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How can it be a "constant standard" across countries or times when costs of "education, medical care and so forth" are not included?

Absolute Poverty: When Necessity Displaces Desire†

By Robert C. Allen*

A new basis for an international poverty measurement is proposed based on linear programming for specifying the least cost diet and explicit budgeting for nonfood spending. This approach is superior to the World Bank's $1-a-day line because it is (*i*) *clearly related to survival and well being*; (*ii*) *comparable across time and space since the same nutritional requirements are used everywhere while nonfood spending is tailored to climate*; (*iii*) *adjusts consumption patterns to local prices*; (*iv*) *presents no index number problems since solutions are always in local prices*; *and* (*v*) *requires only readily available information. The new approach implies much more poverty than the World Bank's*, *especially in Asia.* (*JEL* C61, I14, I31, I32, O15)

The World Bank's famous $1-a-day poverty line began life as the finding of a scientific inquiry in the 1980s, became the Bank's metric for measuring poverty in 1990, and reached full maturity when it was enshrined in the Millennium Development Goals as the standard for tracking poverty around the world. However, the line rests on contestable foundations that give rise to a host of theoretical and practical problems as well as leading, we argue, to underestimates of poverty in much of the developing world.[1] ~~While~~ the World Bank poverty line (WBPL) was originally conceived for developing economies, ~~it must now be applied to all countries in view of the United Nation's new Sustainable Development Goals, which came into effect on January 1, 2016. "Goal 1.1: By 2030, eradicate extreme poverty for all people everywhere, currently measured as people living on less than $1.25 a~~

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[1] The line as been much debated. Recent contributions include Ferreira et al. (2016), Deaton (2010), Reddy and Pogge (2010), and Ravallion (2010). Related research investigates subsistence lines (Lindgren 2015) and consumption floors (Ravallion 2016).

day” (Atkinson 2017, p. 13). If extreme poverty is to be measured everywhere, then the WBPL must be revised since it is not valid outside of the tropics. This paper proposes a new method for defining absolute poverty that avoids the many problems of the World Bank’s line and which makes a more robust tool for measuring extreme poverty on a global basis.

The statistical origins of the WBPL give rise to many of its difficulties. Ravallion, Datt, and van de Walle (1991) were looking for a measure of absolute poverty. They collected poverty lines for 33 countries ranging from the very poor to the rich, converted the lines to US dollars with a purchasing power parity (PPP) exchange rate and plotted the lines against per capita consumption. They noticed that the lines of the six poorest countries were clustered around \$1 per day in 1985 dollars, and that became their measure of absolute poverty. The dollar value was raised to \$1.08 in 1993 dollars when Chen and Ravallion (2001) updated the same data with national price indices.

The empirical base of the WBPL was greatly strengthened in the new millennium when Ravallion, Chen, and Sangraula (2009) put together a new dataset of 74 national poverty lines. Once again, poverty lines increased with income, but, in this case, no such trend was apparent in the 15 poorest countries.[2] Ravallion, Chen, and Sangraula concluded that these lines represented “absolute poverty.” Converting them to US dollars with PPP exchange rates produced the \$1.25 poverty line in 2005 dollars. Most recently, the poverty lines of these 15 countries in their own currencies were raised with national price indices to 2011 values and then converted to US dollars with PPP exchange rates computed from the 2011 round of the International Comparison Program (ICP2011) price data. The average came to US\$1.88, which was rounded up to \$1.90, to give the current WBPL (Ferreira et al. 2016). Similar values have been reached by other methods (Kakwani and Son 2016; Sillers 2015; Jolliffe and Prydz 2016). This “strange alignment of the stars” has increased the line’s credibility (Atkinson 2017, pp. 19–20).

The line is only as good as these procedures, and they raise many troubling issues. First, which countries should be used to define “absolute poverty”? Should the reference group be updated? Deaton (2010) pointed out that India was in the original 1991 sample of poor countries but grew so much in the next 15 years that it was not in the 2005 group of 15 poor countries. However, the Indian poverty line was very low, so excluding it in 2005 raised the average and the WBPL with it. This meant that the number of poor in India and elsewhere increased markedly despite India’s economic growth, a perverse result, indeed!

Not perverse if the line was raised after costs rose.

Second, measuring the prices is tricky. In some countries the data are nationally representative; in others, they describe major cities only. In big countries like India and China where regions are not well integrated, the relative prices for the whole country in the ICP may not represent the price structure of any of its regions. The prices come from surveying shops, but in the case of small farmers, who eat some of their crop and sell the rest, the price of their food is the price they could have sold it for, not a price in a shop. And how should we define the commodity? The ICP takes a very fine grained approach and tries to compare rice to rice (indeed, the

[2] The countries are: Malawi, Mali, Ethiopia, Sierra Leone, Niger, Uganda, Gambia, Rwanda, Guinea-Bissau, Tanzania, Tajikistan, Mozambique, Chad, Nepal, and Ghana.

same grade of rice) and wheat to wheat. But if the poor eat only wheat in a wheat growing country and rice in a rice growing country, might it not be better to compare the price of "grain" and measure that as the price of wheat in the first instance and rice in the second (Deaton 2010)? As it is, the ICP contains the prices of many commodities that have virtually no sales. The ICP2011, for instance, reports the price of mackerel in Zimbabwe, and that is an input into the food component of Zimbabwe's PPP exchange rate, but mackerel is not eaten by the poor in this landlocked country and is probably only available in a specialized shop in Harare.

Housing presents special problems. ICP2011 contains rental (and purchase) values for housing in some developing countries, and these are usually broken down along traditional/modern lines and whether or not they possess running water, electricity, indoor kitchens, and so forth. Location, which is of cardinal importance, is not explicitly dealt with, but presumably the rents are nationally representative. The problems in measuring the volume and price of housing services across countries are so difficult that in 2005 the volume of housing services in Africa and Asia was estimated as a constant percentage markup on the rest of consumer expenditures. The implied prices of housing services were highly erratic (Deaton and Heston 2010). This approach is not systematic enough for poverty measurement, especially when applied to rich countries.

Third, the usual index number issues surrounding formulas and weights bedevil both the PPP exchange rates and measurement of inflation in national statistics. Conversions from local currencies to US dollars are typically done with the PPP exchange rate for household consumption. The spending pattern of the poor differs from that of the average household: does that distort the result? Not as much as one would think (Deaton and Dupriez 2011). However, the spending pattern of the average household in Niger, for example, does differ dramatically from that of the average household in the United States. If Törnqvist-Divisia indices are used, then the US shares are averaged with Niger's to form the weights. These weights will bring into the calculation many goods and services that are never consumed by Niger's poor (Deaton 2010).

They did not look at prices faced by the poor?

Fourth, the existential meaning of poverty depends on the national poverty lines in the group defined as poor. What is their content? The poverty lines in the original Ravallion, Datt, and van de Walle (1991) study did not exhibit a common standard (Allen 2013). The sample of poverty lines for the 74 countries underlying the 2005 poverty line is put together more systematically. The usual procedure involves four steps. First, set a calorie requirement. Twenty-one hundred calories per person is often used, but, in fact, there is considerable variation. Second, using data from a household expenditure survey for the country, find a band of the income or consumption distribution where average calorie consumption equals the chosen standard. Third, set the poverty line equal to the income or consumption per head for the band choosing the calorie standard. The "food" budget is what is spent on food and the rest of spending is "nonfood." No effort is made to investigate these aggregates further. Fourth, convert this national poverty line, which is in local currency, into US dollars with a PPP exchange rate.

Many features of this procedure are problematic. First, should a uniform calorie standard be set or should it vary over time and across space (reflecting differences in work intensity) or demographic structure? In the event, a uniform calorie standard is not maintained. Atkinson (2017) found that it varied between 2,030 and 3,000 calories per adult in 10 poor countries, raising obvious questions of comparability. Second, how adequate is the rest of the food budget in terms of protein, fat, vitamins, and minerals? Is it austere or luxurious? Third, how Spartan should the nonfood budget be? How should it vary with climate? Since most of the 15 poor countries are in the tropics, it is unlikely that the average nonfood budget includes enough fuel and clothing to survive a Russian winter, for instance. Finally, even though the procedure is clear, it suffers greatly from a lack of transparency. Since the Bank does not explore and assess what makes up "food" and "nonfood" spending, there is no persuasive answer to the question "how can you live on $1 a day?" Indeed, we show that people in the United States, the United Kingdom, and France could not live on the 2011 version of that line.

The World Bank is committed to ending "chronic extreme poverty by 2030." To know if it is succeeding, the Bank must measure poverty, and, in view of the many difficulties in so doing, it "convened a high-level Commission led by Sir Anthony Atkinson … to advise the World Bank on the methodology currently used for tracking poverty in terms of people's consumption, given that prices change over time and purchasing power parities across nations shift."[3] While Atkinson was aware of the many difficulties with the current poverty line and favored further research to improve it (including the approach of this paper), he nevertheless endorsed the continued use of the local currency equivalents of the $1.90 line with the only adjustment being to raise them over time in line with inflation in local prices. There are two reasons for this approach. First, Atkinson's terms of reference were narrow. "The Commission was asked to take the 2015 estimates as its point of departure and to assess how the process may be carried forward to monitor progress up to 2030 in achieving SDG goal 1.1." Second, "the $1.90 [line] has acquired an independent political status." Better to stick with imperfect goal posts rather than muddle the scoring by shifting the goal posts in the middle of the match (Atkinson 2017, Ferreira et al. 2016).

No - 3%.

