders, Merrill, Ebersole, Shoham, Rush, Forrester, Durazo-Arvizu & Luke (2011), 'Energy expenditure in adults living in developing compared with industrialized countries: a meta-analysis of doubly labeled water studies', The American Journal of Clinical Nutrition, 93: 427-41

Durnin (1992), 'Low body mass index, physical work capacity and physical activity level', In "The functional significance of low body mass index", edited by James & Ralph. Proceedings of an IDECG workshop held in Rome, Italy, November 4-6, 1992.

El Ghoch, Alberti, Capelli, Calugi & Grave (2012), 'Resting energy expenditure in anorexia nervosa: measured versus estimated', Journal of nutrition and metabolism, Article ID 652932

Endicott (1999), 'The batek of peninsular Malaysia', In "The Cambridge encyclopedia of Hunters and Gatherers", edited by Lee & Daly

FAO (1996), 'The Sixth World Food Survey'

FAO (2013), 'Food security indicators, revision March 15, 2013', Data file downloaded from: http://www.fao.org/economic/ess/ess-fs/ess-fadata/en/

FAO (jointly with WHO & UNU) (2001), 'Human energy requirements. Report of a joint FAO/WHO/UNU expert consultation.',

Ferro-Luzzi, Petracchi, Kuriyan & Kurpad (1997), 'Basal metabolism of weight-stable chronically undernourished men and women: lack of metabolic adaption and ethnic differences', The American Journal of Clinical Nutrition , 66: 1086-93

Floud, Fogel, Harris & Hong (2011), 'The changing body. Health, nutrition, and human development in the western world since 1700',

Garille & Gass (1999), 'Stigler's diet problem revisisted', Operations research, volume 49, number 1.

Goldberg & Black (1998), 'Assessment of the validity of reported energy intakes - review and recent developments', Scandinavian journal of nutrition, volume 42: 6-9

Gray (1995), 'Social and biological consequences of nutritional adaption: do the costs outweight the gains?', Totem: The University of Western Ontario Journal of Anthropology. Volume 2, Issue 1, Article 7.

Henry (2005), 'Basal metabolic rate studies in humans: measurement and development of new equations', Public health nutrition 8 (7A); 1133-1152

Henry (2001), 'The biology of human starvation: some new insights', Nutrition Bulletin, 26, 205-211

Henry (2012), 'How much food does man require? New insights', Nutrition Bulletin, 37, 241-246

Human Mortality Database (2013), 'University of California, Berkeley (USA), and Max Planck Institute for Demographic Research (Germany). Available at www.mortality.org or www.humanmortality.de (data downloaded 2013, august)',

IHME (Institute for Health Metrics and Evaluation) (2013), 'Data visualizations', Accessed 2014 Januari, from: http://www.healthmetricsandevaluation.org/tools/data-visualizations

Irena, Ross, Salama & Collins (2013), 'Anthropometric predictors of mortality in undernourished adults in the Ajiep feeding programme in southern Sudan', The American Journal of Clinical Nutrition, 98: 335-9

James (1992), 'Introduction: the challange of adult chronic energy deficiency', In "The functional significance of low body mass index", edited by James & Ralph. Proceedings of an IDECG workshop held in Rome, Italy, November 4-6, 1992.

Kothari (2005), 'Economic, social and cultural rights. Report of the special rapporteur on adequate housing as a component of the right to an adequate standard of living',

Krishna (2010), 'One illness away. Why people become poor and how they escape poverty.',

Kungliga socialstyrelsen (1961), 'Konsumentpriser och indexberäkningar åren 1931-1959', Sveriges officiella statistik, Priser och konsumtion, Stockholm 1961

Kurpad, Muthayya & Vaz (2005), 'Consequences of inadequate food energy and negative energy balance in humans', Public health nutrition 8 (7A); 1053-1076

Lieberson (2004), 'How long can a person survive without food?', Scientific American, Monday, November 8, 2004

Lindgren (2014), 'GDP per capita by purchasing power parities', Gapminder Documentation 001 - version 13

Lipton (2012), 'Poverty: some issues', – paper based on a Centennial Lecture delivered at Bristol University on 9 June 2009.

