# Global Poverty and Global Price Indexes

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## 1. Introduction

The first of the Millennium Development Goals targets global poverty. The numbers that support this goal are estimated by the World Bank, and come from a worldwide count of people who live below a common international poverty line. This line, loosely referred to as the dollar-a-day line, is calculated as an average over the world's poorest countries of their national poverty lines expressed in international dollars. The counts of those below the line come from household surveys, the number and coverage of which have steadily increased over the years. National poverty lines are converted to international currency using the purchasing power parity (PPP) exchange rates from the various rounds of the International Comparison Program (ICP). These PPPs, unlike market exchange rates, are constructed as price indexes that compare the level of consumer prices across countries.

In the first dollar-a-day poverty calculations, the World Bank (1990) used price indexes for GDP as a whole, but this practice was later improved by the use of price indexes for consumption. But even this is insufficient if the price indexes for national aggregate consumption are different from those that are relevant for people around the global poverty line. Price indexes are weighted averages of prices, and both weights and prices could be wrong. The prices collected by the ICP may be different from the prices faced by those at the poverty line, and the expenditure patterns at the poverty line are almost certainly different from the aggregate expenditure patterns in the National Accounts that provide the weights for the usual consumption PPPs. This paper is concerned with the second of these issues, the recalculation of purchasing power parity exchange rates using the expenditure patterns of those at the global poverty line. We shall refer to these poverty-weighted purchasing power parities as PPPPs or P4s, as opposed to the aggregate weighted PPPs or P3s. Although we recognize the importance of the first issue and shall discuss it briefly, the procedures and calculations here use the national prices of goods and services collected by the ICP so that our P4 indexes differ from the P3s published by the ICP only in the methods that we use to turn these prices into national price indexes.

Although our objectives are relatively modest, there are substantial theoretical and technical issues to be faced. First, in order to calculate the appropriate weights in each country, we need to identify those who are close to the local currency equivalent of the global poverty line. But for this, we need the P4s, so that the P4s and their weights need to be simultaneously calculated. Second, the global poverty line is calculated as an appropriate average of local lines converted to international units using the P4s, so that our calculations need to simultaneously solve for weights, price indexes, and the global poverty line. Third, the current standard procedure uses aggregate data from the *national accounts* to calculate the PPPs and the global poverty line in international dollars, but then takes the global poverty line to *household survey* data to calculate the numbers of poor people in each country. In the calculations in this paper, we use household survey data throughout. We use (a) local currency prices for 102 basic headings of consumption from the 2005 round of the ICP, (b) nationally representative household surveys from 62 poor countries, and (c) national poverty lines in local currency for 50 countries, and combine (a), (b) and (c) to calculate a set of poverty-weighted purchasing power parity exchange rates for consumption, a global poverty line, and a set of global poverty counts for each country and the world as a whole. The 62 countries for which we have survey data represent 83 percent of the population of the countries included in the global poverty counts; the 50 poverty lines also cover 79 percent of the population of poor countries. Fourth, when calculating P4s, we cannot follow the usual practice with P3s of taking the US as base because there are no households in the US at a poverty line in the vicinity of a dollar a day, so it is not possible to calculate weights. Our calculations use only information from the countries included in the global poverty count. This has the advantage that prices and expenditure patterns in rich countries have no effect on P4s or on the global poverty count, and that we are not using a "global" poverty line at which much of the (rich) world could not survive. It has the disadvantage that we lose the rhetorical value of the dollar poverty standard, but we will propose a method for remedying this.

The paper is laid out as follows. In Section 2 we explain the theory of the P4 indexes and the differences between P3s and P4s. This section aims to be succinct but is self-contained, so that it can serve as a brief introduction to the PPP literature for those who are most interested in poverty analysis. We work with three different types of multilateral indexes, the Fisher and Törnqvist versions of the EKS index, and the weighted country product dummy index. We explain why the calculation of poverty-weighted indexes poses a simultaneity problem, and we explore several methods of solving it. We show that the P3 and P4 indexes for any pair of countries will differ according to the cross-commodity correlation between relative prices and the income elasticities. If food is relatively expensive in poor countries, this will raise the P4 relative to the P3 for a poor country relative to a rich country, but there is unlikely to be large differences within poor countries as a group.

In Section 3 we turn to the definition of the global poverty line. We consider two alternatives. One, which follows Chen and Ravallion (2008) (CR), computes the global poverty line from an unweighted average of the national poverty lines (in international currency) of fourteen of the poorest countries in the world based on per capita **(PPP)** expenditure data from the national accounts. (CR have 15 lines, but we lack survey data for one of these countries.) CR's procedure excludes both India and China, whose per capita incomes are too high, though they contain more than half of the world's global poor. So we also consider an alternative in which the global poverty line is a poverty-weighted average of the international currency value of the poverty lines of 50 poor countries. Both of these global poverty lines use the P4 rates in their calculation, and so must be calculated simultaneously with them. Neither depends on information from rich countries, including the purchasing power parity exchange rates between poor countries as a whole and rich countries as a whole. We express it, not in US dollars, as has previously been the case for global poverty lines, but in "world" (Indian) rupees, or "wrupees," for short. However, we also provide exchange rates that allow conversion into US dollars or other rich country currencies.

Section 4 explains how we calculate standard errors for our international price indexes. One concern is with the sample size of some of our household surveys, so that we need to ensure that using samples, as opposed to populations, does not affect the precision of the estimates. Another concern is related to the fact that, in a world where relative prices are different in different countries, different index number formulas give different answers, and we develop a standard error concept that captures the degree of uncertainty from this cause.

Section 5 discusses a number of practical issues. We discuss how the ICP constructs the prices for the basic heads of consumption, and how we need to modify those procedures for our own work. We also note that the P3s calculated by the ICP are constrained by various regional and political constraints that do not apply to our work, and which make a difference to the indexes. We discuss the matching of consumption categories in the household surveys with the basic headings of consumption in the ICP and note that there are several categories—rent and health being perhaps the most important—that are not adequately represented in the surveys. Beyond that, some surveys contain imputations for the use value of durables, as opposed to expenditures on those items in the national accounts and the ICP. As a result, even when we calculate P3s as opposed to P4s, our estimates will not coincide with those in the ICP. A final practical issue is that, for some countries, the ICP collected only urban prices, and we have good evidence from many countries that urban prices are higher than rural prices, so that an adjustment is necessary.

Section 6 presents our results. The first subsection is concerned with the price indexes themselves. We present our estimates of P3s and P4s for 62 of the countries included in the global poverty counts and compare them with the P3s from the ICP itself. Perhaps our major conclusion is that, provided we use household survey data in both calculations, the reweighting to a poverty basis makes little difference, so that our P3s are close to our P4s. However, our P3s are somewhat further away from the P3s in the ICP, in part because of our different aggregation procedures (definitions of the indexes), and in part because survey–based estimates of aggregate expenditure patterns often differ from the those presented in the national accounts. As is often the case in poverty work, data discrepancies are more important than definitional or conceptual issues. The final subsection calculates poverty counts, examining the effects of different P3s and P4s on the estimate of global poverty, as well as the effects of different procedures for calculating the international line.

## 2. Poverty-weighted purchasing power parity exchange rates: theory

### 2.1 PPP indexes: notation, P3 and P4

Purchasing power parity exchange rates are multilateral price indexes designed to summarize price levels in each of a group of countries. In this paper, we are interested in price indexes for consumption, and wish to depart from the standard practice of calculating indexes for aggregate national consumption. Instead, our aim is to calculate indexes for people that are at, or at least close to, the global poverty line. We provide a brief treatment from first principles.

We start with notation. We have $M$ countries, labeled using the index $c$. In each country, there is a vector of prices for $N$ items of consumption, labeled using the index $n$, so that $p_n^c$ is the price of good $n$ in country $c$. Associated with those prices is a pattern of consumption, which we shall typically measure in terms of the shares of the budget devoted to each good, denoted $s_n^c$. The sum of these budget shares over $n$ is unity for each country $c$, so that they can be thought of as weights. They are defined as the expenditure on each good divided by the total expenditure on all goods and services. Each household has a set of budget shares, and the economy as a whole has budget shares defined as aggregate expenditure on each good divided by aggregate total expenditure on all goods. We shall distinguish these as necessary.

Throughout the work described in this paper, we shall assume that the prices are the same for all consumers in the country, and we will use price data on 102 “basic headings” of consumption collected by the ICP. The expenditures and prices of these basic headings are themselves aggregates of the thousands of narrowly defined goods and services whose prices are the collected in the ICP; in our work, we do not go below the basic heading aggregates, and treat them as our underlying prices.  The difference between what we do and the standard practice is in the treatment of the budget shares or weights. In the national accounting treatment of the ICP, the weights are the shares of aggregate national expenditure spent on each good whereas, in our treatment, the weights are calculated from household surveys, and are defined as an average of budget shares for households at or near the global poverty line. The global poverty line is itself defined in PPP terms, and we shall show how to simultaneously measure the price indexes and the global poverty line. For the moment, we assume that we know the line, and that we have calculated the poverty-line budget shares for each country.