While Atkinson's recommendation makes administrative sense, it does not resolve the underlying scientific and philosophical difficulties. Ideally, the international poverty line should satisfy five criteria: (i) It should have a clear meaning related to survival, health, and well being. In terms of Sen's (1987, 1992) theory of capabilities, the poverty line should sustain basic functionings like being active, growing, and healthy. The line should also (ii) represent a constant standard across time and space; (iii) respond to local prices and other pertinent local factors like climate; (iv) avoid intractable index number problems; and (v) require only readily available information.

This paper develops an approach that satisfies these requirements. The paper operates on both the normative and the positive plane. On the normative plane, I propose that the poverty line be set by explicitly budgeting for basic needs. This is a long standing tradition that is still widely used in Europe and the United States when "reference budgets" are drawn up to specify poverty lines (Rowntree 1901, Goedemé et al. 2015, Carlson et al. 2007). The basic needs poverty line (BNPL)

[3] These quotations are from the Forward to the report by Kaushik Basu, Chief Economist and Senior Vice President of the World Bank Group (Atkinson 2017, p. vii).

developed here has three categories of spending: food, nonfood goods, and rented housing. My approach uses linear programming to set the diet portion of the poverty budget and early twentieth century budget studies for industrial workers in St. Petersburg and Bombay to make nonfood spending climate dependent. Housing is also explicitly budgeted. This approach avoids all of the problems of the World Bank's methodology. I illustrate the method here using a sample of 20 countries ranging from Niger and Zimbabwe to France, the United Kingdom, and the United States.

An objection to linear programming diets is that they are unrepresentative of actual behavior and so of no use in setting a poverty line or for any other practical purpose. The second plane on which the paper operates is positive and aims to assess the predictive power of linear programming diets. I agree with the conventional view (Stigler 1945) that linear programming utterly fails to explain the diets in rich countries. It is a different story in developing countries, however. Linear programming does a reasonable job in explaining the total quantity of food and its distribution among broad categories. The linear programming diets are predominantly vegetarian. Grain bulks are very large. Small quantities of animal proteins and oil are also consumed. Linear programming usually predicts the predominant grain consumed in a country. It cannot predict the variety of fruits and vegetables that the poor eat, nor can it explain the universal consumption of small quantities of sugar nor eating associated with festivals. There is a small amount of "wiggle room" in which people have some space to consume a little sugar, favorite spices, or traditional foods at the expense of a healthy diet. But it is the nature of poverty that the latitude for these substitutions is limited, certainly in comparison to rich countries.[4]

I. Specifying the Poverty Line Diet with Linear Programming

The diet problem was the first linear programming problem ever formulated in a famous paper by Stigler (1945). The problem is to choose a diet from a list of foods that minimizes the cost of meeting a set of nutritional requirements. The objective function to be minimized is the cost of the diet:

$$Cost = \sum p_i F_i, \tag{1}$$

where p_i is the price of a food and F_i is the quantity of the food consumed. The summation can extended over a list of t foods $F_1, \ldots, F_t$, many of which will not be selected in the solution.

The nutritional requirements are specified with a set of inequalities, each of which sets the requirement for one nutrient:

$$\sum n_{ji} F_i \geq R_j. \tag{2}$$

Here the summation also runs over all of the foods indexed with i; R_j is the required amount of nutrient j—the minimum calorie requirement, for instance; n_{ji} is the

[4] This is a specific sense in which economic development creates freedom (Sen 1999).

quantity of nutrient j per unit of food F_i, for instance, n_{ji} might be the number of calories per kilogram of wheat flour and F_i, the kilograms of wheat flour in the diet. Each nutrient required in the diet has an inequality describing that requirement.

Finally, the consumption of each food has to be at least zero:

$$(3) \qquad F_i \geq 0 \quad \text{for all } i.$$

The linear program model presents a neat contrast to the standard model of consumer choice in its dual form. In that form, consumer goods are chosen to minimize the cost of meeting a specified utility level U^*. The difference with the linear programming model is that the inequalities (2) are replaced by the utility constraint

$$(4) \qquad U(F_1, \ldots, F_t) \geq U^*.$$

This is the formal sense in which necessity displaces desire in the definition of absolute poverty.

These days, linear programs can be easily solved with the simplex algorithm in Excel. The solutions have two properties that are important for defining the poverty line. First, increasing the number of requirements or increasing the magnitude of a requirement either leaves the cost of the diet unchanged or increases it. A more nutritious diet is never cheaper than a less nutritious diet and may well cost more. Second, the maximum number of foods that solves the problem is equal to or less than the number of requirements. The number of requirements, therefore, limits the variety of the diet.

In his original investigation of the diet problem, Stigler (1945) used US prices from 1939 and 1945 to compute the cost of the least cost diet meeting a set of requirements including calories, protein, iron, niacin, calcium, vitamin C, vitamin A, thiamine, and riboflavin with values appropriate to a "moderately active" man weighing 154 lbs. Stigler did not have Excel at his command but nevertheless reasoned his way to almost the correct answer. The solution for 1939 was 168 kg of wheat flour, 129 kg of dried navy beans, 23 kg of evaporated milk, 50 kg of cabbage, and 10 kg of spinach. The values warrant comparison with ones we compute for developing countries in 2011.

Stigler's reaction to the solution has also been important; he thought the diet was impractical. "No one recommends these diets for anyone, let alone everyone; it would be the height of absurdity to practice extreme economy at the dinner table in order to have an excess of housing or recreation or leisure" (Stigler 1945, pp. 312–13). This theme has been taken up by subsequent economists, who have tried to incorporate "palatability" into the program. Smith (1959, p. 272) remarked that Stigler's diet was "a dramatic illustration of how little purely nutritional needs have to do with the level of actual food expenditures … If we want diets that someone might be willing to eat, we need models that take account of tastes and habits." This is surely true of people in rich countries whose behavior is determined by preferences, income, and prices. Linear programming is much more germane to poor people, however. For them, survival is the issue, and the needs for survival take precedence. Preferences and income give way to nutritional requirements in determining consumption with prices still playing a role. Indeed, from the linear programming perspective, what it means to be poor is that your life is governed by linear programming, rather than standard consumer theory.

"Nutritional requirements" has an aura of scientific objectivity, and Stigler (1945) and Smith (1959) adopted lists of requirements issued by nutritional boards without criticism or examination. Indeed, it was the desire for an objective standard for poverty that motivated the research described here. However, it is clear on examination that the nutritional requirements set by bodies like the World Health Organization are, in important respects, subjective.[5] First, precise values for some nutrients such as calories and protein can be specified with reasonable accuracy, but for others that is not possible. Niacin, for instance, is necessary to prevent pellagra, and field observations suggest widespread appearance of pellagra in populations where adult men receive less than 7 mg of niacin per day. However, the current WHO requirement for adult men is set at 21 mg on the grounds that the higher value contributes to better health (Prinzo 2000; Rao 2009). The poverty line distinguishes the "poor" from the "nonpoor." Should the line be set at 7 mg or 21 mg or somewhere else? I have adopted the recommendations of the medical authorities, but the uncertainties should be recognized. Second, for this reason, most of the world's population is deficient in some nutrients. Ninety percent of the Indian population, for instance, is anemic by current standards, which means they are deficient in iron, thiamine, or folic acid. Evidently, many "nonpoor" are deficient in these regards, so that full adequacy with respect to iron does not distinguish the poor from the nonpoor. Perhaps "moderate anemia" should be the dividing line with correspondingly reduced nutritional requirements? Third, for geographical reasons, some required nutrients are not available to most of the world's population. Iodine, for instance, is naturally available only to people living near oyster beds. Unless iodized salt is available, most people in the world would be iodine deficient, so there is no point including it as a requirement in a programming model defining a poverty line. Fourth, none of these standards takes into account the seriousness of the impairment to life that results from the deficiency. It may be that most people are unconcerned about vitamin A deficiency because night blindness does not appear a costly disability—at least not sufficiently detrimental to require the expenditure necessary to eliminate it.

These uncertainties affect the linear programming approach to diet in two important ways. First, we omit from consideration nutrients whose availability are locationally specific. Iodine is an example, as is vitamin D. People are not vitamin D deficient in sunny climates, although they may be deficient in cloudy, wet places. The poverty line is meant to distinguish the poor from the better off, and the availability of iodine and vitamin D does not do that.

Second, with respect to other nutrients, the linear programming approach takes on the character of an estimation exercise rather than a purely objective determination of the optimal diet. One question we ask is whether there is a set of nutritional standards that is common across the world and that rationalizes the diets that poor people consume. We argue that the answer is (approximately) yes, and that is the standard incorporated in our measure of poverty. In this sense, the choices made by

[5] For a list of relevant WHO publications, most available online, see http://www.who.int/nutrition/publications/nutrient/en/.

the poor imply the poverty line; the poor have a voice in defining poverty, even if they are not aware of it.

II. Data and Empirical Specification

To compare our results to the WBPL of $1.90 per day in 2011, we need prices from 2011. The principal data source is the ICP2011 core spreadsheet and the regional spreadsheets for Africa and Asia.[6] The ICP is a tremendous achievement, but it was necessary to fill some lacunae and add accommodation rental prices derived from other sources (see the online Appendix). I investigate the implications of these prices for 20 countries ranging from the poorest to the richest (Table 1 onward).

Countries are a natural unit of analysis since poverty is a national political issue and since countries share a common currency, but there are also reasons for choosing a regional approach. Prices differ across regions in large countries with poor infrastructure or other impediments to trade, and those differences imply different poverty lines. Climate also varies within countries. The World Bank has set different lines for urban and rural parts of India, China, and Indonesia. However, it is not possible to explore these issues using the ICP, which is the basis for international comparisons, since it reports only one price for each good in each country. When regional issues look likely to be important, they will be noted.