Livi-Bacci (2007), 'A consise history of world population. Fourth edition',

Livsmedelsverket (2013), ”Livsmedelsdatabasen”, accessed 2013 august from http://www.slv.se/sv/grupp1/Mat-och-naring/Vad-innehaller-maten/Livsmedelsdatabasen-/

Luzer (2013), 'How lobsters got fancy', Passific Standard on-line, june 7, 2013

Maddison & Wu (2008), 'Measuring China's economic performance', World Economy, vol 9, no 2.

Milanovic (2013), 'The inequality possibility frontier: the extensions and new applications', Working Paper

Milanovic, Lindert & Williamson (2007), 'Measuring ancient inequality', MPRA Paper no. 5388

Mullainathan & Shafir (2013), "Scarcity. Why having too little means so much"

Naidu & Rao (1992), 'Body mass index: a measure of the nutritional status of Indian populations', In "The functional significance of low body mass index", edited by James & Ralph. Proceedings of an IDECG workshop held in Rome, Italy, November 4-6, 1992.

National Bureau of Statistics Tanzania (2002), 'Household budget survey 2000/01 Tanzania',

NBES (National bureau of statistics Tanzania) (2002), 'Household budget survey 2000/01', Dar es Salaam, july 2002

Nordhaus (1996), "Do real-output measures and real-wage capture reality? The history of lighting suggests not"

Norgan & Ferro-Luzzi (1996 (on-line 2011)), 'Human adaption to energy undernutrition', Handbook of Physiology, Environmental Physiology

Overseas Development Institute (2014), "The chronic poverty report 2014-2015: The road to zero extreme poverty", available at: http://www.odi.org/chronic-poverty

Payne & Lipton, with Longhurst, North & Treagust (1994), 'How third world rural households adapt to dietary stress. The evidence and the issues.', Food Policy review 2

Pednekar, Hakama, Hebert & Gupta (2008), 'Association of body mass index with all-cause and cause-specific mortality: findings from a prospective cohort study in Mumnbai (Bombay), India', International Journal of Epidimiology 37; 524-535

Persson (2010), 'The End of the Malthusian Stagnation Thesis', working paper, 26 april 201 version

Polito, Fabbri, Ferro-Luzzi, Cuzzolaro, Censi, Ciarapica, Fabbrini & Gianni (2000), 'Basal metabolic rate in anorixia nervosa: relation to body composition and leptin concentrations', The American Journal of Clinical Nutrition , 71; 1495-502

Pontzer, Raichlen, Wood, Mapulla, Racette & Marlowes (2012), 'Hunter-gatherer energetics and human obesity', PLOS One 7 (7)

Prentice, Coward, Davies, Murgatroyd, Black, Goldberg, Ashfor & Sawyer (1985), 'Unexpectedly low level of energy expenditure in healthy women', The Lancet, june 22, 1985

Pritchet (1997), 'Divergence, Big time', The Journal of Economic Perspectives, Vol. 11, No. 3 (Summer, 1997), pp. 3-17

Ravallion, Chen & Sangraula (2008), 'Dollar a day revisited', World bank Policy Research Working Paper 4620

Ravallion, Datt, van de Walle (1991), 'Quantifying absolute povery in the developing world', Review of income and wealth, series 37, number 4.

Ravallion (2014), “Are the world’s poorest being left behind”, NBER working paper 20791

Rotimi, Okosun, Johnson, Owoaje, Lwaoyin, Asuzu, kaufman, Adeyemo & Cooper (1999), 'The distribution and mortality impact of chronic energy deficiency among adult Nigerian men and women', European Journal of Clinical Nutrition 53: 734-739

Sauvaget, Ramadas, Thomas, Vinoda, Thara & Sankaranarayanan (2008), 'Body mass index, weight change and mortality risk in a prospective study in India', International Journal of Epidimiology 37; 990-1004

Schneider (2012), 'Real wages and the family: adjusting real wages to changing demography in pre-modern England', University of Oxford, Discussion Papers in Economic and Social History, number 99.