## 2.2 EKS indexes

There are two different types of PPP indexes that we shall use in this paper, the Elteto-Köves-Sculc (EKS) type, and the weighted country-product-dummy (CPD) type. We start with the EKS indexes. They, in turn, start from a set of superlative indexes calculated for each pair of countries. (On superlative indexes, see Diewert, 1976). We work with two familiar superlative indexes, the first of which is the Törnqvist index, defined as

$$\ln P_T^{cd} = \frac{1}{2}\sum_{n=1}^{N}(s_n^c + s_n^d)\ln\frac{p_n^c}{p_n^d} \quad (1)$$

Note that we adopt the convention that the base country, here country *c*, comes first in the superscript on the index, followed by the comparison country, here *d*. The Törnqvist index is thus a weighted geometric average of the price relatives of each good, with the weights the average of the two budget shares in *c* and *d*. We leave the precise definition of the budget shares for later, but (1) will apply whatever budget shares we use.

The second familiar index is the Fisher ideal index, defined as the geometric mean of the Paasche index and the Laspeyres index so that, in logarithms,

$$\ln P_F^{cd} = \ln\left[\sum_{n=1}^{N} s_n^c \frac{p_n^d}{p_n^c}\right] - \ln\left[\sum_{n=1}^{N} s_n^d \frac{p_n^c}{p_n^d}\right] \tag{2}$$

The first term in brackets on the right-hand side is the Laspeyres index for *d* relative to *c*, while the second term in brackets is the Laspeyres for *c* relative to *d*, which is identical to the reciprocal of the Paasche for *d* relative to *c*.

The log Fisher and Törnqvist indexes in (1) and (2) give us an *M* by *M* matrix of index numbers comparing every country with every other country. The diagonals of these matrices are zero because the underlying indexes are unity; the price level in Morocco relative to Morocco is one. The Fisher and Törnqvist indexes, like all superlative indexes, have the reversibility property, that the price level in *d* relative to *c* is the reciprocal of the price level in *c* relative to *d*. In consequence, the matrices of logarithms from (1) and (2) are skew-symmetric with the bottom left triangle equal to minus the top right triangle. Even so, these matrices do not give us entirely what we want. In particular, they are not transitive, so that if we compute the price level of India relative to China, and of the US relative to India, the product of the two will not generally be equal to the price level of the US relative to China. Indeed, we would like this property to hold for all "chains" through the countries, so that we get the same relative price between two countries whether we compare them directly or indirectly via any number of intermediate countries. Arbitrage guarantees that market exchange rates satisfy this property. But here, we need to resort to *force majeure* and somehow adjust the price indexes so that transitivity holds.

It is straightforward to show that transitivity will hold for all paths through the countries if, and only if, there is a vector of price indexes, one for each country, so that the price level of *j* relative to *i* is given by the ratio of the price index for *j* to the price index for *i*. Suppose that we write $b^{ij}$ for the logarithm of the original intransitive indexes, (1) or (2). For transitivity to hold, we need, for all *i*, *j*, and *k*,

$$b^{ij} = b^{ik} + b^{kj} \qquad (3)$$

Suppose that country 1 is the base country, whose currency we are using as numeraire: this will be India in the calculations below. Since (3) holds for all countries, it holds for country 1, so that we can write

$$b^{ij} = b^{i1} + b^{1j} = -b^{1i} + b^{1j} \equiv -a^i + a^j \qquad (4)$$

where we have used the skew-symmetry of the *b* matrix, and we define the $a^i$ to be equal to $b^{1i}$. Because the *a*'s are the logarithms of the price level in each country relative to the numeraire country, they are the logarithms of the PPPs that we are looking for. Once (4) is satisfied, with $b^{ij} = a^j - a^i$ for some set of *a*'s, (3) will be satisfied, and we will have what we want, a system of purchasing power parity exchange rates with only $M-1$ distinct numbers.

The simplest way to adjust the *b*'s to satisfy (4) is the EKS procedure, first proposed by Gini (1921). This chooses the *a*'s so that the differences $a^j - a^i$ are as close as possible in a least-squares sense to the log price indexes $b^{ji}$ given by either (1) or (2). The pairwise indexes (1) and (2) have all of the advantages of superlative indexes, in particular that they can be thought of as approximations to cost of living indexes, at least if tastes are identical in the two countries. (These advantages are a good deal diminished if we recognize that Indians, Bulgarians, Ethiopians, and Peruvians do not have the same tastes.) But there is no basis in standard consumer theory for the particular way in which transitivity is imposed. These concerns are somewhat mollified by the fact that, in practice, the pairwise indexes are usually close to being transitive before adjustment.

To see how the final adjustment works, write $b^{ij}$ for the log price indexes (1) or (2), whichever we are working with. We then select the *a*'s to minimize the sum of squares

$$\phi = \sum_{k=1}^{M}\sum_{j=1}^{M}[b^{kj} - (a^j - a^k)]^2 \tag{5}$$

subject to the constraint that $a^1 = 0,$ so that country 1 provides the base currency in which all others are expressed. The solution to this problem is

$$a^c = \frac{1}{M}\sum_{j=1}^{M}(b^{1j} + b^{jc}) \tag{6}$$

or in terms of the original prices the PPP price index for *c* in country 1's units is

$$P_F^c = \left(\prod_{j=1}^{M} P_F^{1j} P_F^{jc}\right)^{\frac{1}{M}} \tag{7}$$

for the EKS-Fisher, with an identical formula, with *T* replacing *F*, for the EKS-Törnqvist. Each index inside the brackets is the price level of *c* relative to 1 computed via country *j*, so that the EKS index comes from taking a geometric average of these indexes over all possible intermediate countries.

### 2.3 Weighted CPD indexes

We shall also work with PPP indexes, constructed according to what is known as the weighted country product dummy method. A starting point here is what would happen if the law of one price were true with perfect price arbitrage in goods and service across countries. In this case, prices would differ only in currency units, so that we would be able to write

$$\ln p_n^c = \alpha^c + \beta_n \tag{8}$$

where $\alpha^c$ is the logarithm of the value of country *c*'s currency relative to country 1, for which $\alpha^1 = 0,$ and $\beta_n$ is the price of good *n* in country 1, which is also the price of good *n* in all countries, up to unit scaling. If (8) were true, PPP exchange rates would be equal to market exchange rates, and we would be done. In reality, we can construct a set of price indexes that approximate the structure (8) by *projecting* actual prices on to a set of country and product dummies by running a weighted regression of the form

$$\ln p_n^c = \alpha^c + \beta_n + \varepsilon_n^c \tag{9}$$

in which the weights are the budget shares of each good in each country, $s_n^c.$ The intuitive argument for the budget-shares weights is the same as for other price index calculations, that goods with large (small) budget shares should count more (less) in the calculations.

The CPD procedure traces back to Summers (1973), who used it in unweighted form, and the weighted version was developed by Prasada Rao, Selvanathan and Rao (1994), and Rao (1990, 1995, 2001, 2002, 2004), and further investigated by Diewert (2004, 2005). Selvanathan and Rao (1994, p. 25) show that in the two country case, the weighted CPD index is a weighted average of the logarithms of the price relatives with weights that are (normalized) *harmonic* mean of the budget shares in the two countries. Diewert notes that this implies that it is then a second-order approximation to the Törnqvist around any specific price and quantity combination, so that the two indexes are likely to be close in practice, though it is worth noting that this results does not establish that the weighted CPD is a superlative index itself, only an approximation to a superlative index, which is itself an approximation. And as with superlative indexes, there is no known extension beyond the two country case.

For future reference, the formula for the weighted CPD is

$$\hat{b} = (X'SX)^{-1} X'Sy \tag{10}$$

where $X$ is an $MN$ by $N+M-1$ matrix of ones and zeroes, with $N-1$ columns for the commodities, $M-1$ columns for the countries, plus a constant and rows corresponding to the vector $y$, which is the "stacked" vector of log prices, $N$ for each of $M$ countries. The $S$ matrix is a diagonal matrix with the budget shares on the diagonal, $N$ for each country. The element of the estimated parameter $b$ corresponding to the country dummies are the estimates of the log of the weighted CPD-PPP exchange rates for each country in terms of country 1. Note that, although (10) can be thought of as a generalized least-squares estimator, the weighting matrix $S$ is included for substantive reasons to do with the importance of each good in spending patterns, and not because of any supposed relationship between the budget shares and the variances of the error terms in (9). Indeed, (9) should not be thought of as a "true" model of the data generating process; rather (9) and (10) should simply be regarded as a convenient device for projecting the log prices on country and commodity effects in a metric that recognizes the different importance of each commodity in the budget.

### 2.4 Geary-Khamis indexes?

Although we shall not use it in the rest of this paper, we briefly discuss another PPP formula, due to Geary (1958) and Khamis (1970), and which forms the basis of the calculations for the Penn World Table. In the Geary-Khamis system, the prices in each country are compared with those of an imaginary composite country, itself constructed from averaging the countries in the system. The Geary-Khamis PPP index is computed as a Paasche index that compares domestic prices with "world" prices, which are the prices of the composite so that, for $c = 1, 2$,

$$P_{GK}^c = \frac{\sum_{n=1}^{N} p_n^c q_n^c}{\sum_{n=1}^{N} \pi_n q_n^c} \tag{11}$$

where $\pi_n$ is the world price of good $n$, which is itself defined as the quantity weighted average of the prices of good $n$ in each country, expressed in the global currency. Hence

$$\pi_n = \sum_{j=1}^{M} \frac{p_n^j}{P_{GK}^j} \frac{Q_n^j}{\sum_k Q_n^k} \tag{12}$$

where the uppercase $Q$'s denote *aggregate* quantities. Note that (11) and (12) need to be solved simultaneously, which can be done iteratively, or as shown by Diewert (1999) as the solution to an eigenvalue problem.