A. *Least Cost Diets: 1,700 Calorie Model*

We begin by examining the diets implied by various nutritional requirements.[7] We consider them in an increasingly stringent progression. There are four models in the sequence. Each contains all of the nutrients of the previous step and increases the quantity of those nutrients or adds additional nutrients or both.[8] The models are:

- *1,700 calorie* model: The only requirement is 1,700 calories per day.
- *CPF* model: Three nutrients are required: 2,100 calories per day, 50 g of protein, and 34 g of fat.
- *Basic* model: CPF requirements plus the Indian recommended daily allowances (RDA) of iron, folate, thiamine, niacin, and vitamins C and B12.
- *Full course* model: Basic model plus RDA of six more vitamins and minerals.

We begin with the most elementary requirement: calories. What is the minimum cost of a diet that supplies just enough calories for survival? By "survival" we do not mean the minimum for a single adult to subsist from one day to the next but

[6] The core prices were taken from *ICP2011: Data for Researchers*, the African prices from *ICP2011_AFR_Regional2011*, and the Asian from *ICP2011_ASI_Regional2011*. I am grateful to Nada Hamadeh and the World Bank for making these data available to me.

[7] Each requirement is expressed as an inequality in the form of equation (2). The quantity of each nutrient per kilogram of food (n_{ji}) must be specified. Generally, the values used were those shown on the US Department of Agriculture National Nutrition Database website. Some values, however, were taken from the regional nutritional databases listed in the online references. These databases often do not agree with each other, and it might be important to investigate these discrepancies, but that has not been done here.

[8] Details about the linear programs are found in the online Appendix section "Notes on the linear programming."

Table 1—1,700 Calorie Model Diets (*Kilograms per Person per Year*)

	Wheat flour	Bread	Rice	Maize	Millet	Beans/lentils	Oil
Developing countries							
Niger							70
Zimbabwe				178			
Gambia				176			
Liberia			172				
Egypt				172			
Algeria	170						
India							70
China							70
Thailand							70
Indonesia							70
Bangladesh			172				
Myanmar							70
Sri Lanka			175				
Vietnam							70
Middle-income OECD							
Turkey				172			
Mexico				171			
High-income OECD and Eurostat							
Lithuania	170						
United Kingdom	170						
United States							70
France	170						

Source: Author's calculations

rather the minimum, on average, for the species to survive. Adults must have enough energy to work and children to grow.

Children to survive with what probability?

Adults to what age?

The minimum society-wide average can be established in two ways. One is by calculation.[9] The distribution of the population by age and sex is determined, and the energy required for basal metabolism for each age-sex group is calculated with standard formulae. The results depend on the average height of each group and the Body Mass Index that each is expected to maintain. Additional allowances are also required for pregnant and lactating women. Basal metabolism of each group is then increased by its physical activity level (PAL). Determining the PAL requires constructing an activity schedule across the year, so that the appropriate markup can be applied to each hour (the physical activity ratio or PAR) depending on exertion. More strenuous activities get higher PARs. The PAL can then be computed as the average of the PARs over the year.

But if they are malnourished, they can do less and need more.

Height? Is there not a problem here if people are stunted by malnutrition?

Calculations along these lines point to around 2,000 calories per person per year as the average requirement. This provides enough for some people to work very hard and for children to have enough energy to grow. The requirement varies depending on the age distribution of the population: faster growing populations have more children and a lower average calorie requirement. Calculations by the Food and Agricultural Organization (2008b) indicate a requirement of 1,600–2,000 calories per person per day. The US Department of Agriculture (Shapouri et al. 2010) uses a standard of 2,100 calories per person per day (with an unspecified variation across

[9] FAO (2001) explains the methodology.

regions) in assessing food security. I have computed the same figure for Britain in 1841 assuming that the average man was a carpenter and the average woman a domestic spinner (Allen 2013).

An issue that arises with respect to energy requirements is the question of whether the shift from farm work to urban work as well as the mechanization of farm tasks has led to reductions in the need for calories (Deaton and Drèze 2009). Probably not by much. The model of Britain in 1841 can be used to calculate bounds by comparing the average energy requirement if (i) all men performed strenuous work on a continuous basis with the requirement and (ii) half performed moderate work and the other half light work. Energy consumption averaged over the population drops by about 250 calories per day. This drop must overstate the actual change since not all men did strenuous activity all of the time in the "olden days," but it is difficult to explore this further in the absence of detailed information on work intensity and how it has changed. I have made no adjustment for this effect.

The second approach to determining calorie requirements is to look at what people actually consume. Survey data for India shows that the poorest decile of the population consumes about 1,450 calories per person per year (Deaton and Drèze 2009; Suryanarayana 2009). This is below basal metabolism, so it is either an error, or it indicates an unusual demographic structure (which means it is not relevant for society as a whole), or the population is dying out (in which case the standard is too low).

The second decile from the bottom consumes on average 1,700 calories per person per day (Suryanarayana 2009). This is just above the lowest FAO value and about the bare minimum a group requires for survival.

For how long?

In view of these considerations, linear programming diets were calculated with the only constraint being 1,700 calories per person per day. The implied diets are in Table 1. With only one constraint, there can be only one food in the solution to the programming problem. For 12 countries that is a cereal or flour (170–178 kg/year depending on the kind or about a pound per day). For the other eight, it is vegetable oil (70 kg/year or about one cup per day). These are small quantities, which suggests that people eating them might be hungry. The solutions of the linear programs are in kilograms of the various foods, and the total provides a rough indicator of nutritional intake that we use to gauge the effect of increasingly stringent nutritional requirements. Total weight of a diet also provides a summary statistic to compare predicted consumption with actual diets.

The appearance of oil is unexpected, and it is probably also a recent phenomenon in world history. It reflects the widespread cultivation of palm oil in south Asia, a development of the late nineteenth century. Before that, rice or some other grain was the cheapest source of calories around the Pacific Ocean.[10]

It is a tricky question whether man can live by maize alone, but surely he cannot live solely on vegetable oil. Aside from fat, it supplies no nutrients. A population could not survive on the vegetable oil diet. Requiring only calories leads to death rather than survival.

[10] Linear programs like those reported in this paper have been run with price data collected by Lockyer (1711) in Canton in December, 1704. Rice rather than oil was the solution to the 1,700 calorie model, indicating that oil was a more expensive source of calories than rice.

B. *Least Cost Diets: CPF Model*

More satisfactory diets are implied by imposing more requirements. The second class of requirements are the principal nutrients: calories, protein, and fat. In the calculations, we increase the calorie requirement to the USDA value of 2,100 per day. This allows people a more ample supply of energy to do the work that sustains society as well as raising children. Protein is set at 50 grams per person per day. The ultimate basis of this value is experiments that measure the nitrogen intake required to match the body's excretion of nitrogen and thus to maintain the body's nitrogen stocks. Fat is set at 34 grams per person per day, the amount that supplies 15 percent of the energy intake (FAO 2008c). These requirements depend on body mass, age, sex, pregnancy, lactation, and so forth. In these cases (as with all other nutrients to be considered), the value of the requirement used in the linear program is calculated from age and sex specific requirements as a society-wide weighted average using the age and sex distribution of the Indian population as weights.[11] Recommended values for India are used, as they are more likely to reflect conditions in developing countries today than global recommendations.[12] The protein requirement lies at about the thirtieth percentile of the Indian income distribution, while the fat requirement is in the middle (Suryanarayana 2009).

Tables 2 and 3 summarize key features of the diets as functions of the nutrient requirements. Table 2 shows average annual food consumption in kilograms. With the 1,700 calorie diet, the average was 131. This increased to 200 kilograms with the CPF diet. The number of foods in the diet also increased (Table 3). There was only one food chosen with the 1,700 calorie diet. The linear programming solution allows up to three foods with the CPF diet. Three foods are chosen in eight cases and two foods in 12 for an average of 2.40 foods.

The diets that solve the linear program with the principal nutrients as constraints are shown in Table 4. Consumption of oil is cut dramatically to plausible levels, and some is used everywhere. Wheat is the staple in wheat growing areas, as is rice in southeast Asia, and millet, sorghum, or maize in sub-Saharan Africa. Legumes are consumed in six of the cases including all of the rice based diets. It is significant that the diets are purely vegetarian, and that no alcohol, sugar, or vegetables (other than the legumes) are consumed. There is no sugar, no alcohol, and very little meat in any of the diets implied by linear programming.

C. *Least Cost Diets: Basic Model*

While the CPF diets provide better nutrition than the 1,700 calorie diet, they none-the-less suffer many deficiencies. We begin with those that could lead to four of the most common and serious deficiency diseases. Pellagra is due to insufficient

[11] The nutritional requirements are from Rao (2009) and the population structure from http://esa.un.org/unpd/wpp/Excel-Data/population.htm. There is more variation in the recommendations of professional bodies regarding fat than for other nutrients, and I have opted for a low requirement.

[12] The RDAs include an allowance for losses during cooking. "Considering the cooking loss of 50 percent, the RDA of ascorbic acid has been set at 60 mg/day" (Rao 2009, p. 287). An advantage of using Indian RDAs is that the cooking losses are assessed in terms of Indian culinary practices, which are probably more representative of developing, tropical countries than the cooking practices in the West. See Rao (2009) for more examples.