Schön & Krantz (2012), “Swedish Historical National Accounts 1560—2010” Lund Papers in Economic History 123, Lund University.

Shetty (2005), 'Energy requirements of adults', Public health nutrition 8 (7A); 994-1009

Shetty & James (1994), 'Body mass index - a measure of chronic energy deficiency in adults', FAO food and nutrition papers 56

Smith etal (2010), 'Wealth transmission and inequality among hunter-gatherers', Current Anthropology. Volume 51, number 1.

Speakman & Westerterp (2010), 'Associations between energy demands, physical activity, and body composition in adult humans between 18 and 96 y of age', The American Journal of Clinical Nutrition, 92:826-34

Stigler (1945), 'The cost of subsistence', Journal of farm economics, volume 27, number 2.

"Svedberg (2002), 'Undernutrition overestimated', Economic Development and Cultural Change

Vol. 51, No. 1 (October 2002), pp. 5-36"

Walker etal (2006), 'Growth rates and life histories in twenty-two small scale societies.', American journal of Human Biology 18: 295-311

van Zanden, Baten, Foldvari & van Leeuwen (2013), 'The Changing Shape of Global Inequality 1820–2000; Exploring a New Dataset', Review of Income and Wealth 60 (2), pages 279–297, June 2014

Westerterp (2013), 'Physical activity and physical activity induced energy expenditure in humans: measurement, determinants, and effects', Frontiers in physiology, volume 4, article 90

WHO (1995), 'Physical status: the use and interpretation of anthropometry', Report of a WHO expert committee

WHO (2013), 'The dataset 'BMI females % moderate and severe thinness (<=17) '', Accessed 2013 August, from: http://apps.who.int/bmi/index.jsp?introPage=intro_3.html

Williamson (2014), 'What Was the U.K. GDP Then?', MeasuringWorth

World bank (1995), 'Senegal. An assessment of living conditions', Report no. 12517-SE

World Bank data (2013A), 'GDP deflator (base year varies by country)', accessed august 2013, from: http://data.worldbank.org/indicator/NY.GDP.DEFL.ZS

World Bank data (2013B), 'PPP conversion factor, GDP (LCU per international $)', accessed august 2013, from: http://data.worldbank.org/indicator/PA.NUS.PPP

World Bank data (2013C), 'GDP per capita, PPP (constant 2005 international $)', accessed august 2013, from: http://data.worldbank.org/indicator/NY.GDP.PCAP.PP.KD

World Bank data (2013D), 'PovcalNet', accessed august 2013, from: http://iresearch.worldbank.org/PovcalNet/index.htm

World Value Survey (2014). WORLD VALUES SURVEY Wave 6 2010-2014 OFFICIAL AGGREGATE v.20141107. World Values Survey Association (www.worldvaluessurvey.org). Aggregate File Producer: Asep/JDS, Madrid SPAIN.

World Population Prospects (2010A), 'Extended Model Life Tables', Downloaded from http://esa.un.org/wpp/Model-Life-Tables/download-page.html Accessed 2012.

World Population Prospects (2010B), "World Population Prospects: The 2010 Revision", Population by Age data.

Wrangham & Conklin-Brittain (2003), 'Review 'Cooking as a biological trait'', Comparative Biochemistry and Physiology Part A: Molecular & Integrative Physiology. Volume 136, Issue 1, September 2003, Pages 35–46"

# Annexes to the "elusive quest for the subsistence line"

*Mattias Lindgren*

# Annex A – the baskets

**Sweden**

For Sweden we used price data from ”Kungliga social styrelsen" ("Konsumentpriser och indexberäkningar 1931-1959"). We used these price data to calculate the cost of a barebones basket, as well as a basket only consisting of the cheapest source of calories. We calculated a basket for the first and last year in the database, 1931 and 1959.