The Geary-Khamis system of indexes has one great advantage, which is that it preserves aggregation over subgroups of consumption. Because there exists a world price for each good, each item of consumption can be repriced at the world price, and added up to give repriced subgroups or totals. This aggregation property is not shared by the other indexes discussed so far which would give, for example, PPPs for food, non-food, and total consumption that would not be mutually consistent in the sense that the sum of food and non-food in the international currency would not generally add up to total consumption in the international currency. For a system of national accounts, such as the Penn World Table, the absence of aggregation would be inconvenient, although not insuperable; indeed the ICP uses Fisher EKS indexes for all regions except Africa. For the poverty work that is our main concern here, where we need only an exchange rate for total consumption, failure of aggregation is not a serious issue, while lack of comparability with (most of) the ICP would be more serious.

But the Geary-Khamis system has disadvantages that make it unattractive for our purposes. Unlike the Fisher and Törnqvist indexes, it is not superlative. In consequence, if the two countries had the same homothetic tastes, the Geary-Khamis index would not be a second-order approximation to the "true" cost-of-living index. If this were the main concern, Geary-Khamis could be replaced by Peter Neary's (2005) GAIA system, based on Geary-Khamis, but which is fully utility consistent, though its evaluation requires the estimation of a full international system of demand equations. However, given that we do not want to assume identical tastes, nor use the cost-of-living framework that would be arguably appropriate if tastes were identical, these objections to Geary-Khamis are not decisive.

To see the central problem, note that the quantity weighting of prices in (12) means that the country with the larger physical volume of consumption of a good gets greater weight in the construction of the composite world prices. If, for example, we used Geary-Khamis to compute a PPP for Bangladesh relative to the US, the world prices would be close to those of the US. In the Penn World Table as a whole, it has been argued by Daniel Nuxoll (1994) that the composite world prices are those that would characterize a middle-income country such as Italy or

Hungary. The use of such prices has the effect of overstating the level of consumption in poor countries. For example, many services—haircuts, domestic service, restaurant meals—are cheap in poor countries because people are poor, because such services cannot be traded, and because labor is not free to move around the world. If we use (say) Italian prices to value (for example) Indian consumption, these components of consumption will be valued very highly, and will inflate the value of Indian consumption at international prices. This is called the Gershenkron effect, the overvaluation of one country's consumption when evaluated at another country's prices. Put another way, it is the understatement of the price level in one country relative to another that comes from using a Paasche index; in (11) the domestic value of consumption in the numerator is divided by the inflated value of consumption at world prices in the denominator. Of course, the understatement of the Paasche index is an understatement relative to a true cost-of-living index, which is itself not well-defined in the current context. But if we compare the Paasche in (11) with the superlative indexes presented above, the latter always averages weights from *both* countries, whereas the Geary-Khamis index uses only *domestic* weights. Compared with the superlative indexes, Geary-Khamis indexes will understate PPPs in poorer countries relative to richer ones, and overstate their living standards. They make the world look too equal, and understate poverty in the poorest countries. Of course, these effects are likely to be much smaller than the effects in the opposite direction that we would get by using market foreign exchange rates. Even so, we do not want to minimize poverty in the poorest countries in our group by valuing their services at the prices of countries that are better-off.

**2.5 Index weights: P3 and P4**

The EKS and CPD formulas allow us to calculate a set of PPPs given budget shares and prices for each country. In our calculations for poverty-weighted PPPs, we use the budget shares for households at or near the global poverty line. This distinguishes our PPPs (P4s) from the consumption PPPs (P3s) from the ICP, in which the budget shares are the shares of aggregate consumers' expenditure on each good in the aggregate of consumers' expenditure in total. If $s_n^{ch}$ is the budget share on good *n* by household *h* in country *c*, the aggregate budget shares that go into the ICP indexes can be written

$$\tilde{s}_n^c = \frac{\sum_{h=1}^{H} x^{ch} s_n^{ch}}{\sum_{h=1}^{H} x^{ch}} \tag{13}$$

where $x^{ch}$ is the total expenditure of household *h*. Indexes using weights such as (13) are sometimes referred to as plutocratic indexes, because the budget share of each household is weighted by its total expenditure.

The weights that we shall use for the poverty PPPs are, not (13), but

$$\bar{s}_n^c(z^c) = E[s_n^{ch} \mid (x^{ch} / n^{ch}) = z^c] \tag{14}$$

where $n^{ch}$ is household size and $z^c$ is the poverty line in local currency, so that according to (14), the budget shares for poverty weighting are the average budget shares of households at the poverty line. The computation of (14) will be discussed below. Note that the averages in both (13) and (14) include the budget shares of all households, even if they do not purchase a good, in which case their budget share is zero. A household who buys nothing of good *n* is unaffected by changes in its price, and this weight needs to be counted in the overall index. This is also relevant because in many surveys, especially around the poverty line, some goods are bought by only a few households, and the precision of the estimates will depend on the total number of households (or the total number near the poverty line), not on the number who purchase.

### 2.6 Simultaneity of budget shares and P4-indexes: a closed-form approximation

The global poverty line is expressed in international currency—most famously the dollar a day line—while the calculation of the budget shares from the surveys in (14) requires that the line be expressed in local currency at its purchasing power equivalent. In consequence, the expenditure weights used to calculate the price indexes require that we know the price indexes before we start. We propose two methods for dealing with this issue. The first allows the calculation of an exact, one-step solution, but it works only for the Törnqvist index, and requires that the Engel curves in each country have a specific functional form. The second is an iterative procedure that uses the first method to provide starting values.

To illustrate the exact method, start from the two-country case. Suppose that the global poverty line in country 1's currency is *z*. The budget shares in each country are a function—among other things—of household total per capita expenditure (PCE) *x*, which we write as $s_n^c(x)$ for good *n* in country *c*, with the function interpreted as the expected budget share for households with PCE of *x*. The equation we need to solve for the relevant Törnqvist PPP is

$$\ln P_T^{12} = \frac{1}{2}\sum_{n=1}^{N}\left[s_n^1(z) + s_n^2(P_T^{12}z)\right]\ln\frac{p_n^2}{p_n^1} \qquad (15)$$

so that the budget shares for the index are at the global poverty line in both countries. Suppose that the budget shares in each country are linear functions of the logarithm of total expenditures, a functional form that often fits the data well, and that is consistent with choice theory, see for example, Deaton and Muellbauer (1980, Chapter 3.)

$$s_{nh}^{c} = \xi_{0n}^{c} + \xi_{1n}^{c} \ln x_h + \varepsilon_{nh}^{c} \tag{16}$$

where $c$ is the country, here 1 or 2, $\varepsilon_{nh}$ is a disturbance term, and $\xi_{0n}^{c}$ and $\xi_{1n}^{c}$ are commodity- and country-specific parameters. For each country, the $\xi_{1n}^{c}$ parameters add to zero over all the goods in the budget, while the $\xi_{0n}^{c}$ parameters to one. If we substitute the conditional expectation of (16) into (15), the poverty-line Törnqvist index can be written

$$\ln P_T^{12} = \frac{\sum_{n=1}^{N} \left( \xi_{0n}^{1} + \xi_{0n}^{2} + (\xi_{1n}^{1} + \xi_{1n}^{2}) \ln z \right) \ln \frac{p_n^2}{p_n^1}}{2 - \sum_{n=1}^{N} \xi_{1n}^{2} \ln \frac{p_n^2}{p_n^1}} \tag{17}$$

which is in closed-form and can be calculated directly from the prices, the budget shares, and the global poverty line.

The *M*–country extension of (17) is straightforward in principle. Assuming the same set of Engel curves (16), the logarithm of the Törnqvist index for *j* in terms of *i* is written

$$b^{ij} = \frac{1}{2} \sum_{n=1}^{N} \left( (\xi_{on}^{i} + \xi_{on}^{j}) + (\xi_{1n}^{i} + \xi_{1n}^{j}) \ln z + \xi_{1n}^{i} a^{i} + \xi_{1n}^{j} a^{j} \right) \ln \frac{p_n^j}{p_n^i} \tag{18}$$

where $a^i$, from (6), is the Törnqvist-EKS PPP-exchange rate for country *i* in terms of country 1. This can be rewritten in the form

$$b^{ij} = \psi^{ij} + \theta^{ij} a^i - \theta^{ji} a^j \tag{19}$$

where the definitions of the new terms can be read off from (18). Given the relative prices, the coefficients of the Engel curves, and the global poverty line, the quantities $\psi^{ij}$ and $\theta^{ij}$ are known. Equation (6) also links the EKS–Törnqvist PPPs to the pairwise Törnqvist indexes $b^{ij}$ so that, if we combine (6) and (19), we reach

$$a^i\left(1+\frac{1}{M}\sum_{j=1}^{M}\theta^{ij}\right)+\frac{1}{M}\sum_{j=2}^{M}(\theta^{j1}-\theta^{ji})a^j=\frac{1}{M}\sum_{j=1}^{M}(\psi^{1j}+\psi^{ji}) \tag{20}$$

where we have used the fact that $a^1=0.$ Equation (20) is a system of $M-1$ linear equations in the $M-1$ unknown EKS–Törnqvist P4-indexes under the assumption that the Engel curves take the form (16). So once again we have an exact, closed form solution.