Table 2—Total Weight of Linear Programming Diets (*Kilograms per Person per Year*)

	1,700	CPF	Basic	Full course
Developing countries				
Niger	70	187	264	356
Zimbabwe	178	214	325	329
Gambia	176	213	250	325
Liberia	172	197	303	636
Egypt	170	232	265	371
Algeria	172	195	415	471
India	70	191	295	397
China	70	191	250	763
Thailand	70	206	264	275
Indonesia	70	198	330	472
Bangladesh	172	197	353	406
Myanmar	70	200	249	406
Sri Lanka	175	206	274	433
Vietnam	70	196	271	530
Middle-income OECD				
Turkey	172	214	320	386
Mexico	171	195	303	317
High-income OECD and Eurostat				
Lithuania	170	195	506	575
United Kingdom	170	195	286	371
United States	70	191	278	319
France	170	195	370	388
Average	131	200	344	426

Source: Author's calculations

Table 3—Number of Items in Linear Programming Diets

	1700	CPF	Basic	Full course
Developing countries				
Niger	1	2	4	6
Zimbabwe	1	2	5	6
Gambia	1	2	6	6
Liberia	1	3	5	7
Egypt	1	3	5	6
Algeria	1	2	5	6
India	1	2	5	5
China	1	2	4	6
Thailand	1	3	6	7
Indonesia	1	3	6	6
Bangladesh	1	3	6	6
Myanmar	1	3	6	7
Sri Lanka	1	3	5	5
Vietnam	1	3	6	8
Middle-income OECD				
Turkey	1	2	4	6
Mexico	1	2	4	5
High-income OECD and Eurostat				
Lithuania	1	2	5	8
United Kingdom	1	2	4	7
United States	1	2	4	8
France	1	2	5	7
Average	1	2.4	5	6.4

Source: Author's calculations

Table 4—CPF Diets (*Kilograms per Person per Year*)

	Wheat flour	Bread	Rice	Maize	Millet and sorghum	Beans and lentils	Milk	Fish	Eggs	Cheese and Beef	Oil	Potatoes	Cassava	Spinach, cauliflower, peanuts
Developing countries														
Niger					167						20			
Zimbabwe				210							4			
Gambia				210							3			
Liberia			153			33					11			
Algeria	185										11			
Egypt		124		101							7			
India	177										14			
China	177										14			
Thailand				174		26					5			
Indonesia			153			34					11			
Bangladesh			153			33					11			
Myanmar			153			36					11			
Sri Lanka			172			26					7			
Vietnam	163		22								11			
Middle-income OECD														
Turkey	147			59							7			
Mexico	177										18			
High-income OECD and Eurostat														
Lithuania	185										11			
United Kingdom	185										11			
United States	177										14			
France	185										11			

Source: Author's calculations

niacin, beri-beri to a lack of vitamin B1, scurvy to insufficient vitamin C, while anemia can be due to inadequate levels of either iron, thiamine, or folate (folic acid). Table 5 reports nutritional consumption relative to recommended daily allowances for these nutrients in the CPF diet.

In most cases, the CPF least cost diets meet the requirements for calories, protein, and fat exactly, and, when the requirements are over fulfilled, the excess is minor. So far as the minerals and vitamins are concerned, the diets supply no vitamin B12—this is found only in animal products—and none or only negligible quantities of vitamin C. The absence of vitamin B12 means that anemia would be widespread unless consumption of B12 were inadvertent. In India, "since populations subsisting essentially on foods of vegetable origin do not show evidence of widespread vitamin B12 deficiency, it is speculated that polluted environment and unhygienic practices could be providing the necessary minimal vitamin B12" (Rao 2009, p. 278). The lack of vitamin C implies widespread scurvy.

There is a likelihood of other deficiency diseases as well. Two kinds of diets are particularly deficient. The first are the rice-based diets deduced for Vietnam and Myanmar. These diets have low enough niacin levels to suggest widespread pellagra and low B1 levels indicating a risk of beri-beri. It is significant that the short-grain, milled rice which they consume is particularly lacking in these nutrients. In contrast, the brown rice consumed in Sri Lanka supplies more niacin and thiamine, so the deficiency problems are not so severe.

The second kind of diet that indicates a likelihood of deficiency diseases is the wheat-based diet of France, Algeria, and Lithuania. Refined wheat flour in these countries is not enriched, so it lacks niacin and thiamine. Otherwise similar diets

Table 5—CPF Diet: Vitamins and Minerals Relative to RDA (*Percent*)

	Iron	B12	Folate	B1 (thiamin)	Niacin	C
Developing countries						
Niger	72	0	76	121	53	0
Zimbabwe	93	0	76	180	82	0
Gambia	105	0	83	168	86	0
Liberia	48	0	261	96	61	10
Egypt	80	0	349	240	142	0
Algeria	31	0	73	54	43	0
India	30	0	70	52	41	0
China	30	0	70	52	41	0
Thailand	84	0	312	143	72	8
Indonesia	50	0	346	78	60	11
Bangladesh	48	0	261	96	61	10
Myanmar	71	0	223	64	49	0
Sri Lanka	59	0	318	233	182	8
Vietnam	30	0	66	51	44	0
Middle-income OECD						
Turkey	98	0	85	142	167	0
Mexico	239	0	1,030	698	353	3
High-income OECD and Eurostat						
Lithuania	31	0	73	54	43	0
United Kingdom	117	0	781	337	193	0
United States	117	0	781	337	193	0
France	31	0	73	54	43	0

Source: Author's calculations

in the United States, United Kingdom, Turkey, and Mexico do not lead to these inadequacies because the enrichment of wheat flour is mandatory. The comparison indicates the benefits of mandatory food fortification.

In terms of the linear programming, the deficiencies can be cured by imposing the requirements on the solution. As noted previously, we compute the requirements from the Indian recommended daily allowances by computing the weighted average of the RDAs for the various age and sex groups. The results are shown in Table 6.

The additional requirements have major implications for the linear programming solutions. The first is that the volume of food consumed over the year goes up from 200 kg with the CPF diet to 344 kg. More food gives more nutrients.

The second change is an increase in the number of foods from 2.40 on average in the CPF diet to 5.00. The increase is due mainly to the addition of an animal product and a vegetable. Animal products enter the solution as a consequence of requiring vitamin B12. The linear programming solution generally implies either the cheapest available fish (usually mackerel) in coastal districts or milk in inland regions. Meat in any form rarely appears in the solution to a linear program. The appearance of vegetables (most commonly cabbage) or cassava is due to the vitamin C requirment. The B12 and C requirements are independent of the others, so adding these requirements to the program has scant impact on the rest of the diet. Qualitatively, the pattern of food consumption is similar in the CPF and reduced basic model. The same grains are generally consumed in the same regions. Total food consumption rises because of the introduction of animal protein and vegetables.

The increase in total food consumption has another implication that becomes increasingly important, namely, the overshooting of requirements. With the CFP

Table 6—Basic Diets (*Kilograms per Person per Year*)

	Wheat flour	Bread	Rice	Maize	Millet and sorghum	Beans and lentils	Milk	Fish	Eggs	Cheese and Beef	Oil	Potatoes	Cassava	Spinach, cauliflower, peanuts
Developing countries														
Niger					186					26	3		50	
Zimbabwe				148	65		70				2			41
Gambia				137	51			7			4		48	2
Liberia			167			82		7			10		38	
Algeria		248				59	70				5			34
Egypt	79			106					35		4			41
India	36				138		70				10			41
China					191					14	4			41
Thailand	17			168		10				14	4			52
Indonesia			145			30		7			6			141
Bangladesh		33	156			2		7			9			146
Myanmar			92			57		7			1		73	19
Sri Lanka			140			49			35		4			45
Vietnam			82			55		20			3		96	16
Middle-income OECD														
Turkey	69			124			70				4			53
Mexico				189			70				3			41
High-income OECD and Eurostat														
Lithuania	75					26		7			11	387		
United Kingdom	177						70				8			31
United States	150						67				21			41
France	282					54					8			26

Source: Author's calculations

diet, most solutions meet the calorie, protein, and fat constraints exactly. The average degree of overshooting is only a few percentage points. Overshooting is more widespread with the basic diet. Three of the solutions overshoot calories, and the average excess is 7 percent. Virtually all of the diets overshoot protein, and the average excess is 32 percent. Most solutions meet the fat requirement exactly, but the requirement is nonetheless exceeded by an average of 13 percent.

D. *Full Course Model*

The vitamins and minerals considered thus far are only a subset of all of the nutrients that might be considered. Recommended daily allowances have been set for many others. To explore the implications of some of these, requirements for vitamin A, B6, riboflavin, calcium, magnesium, and zinc have been added to the linear program.

The exercise has a surreal air because of difficulties in defining and assessing deficiencies. In the case of vitamin B6, for instance, it is difficult to measure the extent of deficiency in the population (Rao 2009). Setting RDAs is difficult in some cases (vitamin B6) and fraught with conflicting considerations in others. Calcium requirements depend on vitamin D and protein intake. Low protein consumption reduces calcium requirements meaning that standards set for rich people are too high for poor people, and by some measures most Indians look like they get enough calcium. On the other hand, femur fractures occur at younger ages amongst poor women in India suggesting there might be an issue about calcium adequacy after all (Rao 2009). At what level should the calcium RDA be set? In other cases, it is not clear how serious the deficiencies might be. A lack of vitamin A leads to night blindness, but how costly is that (Rao 2009)? In other cases, deficiencies are so common or so rare that the intake of the nutrient provides little information about poverty or wealth. Thus, "dietary deficiency of riboflavin is rampant in India … only about 13 percent of households meet the dietary requirement" (Rao 2009, p. 251). In contrast, "the available reports … in India … do not report any widespread zinc inadequacy" (Rao 2009, p. 225). In neither case, does the RDA provide a boundary that distinguishes poor people from better off people.

Introducing these additional vitamin and mineral requirements implies increased food intake. The number of foods in the diets rises from an average of 5.00 with the basic diet to 6.4. In addition, more nutrients are obtained by increasing the quantity of food consumed in a year from an average of 344 kg with the basic diet to 426. The increase is greatest among the developing countries where average food consumption rises to 440 kg. The Chinese diet reaches a staggering 763 kg. Increasing the volume of food to this extent leads to considerable overshooting of calorie requirements (by 10 percent) and especially protein requirements (by 39 percent on average).