The database contains prices of about 100 food items, both of raw foods (e.g. oat meals), and processed food (e.g. sausages). We used calories information from the nutritional database "livsmedelsdatabasen" (Livsmedelsverket, 2013) (but we occasionally cross-checked with other sources).[71] We deflated the prices with the GDP deflator from Krantz & Schön.

The "meats" that supplied the cheapest calories were black puddings and salted herrings (the calories cost about the same). The cheapest calories from "non-fish" "non-processed" meats were fresh pork. A barebones basket based on that was about 9% more expensive. Below we use "salted herring", herring being quite common food in Sweden.

It was not always straightforward to match the headings in the price data with the headings in the nutritional database. Some food items had no corresponding items in livsmedlesdatabasen, probably because they are not common today (e.g. new born calves, "spädkalv"). In those cases we had to find the closest equivalent. However, some food variants differed substantially in their energy densities. For example, to find an equivalent to mutton steak ("fårkött, stek") we looked at a range of "mutton" items. These had energy densities between 1300 to 1610 calories per kilo, a difference of almost 25%. Livsmedelsdatabasen often had several varieties depending on fatness (with fatter versions being more energy dense), and it is not apparent what the priced items corresponds to. We choose to use thee fatter version when in doubt, which would bias our cost estimate downwards.

[71] We used a Swedish nutritional database in this case, since it made it easier to identify the corresponding items.

For meat some processed food constituted cheaper calories than meat proper, such as “Blodkorv” and “fläskkorv”. We calculated versions based on either the cheapest meat proper, or the cheapest animal protein. In the Swedish case this meant very small differences.

We did not look up the energy densities for all the items in the price database. We concentrated on the items that could potentially be part of the barebone basket (i.e. the meats, beans, fats and staples). We also checked a few other likely candidates of cheap calories. Although we cannot be certain, it does seem that the cheapest staple (which are the ones we use in the barebones baskets) are indeed the cheapest source of calories, all categories. The baskets are shown below.

| **Basket** | **Barebones category** | **English name of item** | **Name in SCB prices** | **Name in livsmedelsdatabasen** | **Energy density** (Calories/ Kg) (from Livsmedelsdatabasen) | **Prices** (current öre per kg) | **Grams per day** | **Calories** |
|---|---|---|---|---|---|---|---|---|
| Barebones food, 1931. | staple | rye | mjöl, råg | Rågmjöl fullkorn | 3260 | 24 | 595,0 | 1940 |
| | beans | yellow peas | gula ärtor | Gula ärter kokta m salt | 1370 | 32 | 54,8 | 75 |
| | fat | margarine | margarin | Bordsmargarin fett 70% berikad typ Milda | 6210 | 129 | 8,2 | 51 |
| | meat alt. 1 | fresh pork | färskt sidfläsk | Fläsk sida gris m svål i bit | 2680 | 147 | 13,7 | 37 |
| | meat alt. 2 | salted herring | salt sill | Salt sill | 2450 | 56 | 13,7 | 34 |
| Barebones food, 1959. | staple | flour | mjöl, vete | Vetemjöl | 3520 | 98 | 560,0 | 1971 |
| | beans | household peas | hushålls ärtor | Gröna ärter | 720 | 220 | 54,8 | 39 |
| | fat | | margarin | Bordsmargarin fett 70% berikad typ Milda | 6210 | 347 | 8,2 | 51 |
| | meat alt. 1 | salt pork | salt svenskt sidfläsk | Fläsk sida gris m svål i bit | 2680 | 706 | 13,7 | 37 |
| | meat alt. 2 | salted herring | salt sill | Salt sill | 2450 | 248 | 13,7 | 34 |
| | meat alt. 3 | pork sausage | fläskkorv | Fläskkorv fett ca 23% rå | 2500 | 469 | 13,7 | 34 |
| | meat alt. 4 | black pudding | blodpudding | Blodpudding blodkorv fett 19% | 3010 | 263 | 13,7 | 41 |
| Cheapest source of calories, 1931. | NA | rye | mjöl, råg | Rågmjöl fullkorn | 3260 | 24 | 644,2 | 2100 |
| Cheapest source of calories, 1959. | NA | flour | mjöl, vete | Vetemjöl | 3520 | 98 | 596,6 | 2100 |