**2.7 Simultaneity of budget shares and P4-indexes: iterative solution**

In general, none of the EKS–Törnqvist, EKS–Fisher, or weighted CPD P4 index has a closed-form solution. Instead, we start from the global poverty line converted to local currencies using the Törnqvist approximation (or some other set of PPPs, such as the consumption PPPs from the ICP), calculate a set of budget shares for households at or near those poverty lines in each country, which are used to calculate a new set of poverty-weighted PPPs. At the next iteration, these are applied to the global poverty line instead of the original starting values, and so on.

We calculate "near the line" budget shares by computing a weighted average of the budget shares in the sample with weights that are largest at the poverty line, and decline as we move away from it. Define the weight $\omega_{h\tau}(z)$ for household *h* in country *i* by

$$\omega_{h\tau}^{i}(z)=\frac{1}{\tau}K\left(\frac{\ln(x_h/n_h)-\ln z-\ln a^i}{\tau}\right) \tag{21}$$

where *z* is the global poverty line, and $x_h/n_h$, for household size $n_h$, is per capita total expenditure in local currency. The function *K*(.) is a "kernel" function; it integrates to unity, is non-negative, symmetric around zero, and decreasing in the absolute value of its argument. (It can be thought of as a density function, and indeed the standard normal density is often used as a kernel weighting function.) The parameter $\tau$ is a "bandwidth," that is ideally set to optimize the trade-off between bias (too large a bandwidth) and variance (too small a bandwidth). If $\tau$ is small, only households near to the poverty line will receive much weight while, if $\tau$ is large, more households will be included. Ideally, we would like $\tau$ to be zero, using only households *at* the line, but this is not possible with a finite sample of households. In general, $\tau$ will be smaller the larger is the sample and, in practice, allows us to trade-off precision (by including more households) and closeness to the poverty line (for relevance, and lack of bias.) In practice, we will work with bandwidths that are multiples of the standard deviation of the logarithm of per capita total expenditure in each sample.

In general, it is not possible to guarantee that there exists a unique solution for the set of poverty-weighted PPP indexes. However, we know that uniqueness is guaranteed for the EKS–Törnqvist when the Engel curves satisfy (16). It is also straightforward to show that in the case where all countries have the same tastes, and the price indexes are cost-of-living indexes, there is a unique solution. Given that both the Fisher and Törnqvist indexes are superlative indexes, this result would be useful if we could accept the unlikely position that there is no international heterogeneity of tastes. Deaton and Schulhofer-Wohl (2009) show that, while it is possible to construct cases with multiple solutions, even for two countries, it is very unlikely that there will be multiple solutions in real data.

**2.8 Differences between P4 and P3 indexes**

In order to interpret our results, it is useful to investigate the differences between the various indexes, between different types, EKS–Fisher, EKS–Törnqvist, and weighted CPD, and between indexes that use poverty weights versus those that use aggregate weights. The two country Törnqvist approximation (17) is a useful starting point for the latter inquiry.  If the budget shares do not vary with total household expenditure, the parameters $\xi_{1n}^{c}$ in (17) are zero, so that the term involving $z$ in the numerator of (17) and the second term in the denominator are both zero. In this case (17) is simply the P3 Törnqvist index, because the $\xi_{0n}^{c}$ parameters are the averages of the budget shares, and because the budget shares do not vary with income, they are also equal to the aggregate weights and (13) and (14) coincide.

More generally, the difference between the poverty-weighted and plutocratic Törnqvist indexes can be written in the form

$$\ln P_T^{12} - \ln \tilde{P}_T^{12} = 0.5 \sum_{n=1}^{N} [\xi_{1n}^{1} (\ln z^1 - \ln \tilde{x}^1) + [\xi_{1n}^{2} (\ln z^2 - \ln \tilde{x}^2)] \ln \frac{p_n^2}{p_n^1} \qquad (22)$$

Where $z^1$ and $z^2$ are the two local currency poverty lines, and $\tilde{x}^c$ is an (entropy) inequality adjusted measure of mean expenditure

$$\ln \tilde{x}^c = \sum_h \frac{x_h^c}{\sum_h x_h^c} \ln x_h^c \qquad (23)$$

and where $\tilde{x}^c$ is measured in local prices. These equations tell us that, if the effects of income on the budget shares, as measured by the $\xi_{1n}^{c}$ parameters, are orthogonal, for each country, to the logarithms of the price relatives, the plutocratic and poverty-weighted indexes will be the same. When these orthogonality conditions fail, the plutocratic and poverty-weighted indexes will differ by an amount that depends on the correlation between the $\xi_{1n}^c$ 's and the relative prices, on the inequality-adjusted levels of living in the two countries, and on the poverty line.

To illustrate with an important case, if we are comparing a rich country and a poor country, and if food in both is mostly traded, then food will be relatively expensive in the poor country, as is typically the case. Suppose that there are only two goods, food *f*, and non-food *n*, and that the Engel curve parameters $\xi_{1n}$ are the same in both countries. The food parameter is typically estimated to be around –0.15, so that the non-food parameter would be 0.15. Then the numerator of (22) simplifies to

$$\xi_{1f} \ln \sqrt{\frac{z^1 z^2}{\tilde{x}^1 \tilde{x}^2}} \ln\left( \frac{p_f^2}{p_n^2} \Big/ \frac{p_f^1}{p_n^1} \right) \qquad (24)$$

which is positive if food is relatively more expensive in the poor country, and if the poverty lines are less than inequality-adjusted mean expenditure in both countries. In this example, the P4 index for the poor country relative to the rich country will be *higher* than the corresponding P3 index, essentially because the food share is declining in income and the relatively higher food price gets more weight in the P4-index than in the P3-index. The size of the effect will be larger the larger the Engel effect, and the larger the distance between the poverty lines and inequality-adjusted mean expenditures in both countries.

It is a good deal harder to think of any such systematic effects between countries at similar levels of development which, as we shall see, is the relevant case here where we calculate P3s and P4s for a set of relatively poor countries.

The above argument is specific to the Törnqvist and to the two country case. But the argument about the correlation between Engel patterns and the structure of relative prices is clearly a general one, and should serve as a rough guide to the way in which we would expect P4 indexes to differ from P3 indexes. The extension to multiple countries is harder to derive formally, but practical experience has been that the EKS adjustment of the matrices of Fisher and Törnqvist indexes is typically not very large, so that the final index is likely to be dominated by the pairwise indexes, not by the final EKS adjustment.

## 2.9 Differences across index number formula

We shall calculate three different indexes, and it is useful to understand something about how they relate to one another. This is not always clear, but some progress can be made by using equation (9), which was earlier used to define the weighted CPD index, as an approximation. Repeating the equation here for convenience

$$\ln p_n^c = \alpha^c + \beta_n + \varepsilon_n^c \qquad (25)$$

we can think of the international structure of prices as being approximated by a common set of relative prices, scaled up by a set of purchasing-power converters, one for each country. We can substitute (25) into the formulas for the various different indexes. For the Törnqvist, we have at once that

$$\ln P_T^{ij} = (\alpha^j - \alpha^i) + \frac{1}{2}\sum_{n=1}^{N}(s_n^i + s_n^j)(\varepsilon_n^j - \varepsilon_n^i)\,. \qquad (26)$$

The logarithm of the Laspeyres index is

$$\ln P_L^{ij} = (\alpha^j - \alpha^i) + \log\left(\sum_{n=1}^{N} s_n^i \exp[\varepsilon_n^j - \varepsilon_n^i]\right) \qquad (27)$$

which, to a first order of approximation, can be written as

$$\ln P_L^{ij} = (\alpha^j - \alpha^i) + \sum_{n=1}^{N} s_n^i \exp[\varepsilon_n^j - \varepsilon_n^i] \tag{28}$$

Recalling that the logarithm of the Paasche index for *j* relative to *i* is minus the logarithm the Laspeyres index for *i* relative to *j*, we have that the approximation to the Fisher is again (26), so that to this order of approximation, the Fisher and the Törnqvist are identical. Given that the EKS adjustment works in the same way for both, we would expect this approximation to carry through to the multilateral indexes.

No similarly useful results are available for the weighted CPD index, where the weighted-regression framework does not lead to simple approximations. However, we know from Selvanathan and Rao (1994) that, for two countries *i* and *j*, the log of the CPD index can be written (exactly) as

$$\ln P_C^{ij} = (\alpha^j - \alpha^i) + \sum_{n=1}^{N} \breve{s}_n^{ij} (\varepsilon_n^j - \varepsilon_n^i) \tag{29}$$

where $\breve{s}_n^{ij}$ is the "normalized" harmonic mean of the budget shares for good *n* in countries *i* and *j*. This normalization procedure involves calculating the harmonic mean over *i* and *j* for each good, and then dividing by the sum of the harmonic means over all goods, so that the normalized harmonic means add up to unity over all goods together. While this formula is somewhat less useful that it might appear because, unlike the case for the other two indexes, there is no immediate link from the two country case to the *M* country case, it does illustrate for the two country case that, to this degree of approximation, the weighted CPD will be different from the other two indexes. In the empirical results in section 6, we shall consistently find that this to be true.

## 3. Constructing a global poverty line

So far, we have assumed that we are simply given the global poverty line in the base currency. Given the familiarity of the dollar-a-day line, and of the US as the base country, this might seems reasonable. However, the global line is calculated from selected national poverty lines converted at PPP exchange rates, which means that the poverty-weighted purchasing power parity exchange rates and the global poverty line need to be derived simultaneously. We shall also argue that it can be unhelpful to think of the line in dollar terms, an issue that we discuss below.