Comparison of the details of the full course diet (Table 7) to the basic diet (Table 6) shows some unusual changes. The consumption of wheat flour falls, while the consumption of legumes, cassave, vegetables, and potatoes reach extreme limits. These features raise questions about the empirical relevance of the diets.

The full course diets have affinities with Stigler's original linear programming diets. The same foods turn up, and the quantities are of similar magnitudes. The reason is that Stigler's nutritional requirements include calories and protein as well as most of the vitamins and minerals considered here. Stigler's specification did not include a fat requirement, and its absence explains why there is no oil or butter in his solution.

III. Linear Programming Diets and the Diets of the Poor

Stigler warned us that linear programming diets provided no guidance for the behavior of Americans, and indeed, the solutions he found do not describe what Americans ate in the 1930s and 1940s. Does this judgment apply to people in 'absolute poverty' in developing countries today? With some qualification, the answer is no. Linear programming explains many features of their behavior.

We have examined a range of four linear programming solutions reflecting different levels of required nutrition. Not all of these explain behavior. For many countries, a pure vegetable oil diet was the solution for the 1,700 calorie diet. That diet cannot sustain life and no one consumes it. The CPF diet looks more promising, but it does not include any animal products or any fruits, cassava, or vegetables (with the exception of beans in the rice based diets). Most vegetarians consume dairy products or eggs, and fruit and veg are almost universally consumed, as will be shown, so the CPF diet does not describe human behavior well. At the other extreme, the full course diet predicts too much food consumption. Food consumption of 440 kg per year greatly exceeds per capita consumption in much of the world in the 1960s and so does not describe what the poor were eating. We are left with the basic model as the best candidate for describing behavior.

We can compare the predictions of the basic model with food consumption to assess its merits. Ideally, one would test the model against the spending patterns for

Table 7—Full Course Diets (*Kilograms per Person per Year*)

	Wheat flour	Bread	Rice	Maize	Millet and sorghum	Beans and lentils	Milk	Fish	Eggs	Cheese and Beef	Oil	Potatoes	Cassava	Spinach, cauliflower, peanuts
Developing countries														
Niger				149	104					26			47	30
Zimbabwe				100	103		70				2			53
Gambia					260			5		8			12	41
Liberia			37			40		2	24		8		502	24
Algeria		220				49	118				4	43		37
Egypt		126		83		3			35		4			120
India	148				31		70				6			142
China	19				139			41			2			561
Thailand	46			92		20	52			4	3			57
Indonesia			175			11		7			10		53	217
Bangladesh		9	194			12		7			9			175
Myanmar			117			27		7			6		68	181
Sri Lanka			178		3				35		3			214
Vietnam						49	16	2	26		2		403	32
Middle-income OECD														
Turkey	174			20			70				6			117
Mexico				187			70				3			57
High-income OECD and Eurostat														
Lithuania	18			59		18	43		40		4	376		15
United Kingdom	95					65	70				8	94		39
United States	66	33		54		39	67				7			53
France	101	29				72	141				5			40

Source: Author's calculations

the income band defining the poverty line in each country in 2011. This information is only available for a few countries and never for 2011. The most widely available information is average consumption as summarized by the UN FAO Food Balances Sheets. I use the balances for 1961, the earliest year available, when many people in developing countries were undoubtedly poor. The first paper to measure poverty globally was Ahluwalia, Carter, and Chenery (1979), which set the poverty line at consumption of the forty-fifth percentile in India in the 1970s. This was not far off average consumption in 1961.

Table 8 compares the predictions of the basic model with the 1961 consumption pattern for 19 countries (data are not available for Lithuania). The correspondence between prediction and behavior is much higher for the developing countries than for the richer countries. Consider first the total weight of the diet. In the rich OECD countries, actual was 2.89 times predicted; in the middle income OECD countries, the corresponding ratio equaled 1.90, while among the 11 developing countries, actual was only 14 percent greater than predicted.

LP models also work best for developing countries when the components of the diet are considered. In the developing countries, the model predicts that animal products would amount to 10 percent of consumption, while average consumption in 1961 was 12 percent. For fats, the prediction was 2 percent against a 1961 value of 1 percent. LP overpredicts the consumption of grain and bread—58 percent against a reality of 41 percent—with the discrepancy made up with greater consumption of vegetables and fruits—prediction of 31 percent versus actual consumption of 40 percent and "other product" where the model predicts zero and 1961 consumption was 6 percent. The latter includes sugar (average of 9 kg per head), which was consumed everywhere, and alcohol (average of 8 kg), which was

Table 8—LP Predictions Compared to 1961 Average Consumption (*Kilograms per Person per Year*)

	Total weight	Grain/ bread	Fats/ oils	Animal and fish	Vegetables, nuts, and fruits	Other
Eleven developing countries						
Predicted	293	170	5	28	90	0
1961 average	334	138	4	41	132	19
Low-income OECD						
Predicted	312	192	3	70	47	0
1961 average	593	183	9	147	222	32
High-income OECD						
Predicted	314	203	12	48	51	0
1961 average	906	109	17	358	259	164

Source: Author's calculations

consumed in significant quantity only in Zimbabwe and Gambia (54 and 40 kg per head respectively).

These predictions are not perfect but are far closer to reality than the predictions for rich countries. For the United States, United Kingdom, and France, the prediction is that grain and grain products would amount to 65 percent of consumption, whereas the actual value in 1961 was 12 percent. The discrepancies were matched by underpredicting the consumption of animal products (15 percent versus a reality of 40 percent), fruit and vegetable consumption (16 percent versus 29 percent), and the consumption of "other products" (0 versus 18 percent). The latter consisted mainly of sugar (45 kg per year) and alcoholic drinks (112 kg per year). The big errors for the rich countries illustrate Stigler's point about the failure of linear programming to predict behavior, while the much smaller errors for developing countries illustrate my point that linear programming can predict fundamental features of the behavior of the poor.

How well does linear programming perform within the broad categories? Linear programming performs poorly in explaining the variety of foods eaten. This is especially true of fruits and vegetables. Normally, linear programming selects cassava or a single vegetable, which is generally the cheapest source of vitamin C. In reality, people consume many different fruits, nuts, and vegetables. Some of this behavior is a response to seasonable prices changes, which do not appear in the ICP. A fundamental reason, however, is that many vegetables sell at similar prices and have similar quantities of vitamin C. The diet can be diversified at very little cost. The same is true of some fish and animal products.

On the other hand, the most important food consumed by the poor is grains and grain products, and linear programming correctly predicts the most important grain in 11 of the 14 developing countries in the sample. Success is high in Africa (millet and sorghum in Niger, maize in Zimbabwe, rice in Liberia, wheat in Algeria and Egypt with some success in predicting grains of secondary importance) and south Asia (Bangladesh, Myanmar, Indonesia, Sri Lanka, and Vietnam all rice).

The model is off the mark in three cases. I tally Thailand as an error since maize is the grain in the linear programming solution, but rice was the predominant crop in 1961. In that year, very little maize was consumed by humans, but now it comprises 10 percent of grain consumption, presumably eaten by the poor. Linear programming anticipated this development, so perhaps this is not a prediction error at all.

The predictions are most problematic for the biggest countries, China and India, where the model predicts sorghum and millet as the principal grains. In India these crops comprised 22 percent of grain consumption in 1961 (down to 9 percent in 2011) and were disproportionately eaten by the poor. The thing is, however, that the poor also consumed large quantities of more expensive wheat and rice, and this behavior is not captured by the basic model. The situation was similar in China where millet and sorghum comprised 18 percent of the grain consumed by humans in 1961. Jinqing (2005) discusses the widespread consumption of sorghum and other coarse grains by peasants in Henan in 1996, for instance. (Virtually none is eaten today.)

The results for India and China raise several broad questions. The first relates to the ICP data used here. The ICP includes a single price for each item that is supposed to be representative of the whole country. India and China are very large, and their economies not highly integrated. The relative prices in the regions differ from the relative prices shown in the ICP. In that case, it would be better to apply the linear programming approach to subnational units, so the baskets would differ in wheat growing districts and rice growing districts, for instance. The same criticism applies to any other approaches (including the World Bank's) that come up with a single basket for large and diverse countries.

The second issue relates to the importance of habit in diet choices. An extreme view would maintain that food choices are entirely driven by customs that have nothing to do with what is cheap. That view is hard to credit for developing countries in view of the results just reported. Atkin (2013, 2016) has proposed a more specific hypothesis that warrants attention. He claims that preferences do reflect local scarcities and these preferences acquire a life of their own, so that they continue to influence behavior when market integration increases or people migrate to districts where relative prices differ. Migrants continue to purchase the foods to which they are accustomed with the result that their diets cost more than those of their neighbors whose tastes accord with the scarcities of their new homes. Atkin's (2013) analysis of intra-Indian migration suggests that habit raises the cost of calories by about 5 percent even for deprived groups. A 5 percent increase in the cost of food would increase the poverty line by about 3 percent given food's share in expenditure. This is not a large amount in view of the many other uncertainties involved in setting the poverty line. Furthermore, habits decay over time, and people adapt to the new price environment.

Third, there is a question: should we pay attention to food habits in setting the poverty line? The former is a matter of fact, while the latter is a matter of value. Many Indians prefer rice and wheat to millet and sorghum. People in Niger eat nothing but millet and sorghum. Should Indians be given a more costly standard than people in Niger just because they have a taste for more expensive food? The poverty line represents the cost of meeting basic needs, not a level of satisfaction, and should be set accordingly.