*The various Swedish baskets. From A8.5 version 5.*

We also include the cost of getting all calories from the cheapest source (rye for 1931 and flour for 1959). The results are shown below.

| | **1931** | **1959** |
|---|---|---|
| Barebones food. Blackpudding used as meats. | | 0,82 |
| Barebones food. Salted herring used as meats. | 0,50 | 0,82 |
| Barebones food. Pork sausage used as meats. | | 0,85 |
| Barebones food. Salted pork used as meats. | 0,53 | 0,89 |
| The cheapest source of calories | 0,43 | 0,65 |

*Costs of various food baskets in Sweden. All baskets supply 2100 calories. Prices in 2005 international $per day.*

**Stigler subsistence diet (US in the 20th century)**

To get data for the US we turn to the so-called Stigler diet. This diet can also shed some light on how our other baskets fare with respect to other aspects than calories and proteins.

The Stigler diet originate from Stigler (1945). He constructed the cheapest diets for 1939 and 1944 that fulfill the minimum requirement for a quite wide range of nutrients. The original diet supplied 3000 calories per day, plus the recommended daily amount of eight other nutrients.[72] He took no other considerations than costs and minimum requirements, e.g. he did neither consider whether the individual items were widely consumed, nor whether the combination is consistent with culturally accepted dishes. [73]

He used prices based on average retail prices for bigger cities in the US. The prices concerned one month only, not the yearly average. The price list contained 77 items for 1939 and only 14 items for 1944. Hence, many food items, such as fresh fish, are not included. The urban source of data and the short list of food items are likely to cause and overestimation of the cost.

Garille & Gass (1999) revisited the Stigler diet, but used updated estimates of nutrition requirements, nutrition content and prices. The prices were taken from Giant Foods supermarket chain in the Washington DC area for April 1998. It is uncertain how representative these prices are for the US at large. The urban origin of the prices, as for the original Stigler diet, are a likely source of upward bias for the cost.

We also used the price list of Stigler to calculate a barebones basket for 1939. The list of items for 1944 is too short to allow us to construct a barebones basket for that year. The information for 1998 is also insufficient for this purpose. For the 1939 barebones basket we

[72] The eight other nutrients were proteins, calcium, iron, vitamin A, thiamin, riboflavin, niacin and ascorbic acid. The requirements, as understood in the 1940s, has since then been revised.
[73] The paper was written before the invention of linear programing so Stigler found his solution by trial and error. However, later recalculations showed that the optimal basket only differ marginally from his results. (zz2648)

used the cheapest source of calories in each of the four food categories.[74] We scaled the staple until the whole basket supplied 2200 calories.

We also made a "basket" consisting only of the cheapest source of calories. For 1939 this was "wheat flour, enriched". For 1944 the cheapest source of calories is corn meal (which was not in the Stigler diet for that year).[75] The information for 1998 is also insufficient for this purpose.

**Modern prices in the US**

For recent data for the US we use Allen (2013). He calculates the value of the barebones basket using two different price datasets. He uses prices from the US labor bureau of labor statistics is for 1980-2011. In addition he uses the prices from Safeway on-line shopping for 2011, which give quite similar results as the previous source. However, it is only for the latter source he gives any cost by items. Hence, we also use that source in order to calculate a food only barebones. Allen calculates the cost of different barebones baskets where different staples, but we only include the cheapest basket, i.e. the one that is based on wheat.

It is unclear how representative the prices are. The Safeway data is obviously a very specific source, at a specific point in time. However, the fact that it matches the US labour bureau is encouraging. However, if the latter source is for urban areas only it could imply an upward bias. The data is deflated by the GDP deflator (from measuring worth).[76]

We used the data from Allen, figure 4 (data from US bureau of labour statistics) & Allen, table 7 (data from Safeway). The former data was estimated from the figure (hence we only looked at a selection of years). They were all deflated with CPI and the GDP deflator.