### 3.1 Which method to use?

Since the dollar-a-day global poverty line was first proposed, the line has been based on the national poverty lines of the poorest countries in the world. The intention is that the global line be a minimum absolute standard of subsistence that can reasonably be taken to be constant across countries. The poverty lines of the poorest countries arguably cluster around such a standard, and in many cases are at least ostensibly set with reference to the amount of money necessary to buy a minimal bundle of food and a few other items, for example at the lowest level of household per capita expenditure at which minimal recommended calorie intakes are met on average. These lines, once chosen, are converted into international dollars using the consumption PPP for each country, and a simple average chosen as the global poverty line in dollars. Hence the dollar-a-day line, though there is nothing that guarantees that it takes this value. Indeed, its nominal dollar value has increased with successive revisions, from a $1.00, to $1.08, to $1.25 in the 2008 revision.

The global poverty calculations that depend on this line require conversion back to local currencies using the consumption PPPs, so the US dollar plays no substantive role; the calculations could have been done with any currency used as numeraire and would have yielded exactly the same values of the poverty counts. The use of the dollar has been very successful as a communication and rhetorical device, and the unimaginable smallness of the dollar amount relative to Western incomes has doubtless played an important part in highlighting the extent and depth of global poverty. The corresponding disadvantage is that it is close to or actually impossible to live in the US on an expenditure of one dollar per person per day, which undermines the notion that the global line is indeed a *global* minimum. In the calculations proposed here, we bypass the dollar altogether though, at a final stage, we link our numbers back to the dollar standard. Indeed, given that there is no one in the US—or other rich countries—living at anything close to a dollar a day, we cannot include those countries in our poverty-weighted PPP calculations, because there are no relevant budget shares with which to compute them. We include only those countries that appear in the World Bank's global poverty counts; these include a number of middle income countries, but all of these have people living near the global poverty line.

In their most recent calculations, Chen and Ravallion (2008) update their previous estimates using consumption P3s from the 2005 ICP. They start from a set of 75 local currency poverty lines from low and middle-income countries around the world; at least some of these have genuine local legitimacy, though some are likely to have been calculated by the World Bank itself. A plot of these lines in international dollars against per capita consumption in international dollars shows that, in general, better off countries have higher poverty lines and that, among the poorest countries, the curve is close to being flat. These observations are consistent with their view that, in the poorest countries of the world, the international dollar values of poverty lines are scattered around an absolute poverty standard that can be taken to be a reasonable cutoff for subsistence. Chen and Ravallion select 15 very poor countries along the flat of their curve, and they use these to compute the international poverty line. All but two of these countries (Nepal and Tajikistan) are in sub-Saharan Africa (Chad, Ethiopia, Gambia, Ghana, Guinea-Bissau, Malawi, Mali, Mozambique, Niger, Rwanda, Sierra Leone, Tanzania, and Uganda). A simple average over the 15 lines, converted to dollars using the 2005 consumption P3s from the ICP, yields a new international poverty line of $1.25 per person per day in 2005 international dollars.

The new line is a good deal lower than the previous line of $1.08 per person per day in 1993 international dollars, which is $1.45 when we allow for US inflation in the intervening period. The proximate reason for this decrease in the real dollar value of the international line is the upward revision in the 2005 ICP of the dollar-denominated consumption price levels in many poor countries, which is part—although not the most important part—of the increase in the price indexes for GDP that has made the economies of India and China much smaller relative to rich countries than was previously thought to be the case. The 2005 US dollar values of the 15 local poverty lines are lower than would have been expected from the 1993 PPPs and intervening inflation rates. Chen and Ravallion attribute the upward revision in consumption price levels to improvements in ICP methodology, particularly the stricter matching of goods and service across countries by much more precise specification of items  The argument that these changes are an improvement almost certainly has some truth to it, but it is also possible that the correction went too far and overstated prices by matching with goods that are rarely consumed locally and are only found, if at all, in a few expensive stores in capital cities, see for example Heston (2008), Deaton and Heston (2008).

It is important to note that the upward revision of poor country PPPs relative to rich country PPPs, although it affects the dollar value of the global poverty line, has an effect on global poverty only in so far as it changes relative PPPs within the countries included in the poverty counts. When there is only one poor country and one rich country, the revision has no effect on the poverty count. To see this, suppose that there were only one poor country in the world, "Africa" say, and that the African poverty line is 10 "africs" per person per day. If the consumption PPP for Africa in US dollars is $P$, and because there is only one poor country, the global poverty line is $10/P$ dollars per person per day. An upward revision in $P$ decreases this dollar line, as was the case in the latest revisions. To count the number of poor in "Africa", we convert the global poverty line to local currency, by multiplying the global line by $P$ which gives, one again, 10 "africs", and the number of global poor is simply the local "African" count of people in poverty. Revisions to PPPs affect the global poverty counts, not by changing the PPPs relative to the US, but by changing the relative PPP exchange rates between the poor countries—or at least Part 2 countries—themselves. And indeed, we shall argue below that the upward revision in the latest counts is largely driven by changes in the PPPs between Africa and Asia, and by excluding the two countries with the most poor people—India and China—from the construction of the global line.

When there are many poor countries, some of whose poverty lines are included in the global line, a similar analysis goes through, but we need a little more notation. Write $z^c$ for the local poverty line in local currency in country $c$, and let $P^c$ be the purchasing power parity exchange rate expressed in local currency per US dollar. The global line (the dollar a day line, or its update) is then given by

$$z^0 = \frac{1}{m_R} \sum_{k \in R} \frac{z^k}{P^k} \qquad (30)$$

where $R$ is the set of $m_R$ countries whose poverty lines go into the global line. The number of people in country $c$ who are globally poor, $N^c$, is given by

$$N^c = F^c(P^c z^0) = F^c\left[P^c \frac{1}{m_R} \sum_{k \in R} \frac{z^k}{P^k}\right] \qquad (31)$$

where $F^c(.)$ is the distribution function of per capita expenditure in country $c$. We see immediately from (31) that the national and global poverty counts are homogeneous of degree zero in all of the PPP exchange rates together and so depend only on the relative PPPs between the poor countries. There is no effect on global poverty if the PPPs of the poor countries are revised upwards relative to the United States although, by (30), this will reduce the dollar value of the global line. Such a revision reduces the size of economies in the poor world relative to the economy of the US (or other rich countries) but it has no effect on the global poverty counts. If this seems counterintuitive, it is because we sometimes think in terms of the US dollar, and of dollar-a-day poverty line as being fixed in dollar terms although, in reality, global poverty is defined entirely in terms of poverty lines from the poor world alone. Scaling up the PPP exchange rates of the poor countries by 10 percent, say, has no effect on global poverty because it reduces the global poverty line from a dollar (say), to 90 cents.

Equations (30) and (31) are also helpful for thinking about how revisions in the PPPs affect global poverty. For example, global poverty will rise when the price levels are revised upwards in countries excluded from *R* relative to countries included in *R*, especially when the former are countries with a large (absolute) number of people near the poverty line. In particular, if the price level in India and China (which are not included in the Chen and Ravallion's reference group) are revised upwards relative to those of the poorer countries that are included in the poorest group from which the global line is computed, global poverty will increase, particularly since India and China are countries with large numbers of poor people near the global poverty line.

We shall follow Chen and Ravallion's methods in one version of our calculations, though we need to make some changes to recognize that our P4s depend on the global poverty line which, in turn, depends on our P4s. We must also exclude one of their 15 countries, Guinea-Bissau, for lack of suitable survey data, though this has little effect on the results. However, we also consider an alternative that uses poverty lines from all low and low-middle income countries. In particular, we use poverty lines from 50 countries; 49 of them listed in Appendix 1 of Ravallion, Chen and Sangraula (2008), plus Bhutan. We drop countries for which we either have no household survey data, or where the surveys are unusable because of some major inadequacy or lack of documentation. We use *all* of these countries to compute the international poverty line, converting them to a common currency and averaging over countries, weighted by the number of people in poverty in each country. Once again, this needs to be done simultaneously because the PPP conversion depends on the line and vice versa.

The difference between what we do and Chen and Ravallion's procedure is the inclusion of many more poverty lines, albeit with poverty weighting, which means that each poor *person* gets equal weight rather than each poor *country*, irrespective of its population of poor. Even so, the poverty weighing will tend to give poor countries more weight, which is similar in spirit to what

Chen and Ravallion do. However, we are more skeptical than are Chen and Ravallion that poverty lines of the poorest countries are really interpretable as global subsistence minima, as opposed to being set through some process of debate and negotiation. If we are really looking for a subsistence minimum, we should not exclude lower poverty lines from major countries, such as the poverty line from India, which is not among the 15 countries used by Chen and Ravallion. We take a more political interpretation of the lines and choose to use all poverty lines available to us from Part 2 countries, ignoring the fact that lines are higher in better-off countries (though our weighting by the numbers of poor will automatically downweight them.)

Our procedure also has a statistical advantage that will become more obvious when we come to the actual numbers. A simple example illustrates. Suppose that there are only two poor countries, Africa and Asia, and that Africa is a good deal poorer than Asia, so we choose the local African poverty line to be our global line, excluding the richer Asia. Suppose, however, that because of population differences, most of the poor people in the world are in Asia, not Africa. If there are errors in the local African poverty line, or in the calculation of African PPPs, these will have their effects, not on the African poverty count—which does not depend on the African PPP, because the global line is the African line—but on the estimate of poverty in Asia. If the Asian and African local poverty lines are *both* included in the calculation of the global line, African errors will still matter, but by less, in part because they are given less weight, but also because the inclusive procedure penalizes deviations between the local values of the global line and the local poverty lines. An error in Africa can no longer result in an Asian poverty line that is unrestrained by the Asian local poverty line.