On the practical plane, however, it should be noted that the linear programming poverty line is generous enough to allow for a small accommodation of habit or variety in diet. This latitude arises because the requirements for micronutrients are set at levels that the medical profession judges to be needed for healthy living. These levels exceed intake needed to prevent acute deficiency symptoms, as we have mentioned. People who receive the income to consume the recommended daily allowance of some nutrient might purchase a diet with less than the RDA in order to indulge a taste. This is probably the reason that most of the Indian population is anemic, for instance. Likewise a calorie standard of 2,100 is higher than absolutely necessary for survival, so taste can be indulged at the expense of energy. Poverty is constraining and linear programming captures those bonds, but it is not wholly immobilizing.

IV. Nonfood Consumption

A poverty budget includes items besides food. In the World Bank approach, nonfood expenditure is the average markup of nonfood spending in the poor countries whose budgets underlie the line. There is no reason to suppose that these markups reflect identical nonfood budgets, and, indeed, the claim that "the judgments made in setting the various parameters of a poverty line are likely to reflect prevailing notions of what poverty means in each country setting" (Ravallion, Chen, and Sangraula 2009, p. 167) belies that possibility. Since the poor countries are mainly tropical, the only safe assumption is that the nonfood spending is appropriate to tropical conditions.

I address this limitation by setting an explicit nonfood budget. It is intentionally austere and is limited to housing, fuel, lighting, clothing, and soap.[13] The cost of education, medical care, and so forth are not included, so the resulting poverty line is an absolute minimum. Arbitrariness is unavoidable. Our approach makes the decisions visible, so they can be debated, rather than leaving them unexamined under the rubric of "other spending." The linear programming framework could be extended to include the nonfoods by specifying the requirements in terms of square meters of living space, BTUs of energy, etc., but the linear programming problem decomposes into separate problems so long as the goods in each category contributed only to meeting the requirement of that category, which is the maintained assumption. So I analyze the categories in turn.

I set the quantity of housing at three square meters per person. By the standards of rich countries, this represents extreme, and often illegal, overcrowding. Even illegally subdivided apartments in New York offer 5–10 square meters per person (Gadanho 2014). Exceptionally high densities, however, are common in Third World slums. In Bombay in 1921, for instance, cotton mill workers lived one family to a room of 13.3 square meters giving each person 2.3 square meters of space. In Ahmedabad in the 1920s, the average was 3.6 square meters per head, in Shanghai in 1952, the average resident had 3.4 square meters, and in the slums of Nairobi today, the rate is 3 square meters per person. UN-Habitat (2003b) proffered a definition of overcrowding as more than 2 people per room or less than 5 square meters each. In 2010, however, this standard was revised to 3 people per room, implying less than 3.3 square meters per person.[14]

[13] The soap requirement was arbitrarily set at 1.3 kg per year (25 g per week).

[14] Shirras (1923), Bombay Labour Office (1928), Sun (2011), UN-Habitat (2003a), UN-Habitat (2003b), and UN-Habitat (2010).

Table 9—Nonfood Consumption per Head Among Workers in Bombay and St. Petersburg

	Bombay		St. Petersburg	
	Low wage	Average	Low wage	Average
Clothing	17.00	23.13	26.86	62.50
Footwear	0.59	1.19	16.19	30.63
Bedding	1.28	3.38	10.08	21.37
Total	18.88	27.69	53.13	114.50
Fuel (mBTU)	2.52	3.15		24.62
Light (mBTU)	0.27	0.37		0.87

Note: Clothing, footwear, and bedding expressed in cotton cloth equivalents, meters.

Sources: Prokopovich (1909) and Shirras (1923)

To work out the cost of 3 square meters, we need the rent per square meter. For six poor countries (Algeria, Niger, Bangladesh, Indonesia, Sri Lanka, and Vietnam), the ICP reports rents for "traditional" structures, so rent per square meter can be calculated.[15] For the remaining countries, it was necessary to use other sources detailed in the online Appendix. The aim was to find market (not subsidized) rents in the poorest districts of the capital or other large cities. In some cases, like New York, rents were found for illegal, substandard apartments, although, in this case, the rent per square did not differ greatly from the US Department of Housing Fair Market Rent for New York County in 2011. Table 10 tabulates the rents. The differences across countries are striking. In most of the poor countries, rents were \$0.50–\$1.00 per square meter per month. Even in China, where the rent is the free market average for the eight largest cities, it came to only \$1.28 per square meter. On the other hand, in the United States, United Kingdom, and France, rents were on the order of \$25 per square meter per month. In the United States, rent on 3 square meters worked out to be \$1.76 per day, which shows the impossibility of living on \$1.90.

The requirements of clothing, fuel, and lighting depend on climate. A point of departure for fuel and lighting is the energy poverty line of the Millennium Development Goals, which sets the minimum at 1.6 million BTUs of fuel and 0.4 million BTUs for lighting (Modi et al. 2006). The former, which is based on engineering studies, provides enough energy for cooking but nothing beyond that for heating, so the requirement is suitable only for hot climates. The latter provides enough energy for three hours of lighting per night from a candle or an electric light bulb. Other sources of information are needed to determine clothing requirements and to extend the fuel and lighting requirements across climate zones. I used household expenditure surveys to set the requirements. In the case of fuel, these are corroborated and extended with engineering calculations.

For the expenditure survey approach, I use Prokopovich's (1909) survey of St. Petersburg workers in 1907–1908 and Shirras's (1923) survey of workers in Bombay cotton mills in 1921–1922. These were chosen to represent opposite ends of the climate spectrum and because the surveys are very early and were taken

[15] The rents shown in this paper are averages of at least two housing classes. They generally have electricity and indoor water supply. Rents for poorer dwellings lacking electricity and indoor water or for better dwellings, which also have indoor toilets and kitchens, give very similar results in these international comparisons.

TABLE 10—HOUSING RENTS

	$/Sq met/ month	$/Person/ year
Developing countries		
Niger	0.53	19.07
Zimbabwe	0.69	24.84
Gambia	0.50	18.00
Liberia	1.00	36.00
Egypt	0.84	30.18
Algeria	1.06	38.21
India	0.54	19.27
China	1.28	46.24
Thailand	3.13	112.67
Indonesia	1.99	71.64
Bangladesh	0.31	11.31
Myanmar	0.50	18.00
Sri Lanka	0.31	11.08
Vietnam	1.79	64.32
Middle-income OECD		
Turkey	2.28	81.91
Mexico	5.00	180.00
High-income OECD and Eurostat		
Lithuania	1.18	42.32
United Kingdom	21.36	768.84
United States	17.94	645.83
France	25.51	918.43
Developing	1.03	37.20
Middle-income OECD	3.64	130.96
Rich OECD Eurostat	16.50	593.86

Source: Author's calculations

when the workers were indubitably poor. Both surveys show average spending on clothing, footwear, bedding, fuel, and lighting. The Bombay survey breaks all categories down by income bands, and the St. Petersburg survey does the same for clothing, footwear, and bedding. In Bombay the range 30–40 rupees/month was the lowest income band with a large number of workers as was 300–400 rubles/year in St. Petersburg. I assume these low-income workers were at similar levels of deprivation, so that differences in their expenditures represent responses to climate and not to real income or price differences.[16] For fuel and lighting, the averages for all workers provide a less nuanced basis of comparison.

The surveys reveal much more substantial purchases of clothing, footwear, and bedding in Russia than in India. Both surveys tell us expenditures in money: rupees or rubles. To compare quantities in the two countries, these must be divided by prices. For clothing and related items, the prices of coarse cotton cloth were used as the deflator. In that way we compare expenditures in "meters of cloth equivalents." Table 9 shows the results. In St. Petersburg, the low-wage workers consumed almost three times as many meter-equivalents of clothing, footwear, and bedding as their counterparts in Bombay. Clothing consumption was almost 60 percent greater, bedding was eight times more—the nights are much colder in Russia than in India—

[16] Without the adjustments for climate, the real annual earnings of the average cotton mill operative in Russia in 1907–1908 look to have been about 50 percent higher than that of their counterparts in Bombay in 1921–1922. With the climate adjustments, their average real earnings were virtually identical (Allen and Khaustova 2017).

while footwear was, not surprisingly, 27 times greater. Spending on these items increased more with income in Russia than in India. The average family member in St. Petersburg consumed almost four times as many meter-equivalents as the average Bombay family member. Much of the extra income went on clothing for which the Russian consumption was three times that of India. Living in the northern winter required considerably more clothing.

Similar calculations for lighting and fuel can only be done for the average worker since the Russian survey did not break these expenditures down by income band. Each member of the average working class household in Bombay consumed 0.37 million BTUs of kerosene in lamps (very close to the Millennium Development Goal), while the average household member in St Petersburg consumed 0.87 million BTUs—over twice as much. This looks like the cost of long winter nights.

The disparity was much greater for fuel. In Bombay, fuel consumption averaged 3.15 million BTUs per person. Among the low-income workers, fuel consumption was only 2.52 million BTUs, marginally greater than the Millennium Development Goal. In Russia, however, average consumption in working class families was 24.62 million BTUs per year: close to 10 times more than in Bombay. One limitation of this calculation is that there was no breakdown of fuel spending by income class in Russia. Judging by clothing, footwear, and bedding, where average spending was double that of the low-wage workers, the low-wage workers in St. Petersburg might have been consuming on the order of 12 million BTUs per person.