**Tanzania**

The basket is based on the consumption pattern of the poorest half of the population so the composition no doubt represents a very simple diet. However, it does not stand out as being as simple as the barebones basket. It contains 108 different food items. 21% of the expenditure

[74] For fat the cheapest calories is "lard" which we feel is a bit outside the barebones definition of fat and oil. However, margarine (the second cheapest fat) only increases the cost with 2%. Hence, this is no big issue.

[75] Sugar is strictly speaking the cheapest calories in this year, but only slightly cheaper than corn meal. Sugar contains no other of the nutrients than calories.

[76] Other modern poverty line baskets are also evaluated with these US prices. They are all more expensive, even one from Kenya that contain only 1715 calories and are based on only two food items (maize and beans). This is not that surprising since they have not been constructed focusing on the staple that supplies the cheapest calories by US prices. Furthermore, all contain a relative high share of non-staples (even the Kenyan basket, since the share beans are higher than in the barebones).

in the basket goes to meat and fish, although that contributes to only 4% of the calorie intake.[77]

| Items (names as in source) | grams per day | calories per day | cost per day (local current currency) |
|---|---|---|---|
| sorghum,flour | 530 | 1809 | 55 |
| peas,dry | 55 | 188 | 14 |
| other cooking oil | 8 | 73 | 8 |
| canned meat | 14 | 31 | 7 |
| | | | |
| Sum | | 2100 | 84 |

The local currencies were transformed with GDP deflator from the World Bank, and the PPP for GDP. We used the items in each categories that supplied the cheapest calories, if the items were consumed in significant quantities (NMST provided information on quantities consumed by the poorest half of the population).

**Historical baskets in England**

Much work has been done on English prices throughout history. Price data is available for about 700 years, so we can get sense of the range of changes in relative prices over an extended period. The data I have looked at do not cover many food items, so we cannot use them to examine to what extent the items we look at are the cheapest source of calories in any particular year.

We calculated[78] the cost in current prices of a barebones food basket by using the price data from the homepage of the global price and income history group[79]. We also calculated a basket consisting of the "staple" item only. We cannot be sure that this was the cheapest source of calories in every and each years since we only priced the items included in the barebones food basket.

We did this for all years with available data (e.g. from 1209 for oats). The current costs were transformed to 2005 international dollars. We first deflated the current prices with the retail price index from measuring worth.  We then used the PPP for GDP from the World Bank data (2013B). We did not calculate a separate series with the GDP deflator rather than the retail

[77] The 43 items that make up the most expensive calories sources correspond to 30% of expenditures in the basket. We can take those 43 items out and adjust the consumption of the remaining items up. That lower the cost of the basket to some 71% of the original food basket (tab 4 in a5)

[78] The procedure is inspired by a power point by van Zanden.

[79] http://gpih.ucdavis.edu/Datafilelist.htm, file name: England prices and wages since 13th (Clark)

price index. However, the GDP deflator seems to imply accost that are about 15% lower than the retail price index.[80]

I used the food items for the barbonebasket for 2100 calories from (zz2587: high wage economy a restatement (2013), table 2). I used the implied calories values per kg to get quantity needed to get 2100 calories from each item only. I also calculated the cost of the barebones basket.

Some of the prices were specified in litres, whereas the food baskets were defined in kg. I used various sources for densities, but they differed quite a bit depending on the details of the item (raw or cooked, type of grain etc). Hence, the chance is high that I got it wrong for those items. This creates a lot of uncertainty for the levels. However, for the variation in the prices it should matter less.