One disadvantage of our procedure is that we are hostage to a large country that is not one of the poorest but which nevertheless, sets a high poverty line, which will possibly attract a large amount of weight in the construction of the global line. In practice, however, it is almost exactly the opposite situation that is relevant. Because neither India nor China are among Chen and Ravallion's 15 poorest countries, these two poverty lines—which are low relative to their income levels, at least judged by the standards of the 15 reference countries—are not included in the construction of the global average, in spite of the fact that those two countries contain more than half of the world's poor.

Figure 1 illustrates our argument. The graph uses data from Table A1 of Ravallion, Chen, and Sangraula (2008) and plots the value of poverty lines, in 2005 P3 dollars per month, against the log of monthly per capita taken from the National Accounts. It shows the well-established regularity that, in general, poverty lines are higher among the richer countries, albeit with very little such relation among the poorest countries. The size of the circles in the figure is proportional to the population of each country, and we note in particular two countries of very different sizes, India, with a population of more than a billion, and Guinea-Bissau, with population of 1.5 million. The line PP, which is the unweighted average of the poverty line of the 15 countries with lowest levels of mean per capita expenditure is the global poverty line of $38 a month or $1.25 a day. The line, AA, shows the cut-off level of per capita expenditure, below which the country's national poverty line is included in the international poverty line.

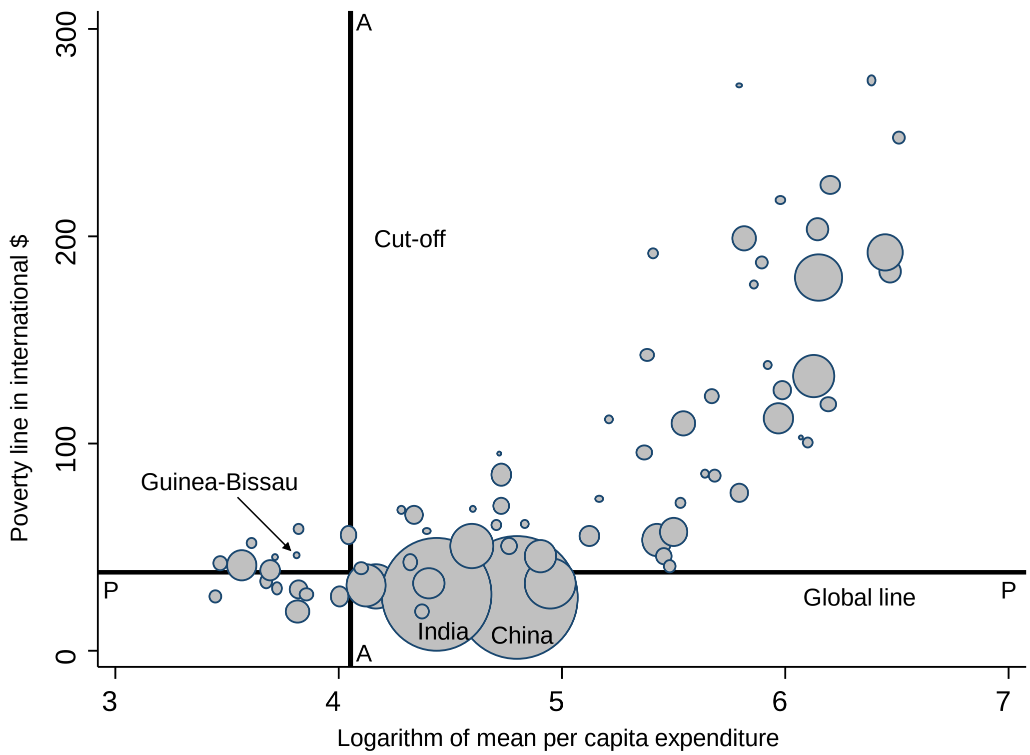


**Figure 1: National poverty lines and mean expenditure**
(data from Ravallion, Chen, and Sangraula, 2008)

Over time, as country incomes change, either in reality, or through measurement error, some countries will move across the cutoff AA. Consider first India, and suppose that India has recently moved across the line. At the point where it is just on the line, there will be a discontinuity in the global poverty line as India drops out of the average, and the global line will increase discontinuously when India crosses AA, and this discontinuity will be transmitted into the global poverty count. There will be a large *increase* in global poverty—much of it from India—associated with a marginal *increase* in Indian incomes. Not only are such discontinuities undesirable in and of themselves, but in this particular example, the change is of the wrong sign, with a small *increase* in Indian incomes causing a large *increase* in Indian and other countries poverty counts. India becomes poorer because it has become richer! Turn now to Guinea-Bissau, and suppose that it become richer—either in reality, through an increase in the world price of cashews, or only apparently so through measurement error. Because Guinea-Bissau has a high poverty line, the global poverty line will decrease, as will global poverty, by rather more than 20 times the population of Guinea-Bissau even though, by assumption, there has been no change in poverty in any other country. As with India, as Guinea-Bissau crosses the line there will be a discontinuity in global poverty.

These problems would not occur if the relationship in Figure 1 were exact, rather than a scatter. Countries would immediately adapt their poverty lines to changes in their incomes. This will likely happen in most cases, but only over time, and when poverty lines do not adapt immediately, discontinuities are always a possibility. Note also that our alternative procedure, which takes a weighted average of all poverty lines, is not subject to these problems. There are no discontinuities, and no sign reversals.

When all poor countries are included, the global line in (30) is replaced by

$$z^0 = \frac{\sum_k \frac{z^k}{P^k} F^k(z^0 P^k)}{\sum_k F^k(z^0 P^k)} \tag{32}$$

where the index $k$ runs over all part II countries for which we have lines. Equation (31) is also adapted in an obvious way. Equation (32) defines the global line implicitly and because the line appears in the weights, it is no longer true that the global poverty line is linearly homogeneous in the local poverty lines. But these effects work entirely through the weights, and are likely small.

Our calculations proceed as follows. Because we cannot use the United States or any other rich country in our calculations, we use the Indian rupee as our base, and convert everything to world rupees, which we refer to as "wrupees." As a starting point, we take our 50 local poverty lines and convert them to wrupees using Törnqvist P3s that are computed using the ICP prices and aggregate expenditure weights from the national accounts; we shall describe these P3s in more detail below, but because they are P3s and not P4s they require no iterations. Our starting value of the global poverty line is a population-weighted average of those 50 lines in wrupees. We then use this initial global poverty line to calculate the closed-form approximation to the EKS-Törnqvist P4. These P4s are then taken back to the 50 local currency poverty lines and used to convert them to wrupee lines, which are averaged over the 50 countries using as weights the numbers of poor people in each of the 50 countries at its own local poverty line. (These poverty counts are based on the latest available survey data updated using consumption growth from the national accounts, following the procedures in Chen and Ravallion, 2008.) This new global line is used to calculate EKS-Törnqvist, EKS-Fisher, and weighted CPD indexes, which are the new P4s. These are taken back to the 50 local poverty lines, which are averaged with weights equal to the numbers of people in each who are below the new global line in local currency. This procedure is then repeated until we have a convergent solution for the three different P4s. At the last stage, we also calculate the standard errors using the concepts and procedures laid out in the next section. Our version of the Chen and Ravallion procedure works exactly as above, but we average not the 50 lines but the lines from the 14 of the 15 poorest countries for which we have data, and the averages poverty lines are simple averages without weights.

The resulting set of P4s are denominated in world rupees, but it is important to note that India plays no special role in the calculations, and the results would have been identical (up to scaling) if we had worked in international Indonesian rupiah, Bangladeshi taka, or Kenyan shillings, for example. Nor does the Indian poverty line play any special role in the calculations, though it is certainly true that because a large fraction of the world's poor are in India, the Indian national poverty lines play a relatively large role in the calculations. In one (typical) final calculation, India accounts for a little less than 46 percent of the total number of poor people in the 50 countries, followed by China (15 percent), Nigeria (8 percent), and Bangladesh (3.5 percent). In our version of the Chen and Ravallion procedure, like theirs, the Indian line does not appear.

### 3.2 A dollar line?

The calculations so far give us everything we need to produce counts of global poverty for the countries for which we have survey data. We have a common international line denominated in world rupees with a set of P4s that are weighted by expenditure patterns around that line, which is all that we need to convert to local currencies and to calculate the number of people below that line. We do not need to know its equivalent in international dollars, and indeed, no dollar labeling would have any effect on the line or on the global poverty calculations, given that there are no people in the US that are at or below the international line. So the first question to ask is why we need a dollar equivalent at all.

One response is that we need some link with previous global poverty lines, which were calculated in terms of per capita dollars a day. Even so, previous attempts to update the dollar lines, have sometimes generated more confusion than elucidation because the change in the international line has not been in line with inflation in the US, either because of shifts in the international PPP value of the dollar relative to a basket of poor currencies or because successive revisions of the line do not match the relative rates of inflation of the US and some average of the inflation rates in which poor people live. It is also unclear, to say the least, why variations in the US CPI should play any role in counting the world's poor. It is also true that we could backcast our own calculations, at least in principle, and provide a link with previous poverty rates without ever involving the US dollar.