We can test this conjecture by approaching the problem from a different perspective. Heating engineers have developed a methodology to calculate the energy required to keep a building at a desired temperature.[17] Critical parameters are the dimensions of the space to be heated, the temperature to be maintained, the pattern of the exterior temperature over the year, and the insulating efficiency of the construction. No matter how many rooms there were in a dwelling, it was normal to heat only one, and we proceed accordingly. On the assumption of 3 square meters per person, a family of four lived in a room of 12 square meters. The room is assumed to have been 3×4 meters with a ceiling height of 2.4 meters. The R-value of the floor, walls, and ceiling depends on the construction materials used, their thickness, and layering. An R-value of 2 is assumed.[18] We assume the room is heated to an internal temperature of 15 degrees centigrade. The external temperature is measured by the "heating-degree days," that is, the sum over the year of the difference between the desired internal temperature and the external temperature. We obtained this from a heating industry website.[19] This website gives heating degree-days calculated at half hour intervals over five years for most airports and weather stations in the world. The values chosen for the parameters could be debated, but alternatives give similar results. Under the assumptions made, the fuel required per person per year works out to have been 12 million BTUs in St. Petersburg and 0 in Bombay. For the

[17] http://hyperphysics.phy-astr.gsu.edu/hbase/thermo/heatloss.html summarizes the basic theory and equations. I am indebted to Michail Moatsos, who has used this methodology in his own work, for bring it to my attention. See Moatsos (2016).

[18] For R-values of common building materials, see, for instance, http://www.coloradoenergy.org/procorner/stuff/r-values.htm. Inspectapedia assessed an old log cabin with an uninsulated roof, upper exterior walls made of three-fourths inch lumber, and drafty windows as having an R-value of 2 overall (https://inspectapedia.com/structure/Log_Home_Insulation.php).

[19] http://www.degreedays.net/

TABLE 11—LINEAR PROGRAM POVERTY LINES CONVERTED TO US DOLLARS PER DAY AT PPP

	1,700 cal	CPF	Basic	Full course
Developing countries				
Niger	0.91	1.15	1.86	2.39
Zimbabwe	0.88	0.98	1.74	1.86
Gambia	1.10	1.25	1.46	2.20
Liberia	1.74	2.18	3.20	6.08
Egypt	2.12	2.42	3.19	3.45
Algeria	1.67	1.85	3.05	3.44
India	1.33	1.52	2.03	2.42
China	1.60	1.83	2.39	3.38
Thailand	2.20	2.83	3.48	3.78
Indonesia	1.85	2.43	3.25	3.35
Bangladesh	1.12	1.36	1.87	1.88
Myanmar	2.22	2.74	3.31	3.77
Sri Lanka	1.11	1.44	2.43	2.96
Vietnam	1.75	2.30	3.55	4.10
Middle-income OECD				
Turkey	1.49	1.64	2.09	2.28
Mexico	1.51	1.74	2.00	2.03
High-income OECD and Eurostat				
Lithuania	3.63	3.77	4.62	5.17
United Kingdom	3.14	3.21	3.49	4.24
United States	3.27	3.42	3.72	4.28
France	3.31	3.38	4.02	4.46
Developing	1.54	1.88	2.63	3.22
Middle-income OECD	1.50	1.69	2.05	2.15
High-income OECD Eurostat	3.34	3.45	3.96	4.54

Source: Author's calculations

latter, the appropriate fuel allowance is the 1.6 million BTUs required for cooking in the energy poverty line of the Millennium Development Goals.

Heating degree days were ascertained for major cities in the 20 countries studied here, and heating requirements were then calculated. Requirements were set at these calculated values so long as they exceeded the Millennium Development energy poverty line; otherwise, the poverty line value of 1.6 million BTUs was adopted. Requirements for lighting, clothing, footwear, and bedding were scaled between those for Bombay and St. Petersburg in proportion to the heating degree days of the city relative to the difference between Bombay and St. Petersburg.

The cost of the requirements for fuel, lighting, clothing, footwear, and bedding can be calculated from the prices of cloth and fuels in the ICP. The cheapest source for each requirement in each country was used in these calculations.

V. Basic Needs Poverty Line and the Extent of World Poverty

The BNPL is the sum of the cost of the linear programming diet, the nonfood costs, and rent. How do the BNPLs compare to the WBPL? Does the BNPL change our view of global poverty?

To allow comparison with the WBPL of $1.90 per day, Table 11 shows the values of the BNPLs when they are converted to US dollars in the usual manner. The cost of the BNPL line is greater, the higher the quality of the diet. The BNPL lines for

Table 12—Expenditure Breakdown of Basic Needs Poverty Line (*Percent*)

	Food percent	Nonfood percent	Housing percent
Developing countries			
Niger	66	28	6
Zimbabwe	69	24	7
Gambia	61	30	9
Liberia	68	26	5
Egypt	68	24	9
Algeria	69	23	8
India	62	30	8
China	52	39	9
Thailand	57	21	21
Indonesia	62	25	13
Bangladesh	64	31	5
Myanmar	53	42	4
Sri Lanka	81	16	3
Vietnam	66	21	13
Middle-income OECD			
Turkey	54	30	16
Mexico	47	18	34
High-income OECD and Eurostat			
Lithuania	33	63	3
United Kingdom	16	34	50
United States	26	27	48
France	23	26	51
Developing	64	27	9
Middle-income OECD	51	24	25
High-income OECD Eurostat	25	37	38

Source: Author's calculations

the OECD countries exceed those of the non-OECD countries for any diet in view of the much higher cost of housing in developed countries[20] and the relative coldness of the climate. The CPF line at $1.84 comes closest to the WBPL for developing countries. The CPF model could be regarded as micro-foundations for the World Bank's line. However, since people eating a CPF diet suffer many nutritional deficiencies, it is not a good poverty line. Instead, the line implied by the basic diet is preferable. Henceforth, I will confine discussion of the BNPL to the version using the basic diet.

Table 12 shows a breakdown of poverty line spending by broad category. In the developing countries, about two-thirds of spending is on food, one quarter on nonfoods, and 5–10 percent on rent. This rent share is consistent with the experience of pre-industrial Europe (Allen 2001). These shares shift dramatically with income. The food share drops to one quarter in the United States, United Kingdom, and France, the nonfood share remains at one quarter, and the rent share explodes to half

[20] The costs per square meter of housing for six of the developing countries come from ICP2011, as noted, and appear to be "nationally representative." The costs for the remaining countries are the costs of poor quality housing in low-income districts in large cities. Sensitivity analysis of the impact of this selection procedure was done to see if it affected the BNPL. Halving the cost of such housing in the developing countries, for instance, had only a negligible impact on the BNPL since even expensive urban housing in those countries is very cheap. Since the prices of everything else are "nationally representative," the BNPLs for the developing countries also are "nationally representative." This, however, is not true in the rich countries where the cost of housing amounted to just over half of the cost of the poverty budget. Halving the cost of housing there had a large impact on the BNPL. For the rich countries, the BNPLs must be interpreted as applying to large cities.

Table 13—Expenditures by Category in US Dollars at Market and PPP Exchange Rates

	Market $/year food	Market $/year nonfood	Market $/year housing	PPP $/year food	PPP $/year nonfood	PPP $/year housing
Developing countries						
Niger	216	93	19	446	192	39
Zimbabwe	235	82	25	438	152	46
Gambia	119	59	18	323	159	49
Liberia	454	174	36	799	306	63
Egypt	239	83	30	789	276	100
Algeria	334	113	38	766	259	88
India	148	71	19	462	220	60
China	260	194	46	454	339	81
Thailand	307	115	113	730	272	267
Indonesia	343	139	72	736	298	154
Bangladesh	147	70	11	439	208	34
Myanmar	217	172	18	643	511	53
Sri Lanka	273	55	11	715	143	29
Vietnam	316	101	64	850	271	173
Middle-income OECD						
Turkey	285	161	82	412	232	118
Mexico	249	97	180	346	135	250
High-income OECD and Eurostat						
Lithuania	406	764	42	565	1062	59
United Kingdom	254	520	769	210	429	635
United States	347	366	646	347	366	646
France	415	458	921	339	374	753
Developing	258	109	37	614	258	88
Middle-income OECD	267	129	131	379	183	184
High-income OECD Eurostat	356	527	594	365	558	523

Source: Author's calculations

or more of income. The very poor in the United States pay this much or more in rent (Desmond 2016).

In Table 13, the expenditures on broad categories of the basic poverty line are converted to US dollars using both the market exchange rate and the PPP exchange rate for individual consumption expenditure by households normally used by the World Bank. The conversion at the market exchange rate shows that food is most expensive in rich countries. The cost of nonfood goods is also much greater among the rich than elsewhere due to the colder climate in the United States and northern Europe, and high rents in rich countries mean that spending on housing is an order of magnitude greater than in the developing world. When currencies are converted at PPP, costs rise in the poor countries relative to the rich, and food costs in dollars end up being greater in the poor countries than in the rich. The burden of cold weather and the high cost of housing in rich countries remain, although diminished in relative magnitude.

The BNPL costs on average about 40 percent more than the WBPL in developing countries (Table 11). The dispersion about this average, moreover, is substantial. The basic diet BNPL in several African countries costs less than $1.90 per day. On the other hand, the basic diet BNPL costs almost twice as much in some south Asian countries and in the rich OECD countries.

The import of these discrepancies is that world poverty is greater than implied by the WBPL and its geographical distribution is different. Table 14 shows head count poverty rates for these countries as implied by the $1.90 line and by the basic diet BNPL. The head counts are computed with the World Bank's PovcalNet online calculator and, in the cases of the United States, United Kingdom, and France, directly from the national household surveys made available by the Luxembourg Income Study.[21] The BNPL indicates that there were 50 percent more poor people than estimated by the World Bank in the 17 countries in the table for which we have estimates. The picture of sub-Saharan Africa does not change much. On the other hand, there are many more poor people in Asia. In India, the increase is 20 percent, in China 74 percent, and in Indonesia, Vietnam, and Sri Lanka, the number of poor increases by about threefold. The numbers involved are large, and the head count ratio in Indonesia, for instance, rises from 14 percent to 46 percent. Economic growth in Asia has been significant but perhaps not as impressive as it seemed. While the previously noted decline in the consumption of sorghum and millet in India and China suggests the number of poor people is falling, it is still substantial.