We have only checked the original items in barebones (there were some alternatives for some of the 4 items, we took the longest series) so we cannot say whether there for some periods were cheaper alternatives.

| | *Beef* | *Butter* | *Oats* | *Peas* |
|---|---|---|---|---|
| Grams per day in the barebones basket | 13,7 | 8,2 | 465,8 | 54,8 |
| Grams per day for the "item only" basket | 846,1 | 287,7 | 538,2 | 615,3 |

*The content of the baskets, in grams per day. The headings are the names used in the data source (Clark).*

**Uganda**

Appleton etal (1999) have estimated a poverty line and food poverty line for Uganda in 1993.[81] Their food basket contains 28 items and is based on the consumption of poorest half of the population. Home consumption was priced at farm gate prices (as estimated by the respondents). Meat and fish makes up 2% of the calories and 5% of the cost. The non-food expenditure is 30% of the total poverty line (added by the usual mark-up method).

The original basket took into account losses in preparation etc. We calculated all the baskets without these deductions, in order to be consistent with all the other baskets we look at. We did the following calculations:

Ugandan food poverty, preparation losses taken into account: The basket in Appleton etal have already taken the losses into account. Hence, we use the basket as given in the source. The basket contains 3000 calories per day after deductions for losses. We scale down the

[80] Measuring Worth seems to have data for the GDP deflator as well. However, I have not figured out how t download the whole dataset yet. Instead I looked at a selection of years. The figures I have are about 65% to 95% of the retail prices, depending of the year. For most years the deflator seem to hoover at around 85%, so we use this.
[81] This is one of the sources in Ravallion's dataset. If we deflate figure of Appleton etal (in 1993 Ugandan Shillings) with the CPI and PPP for consumption we get the figure of Ravallion's (or almost the same figure).

basket proportionally to get from 3000 to 2100 calories (i.e. we multiply all values with 2100/3000).

Ugandan food poverty line, without taking preparation losses into account: We use the basket as in the source (which gives 3000 calories per day after retention). We then assume retention is zero. The same basket then supply 4065 calories. We scale down the basket proportionally to get from 4065 to 2100 calories (i.e. we multiply all values with 2100/4065).

The full poverty line: we scale down the full poverty line proportionally to any adjustment to the food poverty line. Hence, we maintain the relative share of non-food expenditure in total expenditure.

Barebones basket: we use the values of the sorghum basket (in Allen), and adjust the sorghum content to get 2100 calories. We maintain the weight of all items except Sorghum and use the caloric content of Appleton etal (with or without retention) to see how many calories the baskets contain. We then adjust the Sorghum weight to match 2100 calories.

Using “other meat” rather than “smoked fish” only makes a difference of a few percent.

| | | *Losses in preparation etc taken into account* | | | *No adjustment for losses.* | | |
|---|---|---|---|---|---|---|---|
| **barebone** | **Names in source** | **grams per day** | **calories** | **costs (international dollars 2005)** | **grams per day** | **calories** | **costs (international dollars 2005)** |
| sorghum | sorghum | 604,4 | 1 877 | 0,368 | 528,7 | 1 824 | 0,322 |
| beans/peas | beans (dry) | 54,8 | 136 | 0,058 | 54,8 | 181 | 0,058 |
| butter/oil/ghi | cooking oil/ghee | 8,2 | 70 | 0,035 | 8,2 | 70 | 0,035 |
| meat | smoked fish | 8,2 | 17 | 0,015 | 8,2 | 25 | 0,015 |
| | | | | | | | |
| *Sum* | *Sum* | | *2 100* | *0,48* | | *2 100* | *0,43* |

| | **Cost without losses** | **Cost with losses** | **increase in percent** |
|---|---|---|---|
| Barebones food (with Sorghum) | 0,430 | 0,476 | 11 |
| Ugandan food poverty line | 0,593 | 0,803 | 36 |

*Table x. All baskets contain 2100 calories. File a7.4 v3*

## India

Allen (2013) also price various baskets in Indian rural retail prices, and transfer them to US dollar using the consumer PPP. We used PPP for GDP instead, in order to be consistent with our other baskets. This increases the costs with about 6%.