A better reason for deriving a dollar equivalent is the rhetorical success of the dollar a day in discussions and programs concerned with global poverty, the lead MDG being only the most obvious example. The target here is the educated public in the US and other rich countries, for whom an international line of 17 world rupees per day would require some explanation, especially if the 17 rupees is converted at the current exchange rate to get even less than a dollar a day (41 cents at the current exchange rate.)

Here we explore one way of calculating a dollar equivalent which is an "add-on" calculation in the sense that there is no feedback from this step to the international line which has been established as described in Section 3.1 above. Instead we are simply trying to establish the value of this international line (17 wrupees per person per day) in US dollars using some appropriate index number. We do this by computing a "star" system of purchasing power indexes for each of our 62 countries using the US as the star; a star system of PPPs is simply a set of bilateral index numbers for each country *c* in terms of the star. As always, we use the ICP prices for each of the 102 basic headings. That leaves the question of which expenditure weights to use. In line with the target group of educated people in the US thinking about poverty in the world, we use the poverty-line weights for each poor country and the aggregate NIPA consumption weights for the US. Under appropriate conditions, the NIPA weights represent a household at around the third quartile of the US expenditure distribution, which is perhaps reasonable for those who concern themselves with world poverty. In this calculation, each of the poor country's prices are first converted into world rupees, so that the star calculations give us 62 purchasing power parity exchange rates, all of which are expressed in wrupees per US dollar. In practice, we shall see that they are close to one another, and we use their average to express our international wrupee line in dollars.

## 4. Standard errors: concepts and formulas

We provide two different sets of standard errors for our P3 and P4 estimates. The first and probably the more important—although they are not the largest—are the sampling standard errors. These treat the prices from the ICP as fixed data, and are concerned with the variability in the indexes that is induced by the fact that the household surveys only sample the population so that the weights for the indexes are estimated, not known. This is a particular concern for the smaller surveys, and for poverty-weighted indexes in relatively rich countries, where there are relatively few households near the poverty line. The sampling standard errors typically rise when we use smaller bandwidths, so that we are more exclusively focusing on households near the poverty line. They are therefore useful in deciding which bandwidths to use.

We also provide a second type of type of standard error which we refer to as the "failure of arbitrage" standard errors. These come from the following conceptual experiment. Suppose that we write the price of good $n$ in country $c$ in the form (9) or (25)

$$\ln p_n^c = \alpha^c + \beta_n + \varepsilon_n^c \tag{33}$$

so that, as in the CPD formulation, the logarithm of price is the sum of a country effect, a commodity effect, and an error. In a world of perfect arbitrage, where relative prices were the same in all countries, and absolute prices differed only according to the currency unit, the error terms in (33) would be zero, and the $\alpha^c$ would be the logarithms of the PPPs, of the exchange rates, or of any reasonable index of prices in the country. Because perfect arbitrage does not hold, the $\varepsilon_n^c$ are not zero, and different index number formulae will give different answers for the indexes. It is this variability across indexes that is captured by the "failure of arbitrage" standard errors.

There is a simple link between our concepts here and the "Paasche-Laspeyres spread," another measure of the extent to which different price formulas give different answers when relative prices differ across countries. By equation (28), and the corresponding expression for the logarithm of the Paasche index, the log of the ratio of the Laspeyres to the Paasche takes the form

$$\ln \frac{P_L^{cd}}{P_P^{cd}} = \sum_{n=1}^{N} (s_n^c + s_n^d)(\varepsilon_n^c - \varepsilon_n^d) \tag{34}$$

from which we see that the spread depends on the "residuals" in (33) with residuals with goods with larger budget shares getting larger weights.

In calculating our "failure of arbitrage" standard errors, the conceptual experiment is one in which we think of $\varepsilon_n^c$ as drawn repeatedly, which generates stochastic prices according to (9) or (33), which are then combined with non-stochastic expenditure weights to generate stochastic P3s and P4s whose standard errors are calculated. Note that these standard errors are conditional on the budget shares which we are taking as fixed. It is easy to imagine an alternative set of standard errors which models the dependence of the weights on the prices, for example through a cross-country model of consumer behavior. We do not consider that extension here, in large part because we do not want to commit to any such model, instead regarding the failure of arbitrage standard errors as descriptive measures of the dispersion of the $\varepsilon_n^c$, not directly, but through the PPP indexes.

The formulae are developed in the rest of this section, which can be skipped by readers willing to take them for granted. We start with the "failure of arbitrage" standard errors developed above, continue on to the sampling standard errors associated with the household surveys, and finally show how to deal with both at once. The simplest case to deal with is the weighted-CPD P3 and P4 indexes. The CPD indexes are estimated by running a generalized least squares regression on (33), see (10) above, and an estimate of the variance covariance matrix of the estimated parameters can be obtained from

$$\widehat{V}(\widehat{b}) = (X'SX)^{-1}(X'S\Sigma SX)(X'SX)^{-1} \tag{35}$$

where $X$ is the matrix of country and product dummies, $S$ is a diagonal matrix of the budget share weights, and $\Sigma$ is an estimate of the variance-covariance matrix of the $\varepsilon_n^c$, the deviation of the log prices from perfect arbitrage. In practice, we estimate $\Sigma$ by a diagonal matrix containing the squares of the estimated residuals from the CPD model.

We can use equation (33) to derive "failure of arbitrage" standard errors for the other indexes. Here it is best to start with the two country case and then move to the EKS adjustment.

Note that (33) implies that we can write logarithms of the relative prices of country 2 relative to country 1 as

$$\ln(p_n^d / p_n^c) = \theta^{cd} + \eta_n^{cd} = (\alpha^d - \alpha^c) + (\varepsilon_n^d - \varepsilon_n^c) \tag{36}$$

where θ is the logarithm of the P3 or P4 exchange rate of country *d* in terms of country *c*. From (36), we have immediately that the log of the Törnqvist index satisfies

$$\ln P_T^{cd} = \theta^{cd} + \frac{1}{2}\sum_{n=1}^{N}(s_n^c + s_n^d)\eta_n^{cd} = \theta^{cd} + \bar{s}^{cd}\,'\eta^{cd} \tag{37}$$

in an obvious notation for the mean of the budget shares over the two countries. The variance of this expression can be written

$$V(\ln P_T^{cd}) = \bar{s}^{cd}\,'V_{\eta\eta'}^{cd}\bar{s}^{cd} \tag{38}$$

where $V_{\eta\eta'}^{cd}$ is the variance-covariance matrix of $\eta^{cd}$. We can estimate this using the information from the unweighted CPD regression, in parallel to the estimation of Σ for (35). In particular, from the definition of η in (36), we can rewrite (38) as

$$V(\ln P_T^{cd}) = \bar{z}^{cd}\,'V_\varepsilon \bar{z}^{cd} \tag{39}$$

where $\bar{z}^{cd}\,' = [-\bar{s}^{cd}\,', \bar{s}^{cd}\,']$ is a (1 x 2*N)* matrix formed from the (*N* x 1) matrix of averaged budget shares $\bar{s}^{cd}$. Equation (39) can be estimated using the $\Sigma$, the diagonal matrix of squared residuals from the CPD regression by

$$\widehat{V}(\ln P_T^{cd}) = \bar{z}^{cd}\,'\Sigma\bar{z}^{cd}. \tag{40}$$

Given (36), the approximate log Laspeyres index takes the form

$$\ln P_L^{cd} = \theta^{cd} + \sum_{n=1}^{N} s_n^c \eta_n^{cd} \tag{41}$$

So that, parallel to (40), we can approximate the variance of the log Laspeyres by

$$\widehat{V}(\ln P_L^{cd}) = z^c{}'\Sigma z^c \tag{42}$$

where $z^c{}' = [-s^c{}', s^c{}']$. Following through the same logic for the log Paasche, and remembering that $\ln P_P^{cd} = -\ln P_L^{dc}$ we have the parallel estimate of the variance

$$\widehat{V}(\ln P_P^{cd}) = z^d{}'\Sigma z^d \tag{43}$$

where $z^d{}' = [s^d{}', -s^d{}']$. By averaging the log approximations for the Laspeyres and Paasche, it turns out that the corresponding approximation for the log Fisher is identical to the approximation for the log Törnqvist, (37), so that (40) can serve double duty, as an estimator of the variance of both the log Fisher and the log Törnqvist. We could also have shown this directly from the earlier demonstration that, to the same order of approximation that we are working to here, the Fisher and Törnqvist indexes are identical, see Section 2.9 above.

Before extending these standard errors to the multilateral EKS indexes, it is useful to consider the sampling standard errors, since the extension from bilateral to multilateral is the same in both cases. The bilateral plutocratic Laspeyres index for country *d* relative to country *c* can be written in the form

$$P_L^{cd} = \frac{\sum_{n=1}^{N} \bar{x}_n^c (p_n^d / p_n^c)}{\sum_{n=1}^{N} \bar{x}_n^c} = \frac{\sum_{h=1}^{H^c} w_h^c \left( \sum_{n=1}^{N} x_{nh}^c (p_n^d / p_n^c) \right) \Big/ \sum_{h=1}^{H^c} w_h^c}{\sum_{h=1}^{H^c} \left( \sum_{n=1}^{N} x_{nh}^c \right) \Big/ \sum_{h=1}^{H^c} w_h^c} \tag{44}$$

where an overbar denotes a sample average, $w_h^c$ is the survey weight in country *c* for household *h*, $H^c$ is the total number of households in the survey for *c*, and *x* denotes expenditure, so that

$x_{nh}^{c}$ is the expenditure on good *n* by household *h* in country *c*. Note that (44) can be interpreted as the ratio of the (weighted) average over country *c*'s households of expenditure revalued at country *d*'s prices to the weighted average of expenditures at country *c* prices. Since the relative prices are taken to be measured without error, this is simply a ratio estimate, and given the survey design in country *c*, typically the weights, the stratification, and the multistage structure, its (asymptotic) sampling standard error can be calculated from standard software (such as STATA) that handles complex survey designs.