Table 14 also reports numbers in absolute poverty in OECD countries. This is a new focus of research and one of considerable importance in view of current interest in inequality in these countries. Edin and Schaefer (2015) estimated that 2.8 million children lived on less than $2 per day in the United States. Table 11 shows that people cannot survive on $2 a day since it does not cover the minimum food, clothing, and shelter required in big cities in a cold, rich country. Using the basic needs value of $3.72 per day for the United States implies that 1.5 percent of the American population—4.6 million people—lives in absolute poverty. This is marginally more than in the United Kingdom (1.25 percent) and significantly more than France (0.63 percent). If France is representative of western Europe, then extreme poverty looks to be a peculiarly Anglo-American problem.

The role of rent in the BNPLs of rich countries is particularly prominent since their rents are so high. Rents in rural locations in the United States, however, can be very low. In that context, the WBPL offers an insight, for it sets rent close to zero. Even with that reduction, however, there were still 3.6 million people in extreme poverty in the United States in 2011. Country living does not eliminate absolute poverty.

VI. Poverty Purchasing Power Parity

One of the contentious issues that has arisen with the WBPL is the exchange rate to use in converting the dollar value of the line into local currencies. The standard World Bank procedure is to use the PPP exchange rate for individual consumption expenditure by households. The spending pattern of the poor differs from the average pattern and so does the spending pattern of developing countries vis-à-vis

[21] See www.lisdatacenter.org. The samples for 2010 were used, and the 2011 poverty lines were converted to 2010 values with the rates of consumer price inflation in each country. This source was used for United States, United Kingdom, and France since the World Bank counsels against using PovcalNet for these countries. PovcalNet gives similar estimates of the number of poor to those computed with lisdatacenter.org, but the latter permits finer measurement.

TABLE 14—HEAD COUNT POVERTY RATES

	Percent below poverty line		Millions of poor		Population (millions)
	BNPL	WBPL	BNPL	WBPL	
Developing countries					
Niger	48.84	50.34	8.28	8.53	17
Zimbabwe	17.95	21.40	2.56	3.05	14
Gambia	32.88	45.29	0.44	0.61	1
Liberia	90.37	68.64	3.18	2.42	4
India	25.56	21.23	322.97	268.26	1,264
China	13.71	7.90	184.28	106.19	1,344
Thailand	1.94	0.04	1.30	0.03	67
Indonesia	46.25	13.58	113.22	33.25	245
Bangladesh	17.65	18.52	26.76	28.08	152
Sri Lanka	6.24	2.41	1.26	0.48	20
Vietnam	16.35	4.78	14.21	4.16	87
Middle-income OECD					
Turkey	0.73	0.28	0.54	0.21	74
Mexico	6.28	3.80	7.45	4.51	119
High-income OECD and Eurostat					
Lithuania	3.80	0.87	0.12	0.03	3
United Kingdom	1.25	0.93	0.79	0.59	63
United States	1.50	1.17	4.64	3.61	309
France	0.63	0.43	0.41	0.28	65
Developing	29	23	678.47	455.05	3,214
Middle-income OECD	4	2	7.99	4.71	192
High-income OECD Eurostat	2	1	5.96	4.51	441
Overall	6	6	692.41	464.27	3,847

Notes: PovcalNet does not generate poverty estimates for Algeria, Egypt, or Myanmar. The figures for the United Kingdom, United States, and France were computed from the 2010 household surveys in the Luxembourg Income Survey Cross-National Data Centre (http://www.lisdatacenter.org/).

OECD countries. The question is whether a poverty purchasing power parity (PPPP) exchange rate would give a different conversion.

This issue can be explored with the BNPL's calculated in this paper. In the dual formulation of the standard model of consumer choice, the solution to the problem of minimizing the cost of reaching a specified utility level is the expenditure function, which expresses that cost as a function of the prices of the consumer goods and the specified utility level. If the expenditure function is evaluated at two sets of prices, the ratio of the expenditures in the two cases is the "true cost of living index": It indicates the relative change in spending needed to compensate the consumer for the differences in prices by keeping him or her at the same level of utility. The solution to the linear programming problem does not give an explicit expenditure function, but it does indicate the cost of meeting the specified requirements at the given prices. The ratio of the costs of meeting the specified requirements at two sets of prices is the linear programming analogue to the true cost of living index. Consequently, when the nutritional requirements are set at poverty levels, that ratio is the true PPPP exchange rate.

It should be noted that the ratio of the costs in the "true linear programming cost of living index" is not an index number of the orthodox sort. The numerator and the denominator need not have any foods in common, for instance. Uniform

Table 15—Linear Programming PPP Relative to Individual Consumption PPP

	1,700 cal	CPF	Basic	Full course
Developing countries				
Niger	0.28	0.34	0.50	0.56
Zimbabwe	0.27	0.29	0.47	0.43
Gambia	0.34	0.36	0.39	0.51
Liberia	0.53	0.64	0.86	1.42
Egypt	0.65	0.71	0.86	0.81
Algeria	0.51	0.54	0.82	0.80
India	0.41	0.44	0.55	0.56
China	0.49	0.53	0.64	0.79
Thailand	0.67	0.83	0.93	0.88
Indonesia	0.57	0.71	0.87	0.78
Bangladesh	0.34	0.40	0.50	0.44
Myanmar	0.68	0.80	0.89	0.88
Sri Lanka	0.34	0.42	0.65	0.69
Vietnam	0.53	0.67	0.95	0.96
Middle-income OECD				
Turkey	0.46	0.48	0.56	0.53
Mexico	0.46	0.51	0.54	0.47
High-income OECD and Eurostat				
Lithuania	1.11	1.10	1.24	1.21
United Kingdom	0.96	0.94	0.94	0.99
United States	1.00	1.00	1.00	1.00
France	1.01	0.99	1.08	1.04
Developing	0.47	0.55	0.71	0.75
Middle-income OECD	0.46	0.49	0.55	0.50
High-income OECD Eurostat	1.02	1.01	1.06	1.06

Source: Author's calculations

requirements ensure comparability as the consumption pattern shifts in response to price differences.

Table 15 shows how the linear programming PPPPs for the various levels of nutritional requirements compare to the household expenditure PPPs. Among the rich OECD countries, the linear programming purchasing power parity exchange rates average close to the exchange rate for household consumption normally used to converted poverty lines between countries. Among the middle income OECD countries and the developing countries, however, the situation is very different. Their PPPP exchange rates are about half to three quarters of the PPP exchange rates for household consumption. Using the household consumption PPP to convert poverty lines gives seriously misleading results.

VII. Conclusion

In this paper we have proposed that poverty lines can be defined by specifying a basic needs basket. Linear programming is used to specify the food component of basic needs. While the diet problem was the first problem ever formulated as a linear programming problem and remains a classic for teaching purposes, the common view amongst economists is that it does not describe anyone's behavior. While that belief is certainly appropriate for rich people, we have argued that it is not correct for the "absolute poor." When people are on the margin of survival, their needs take precedence over their desires, and their behavior is governed by linear programming. This statement is not unambiguous, however, for a range of nutritional requirements can be imposed on the diet problem. We have argued that the "basic"' requirements—those which supplied adequate amounts of calories, protein, fat, and the vitamins and minerals needed to prevent anemia, beri-beri, pellagra, and scurvy—imply diets that describe the main features of the diets of the poor. Those diets are based around common grains, legumes, a little milk or fish, oil, and vegetables. Linear programming cannot, however, describe all of the details of the diets.

We have also explicitly budgeted the nonfood component of "basic needs" and expressed many of them as functions of climate. This is important if the poverty line is to be applicable everywhere on the globe since the existing World Bank procedure gives a line which is only appropriate for hot climates. Accommodation rents vary enormously between rich and poor countries, and the basic needs line includes that differential, while the World Bank line does not.

Although the poverty line proposed here is intended to be austere, it does nonetheless provide some latitude for habit and taste since the nutritional requirements are those recommended by the medical profession for "good health." This leaves scope for people to trade off some health for customary consumption, sugar, or alcohol, as they prefer. Basic needs are not the same as local taste. However, the trade-offs are limited. That is the nature of poverty.

We argued in the introduction that an international poverty line should satisfy five conditions. The BNPL meets all of them. First, the line should have a clear meaning related to survival. The BNPL meets this condition since it is defined in terms of the food, fuel, clothing, and shelter requirements to ensure social reproduction and defense against the main deficiency diseases and survival in cold as well as hot countries. Second, the line should represent a constant standard across time and space. This requirement is met by imposing the same or equivalent requirements in all cases. Third, the poverty line should respond to local prices and climate. Indeed, local prices determine the solution to the linear programming along with the nutritional requirements, and nonfood consumption varies with climate. Fourth, the poverty line should avoid intractable index number problems. There are no index number problems with the linear programming approach since the solutions to the diet problem are in local prices and the nonfood requirements are also costed with local prices. Comparability across countries and over time is guaranteed by using the same requirements everywhere, not by PPP. Fifth, the poverty line should require only readily available information. An ICP dataset including relevant accommodation costs would do the job, although it is not detailed enough for regional breakdowns in large countries.

The BNPL provides a direct connection between the value of the line and its meaning in terms of human health and social reproduction. Using the BNPL provides a more transparent approach to poverty measurement than existing World Bank procedures. The BNPL indicates that there is considerably more poverty in the countries analyzed here—and they include much of the population of the developing world—than the World Bank has counted. The BNPL also indicates there are millions in "absolute poverty" in rich countries—especially the United States and United Kingdom.

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