# Annex B – estimating energy for boiling porridge on an open fire

We can try to get a sense of how much energy we need to cook our staple into porridge by looking at a number of estimates for energy use for cooking various dishes on a hotplate. These are displayed below. We should note that there are substantial economies of scale for energy in cooking, i.e. the energy cost per portion is substantially smaller for the 4 portion case.[82] Hence, if the food is cooked in larger batches, e.g. for the whole family and perhaps only once a day, then energy will be saved.

| | **Energy** for cooking on hotplate (kilo Joules) | | **Used for 4 portions** | | |
|---|---|---|---|---|---|
| | **1 portion** | **4 portions** | **Mass (grams)** | **Water (grams)** | **Time (minutes)** |
| whole wheat | 290 | 440 | 180 | 350 | 17 |
| rice | 340 | 480 | 240 | 600 | 20 |
| barley | 470 | 720 | 160 | 700 | 30 |
| potatoes | 700 | 1200 | 800 | 1000 | 32 |
| fresh pasta | 680 | 1640 | 520 | 2500 | 12 |
| spaghetti | 850 | 2160 | 280 | 2500 | 18 |

*Source: Carlsson-Kanyama & Boström-Carlsson (2001)*

To boil 466 grams oats into porridge we would need some 1000 grams of water and probably somewhat less than 12 minutes. None of the examples above really fit into that. For now we just do a crude estimate for one barebones, which seem to be around 660 kilojoules. If make a batch of four the estimate is about 460 kilojoules (for a 466 gram portion).[83]

However, the heat losses for an open fire is likely to be much larger than for the hot plates used in the table. Bhatt (1982) has measured the energy efficiency for cooking on a three stones open fire. The estimate ranges between 6% and 14%. The lowest value 6% is for when simulating cooking (talking into account the time when fire is not utilized due to change of pot, start and stop etc). If the efficiency from electricity to food is 80% (a guess based on almost nothing) we could perhaps accept that the energy efficiency of an open fire is about 15% of what is give above.

[82] Energy losses are proportionate to the surface of the vessel, which increase less than proportionally than the mass.

[83] We calcaulted the total mass * time cooking and correlated that against the energy needed. It fitted quite well. We used the predicted values for 1500 gram cooked in 10 minutes.

Boiling 460 grams of oats (in batches of four barebones portions) would then require about 3100 kilojoules, which is slightly more than half of the energy in the barebones basket. This would, of course, also supply some heat and light as a side effect, but only under a very short time of the day. However, this is based on very crude estimates and will try to find more elaborate estimates of this.

# Annex C: measured energy use

| **Reference** | **Type of data** | **Measure what** | **Calories per day** | **Other notes** |
|---|---|---|---|---|
| El-ghosh etal (2012, zz2663) | 15 anorexia patients measured with indirect caliometri | Lowest BMR | 652 | BMI for all fifteen patients: 14.5 (SD 1.45) |
| Henry (2005, zz2676) | "The oxford database" – big database form secondary sources | Lowest BMR for women 18-30 | Slightly lower than 720 | |
| Henry (2005, zz2676) | "The oxford database" – big database form secondary sources | Lowest BMR for men 18-30 | 720 | Weigh slightly less than 50kg |
| Polito etal (2000, zz2655) | 16 anorexia patients. Weight stable. | Lowest BMR | 795 | Group BMI is 15.5 (SD 1.2) |
| Ferro-Luzzi etal (1997 zz 2664) | Low-income persons in India with BMI <17. Weight stable. | Lowest BMR for women | 956 | Weigh about 33 kg. Group BMI is 15.7 (SD 0.9) |
| Westerterp (2013 zz2730) | 301 women in Netherlands measured with DLW | Lowest TEE | 1147 | Lowest BMI was 14.1 (not necessarily the same person) |
| Prentice etal (1985, zz2725) | 12 women from rich countries, normal weight, office workers | Lowest TEE | 1466 | |
| Westerterp (2013 zz2730) | 346 men in Netherlands measured with DLW | Lowest TEE | 1530 | Lowest BMI was 15.7 (not necessarily the same person) |

*Table: lowest individual observations in various studies. I note "weight stable" when it is specifically specified. That does not necessarily mean that the other cases were not weight stable.*