The log of the Fisher index is the average of the log of the Laspeyres index for *d* in terms of *c* and the Laspeyres index for *c* in terms of *d*. The variance of the Fisher index for *d* in terms of *c* is therefore given by

$$V(\log P_F^{cd}) = [V(\log P_L^{cd}) + V(\log P_L^{dc})]/4 \qquad (45)$$

because the surveys for *c* and *d* are statistically independent of one another. The variances of the log Laspeyres can be approximated from (44) using

$$V[\log P_L^{cd}] = \frac{1}{(P_L^{cd})^2} V[P_L^{cd}] \qquad (46)$$

The pairwise Törnqvist index (1) can be rewritten in terms of the survey data as

$$\ln P_T^{cd} = \frac{1}{2} \frac{\sum_{h=1}^{H_c} w_h^c \sum_{n=1}^{N} x_{nh}^c \ln\left(p_n^d / p_n^c\right) \Big/ \sum_{h=1}^{H_c} w_h^c}{\sum_{h=1}^{H_c} \sum_{n=1}^{N} w_h^c x_{nh}^c \Big/ \sum_{h=1}^{H_c} w_h^c} + \frac{1}{2} \frac{\sum_{h=1}^{H_d} w_h^d \sum_{n=1}^{N} x_{nh}^d \ln\left(p_n^d / p_n^c\right) \Big/ \sum_{h=1}^{H_d} w_h^d}{\sum_{h=1}^{H_d} \sum_{n=1}^{N} w_h^d x_{nh}^d \Big/ \sum_{h=1}^{H_d} w_h^d} \qquad (47)$$

where $H_c$ and $H_d$ are the numbers of sample households in each of the two surveys. Because the prices are being treated as known, the first term depends only on the first survey, and the second only on the second survey, so the sampling variance of (47) is the sum of the two variances. Each term is a ratio of means so that, once again, standard software will give the asymptotic variances given the design of each survey.

The budget shares used in the formulas above are the budget shares as they would appear in the national accounts, the average expenditure on each good divided by the average expenditure on all goods. We shall present these calculations below. But we are also concerned with the poverty-weighted indexes that use the average of the budget shares for households at or near the poverty line. Estimation variances for these P4 indexes can be calculated in essentially the same way, both for the sampling variances and for the variances associated with the stochastic approach. When calculating variances and covariances for the weighted average budget shares using the kernel weights (21), we have once again a ratio estimator, in this case the average of the budget shares multiplied by the kernel weight, divided by the average of the kernel weights themselves. Once again, standard software for surveys with complex design can be used to calculate variances and covariances.

We can either present the two kinds of standard errors separately—they correspond to different concepts, and the sampling error might be seen as of obvious relevance, but the failure of arbitrage standard error as less so—or we can add them together by summing the two kinds of variance and taking the square root. The sampling variances come from variability of the budget shares in the survey, while the failure of arbitrage variances are associated with the variability of the prices across goods and countries, so the two can be taken as independent.

The weighted CPD index is given by (10), which is a GLS estimator, and the sampling variability comes through the budget shares, so that, given the variance-covariance matrix of the budget shares from the surveys, we can calculate the sampling variance covariance matrix from (8) using the delta method, as described, for example, in Hayashi (2000, pp 93-94). The estimated budget shares for country $c$ are calculated as

$$\hat{s}_n^c = \sum_{h=1}^{H} w_h^c x_{nh}^c \Big/ \sum_{n=1}^{N}\sum_{h=1}^{H} w_h^c x_{nh}^c \tag{48}$$

In equation (10), these budget shares are arranged into a diagonal matrix with $N$ shares for country 1 followed by $N$ shares for country 2 and so on up to country $M$. As usual, (48) is a ratio estimate, and its variance and covariances with the other commodity shares for the country can be calculated in the usual way.

Suppose that we denote by $s$ the $MN$ by 1 vector of stacked shares whose elements are estimated from (48). We then write

$$\Omega = E(\hat{s}-s)(\hat{s}-s)' \tag{49}$$

for the variance-covariance matrix. Because the surveys are independent of one another, this is an $NM$ by $NM$ block diagonal matrix. It is then possible to show, using the delta-method applied to (10), we obtain a variance covariance matrix for the weighted CPD estimates of

$$\hat{V}_\beta = (X'SX)^{-1}X'E\Omega EX(X'SX)^{-1} \tag{50}$$

where $E$ is a diagonal matrix whose diagonal elements are the $MN$ residuals $e$ defined by

$$e = y - X\beta \tag{51}$$

Paralleling the discussions of the Fisher and Törnqvist above, (50) captures the sampling variance. If we add the variance from the stochastic approach, (35), we get the total variance-covariance matrix for the CPD index

$$\tilde{V}_\beta = (X'SX)^{-1}X'[E\Omega E + S\Sigma S]X(X'SX)^{-1} \tag{52}$$

where, once again, $\Sigma = E^2$ is a diagonal matrix with the squared residuals on the diagonal. The variances and covariances of the logarithms of the PPP indexes are the top left *M* by *M* submatrix of (52).

The final task is to use the variances of the pairwise Fisher and Törnqvist indexes to derive variances for the multilateral EKS indexes based on them. Equations (6) and (7) give the log EKS PPP rates as a function of the underlying log Fisher or Törnqvist indexes, whose standard errors we have already discussed. So the only new issue is to deal with the covariances between the various fundamental indexes in these formulas. The Törnqvist is the most straightforward case, and we deal with it first.

We write the Törnqvist index for country *j* with country *i* as base in the form

$$b^{ij} = \frac{1}{2}\sum_{n=1}^{N}(s_n^i + s_n^j)t_n^{ij} = \frac{1}{2}(s^i + s^j).t^{ij} \qquad (53)$$

where

$$t_n^{ij} = \log(p_n^j / p_n^i) \qquad (54)$$

is the vector of the logarithms of the price ratios, and the second term in (53) is a dot product. If we substitute (53) into (6), we get the logarithm of the Törnqvist indexes

$$a^i = \frac{1}{2M}\sum_{j=1}^{M}\left[s^1.t^{1j} + s^j.(t^{1j} + t^{ji}) + s^i.t^{ji}\right] \qquad (55)$$

The variance of these log PPPs is driven by the sampling variances of the vectors of budget shares. Because the surveys in each country are drawn independently of one another, there are no cross-country covariances. If we denote the sampling variance-covariance matrix of the budget shares for each country by the $N$ x $N$ matrix $V^i$, (55) gives an exact sampling variance for the log PPPs as, for $i$ running from 2 to $M$

$$4M^2V(a^i) = (1-2\delta_{i1})\sum_{j=1}^{M}\sum_{k=1}^{M} t^{1j}.V^1t^{1k} + 2\sum_{j=1}^{M} t^{1j}.V^1t^{1i} + 2\sum_{j=1}^{M} t^{ji}.V^it^{1i} + \sum_{j=1}^{M}\sum_{k=1}^{M} t^{ji}.V^it^{ki} + \sum_{j=1}^{M} t^{1i}.V^jt^{1i} \tag{56}$$

The expressions in (56) of the form $x.Vx$ demote quadratic forms in the various country variance covariance matrices. The quantity $\delta_{i1}$ is the Kronecker delta and is unity when $i=1$ and zero otherwise. As is easily checked, the variance of the baseline PPP, for which $a^1 = 0$, is zero.

The pairwise Fisher indexes are not linear functions of the budget shares, so that we need to take an approximate linearized approach. The pairwise log Fisher indexes can be written

$$b^{ij} = \frac{1}{2}\left(\ln s^i.r^{ij} - \ln s^j r^{ji}\right) \tag{57}$$

where

$$r_n^{ij} = p_n^j / p_n^i \tag{58}$$

is the vector of price ratios. Equation (57) gives the log Fisher as the average of the log Laspeyres and the log Paasche. The log EKS index (6) is then given by

$$a^i = \frac{1}{2M}\sum_{j=1}^{M}\left[\ln s^1.r^{1j} - \ln s^j.r^{j1} - \ln s^i.r^{ij} + \ln s^j.r^{ji}\right] \tag{59}$$

We then apply the delta-method to derive the approximate variances. Define the vectors whose $n$th element, $n = 1, \ldots, N$, is given by

$$\beta_n^{ij} = \frac{r_n^{ij}}{w^i.r^{ij}} \tag{60}$$

If we follow through the algebra in a way that closely mirrors the calculations for the variance of the Törnqvist index in (56), we eventually reach

$$4M^2V(a^i)=(1-2\delta_{1i})\sum_{j=1}^{M}\sum_{k=1}^{M}\beta^{1j}.V^1\beta^{1k}+\sum_{j=1}^{M}\sum_{k=1}^{M}\beta^{ij}.V^i\beta^{ik}+\sum_{j=1}^{M}(\beta^{ji}-\beta^{j1}).V^j(\beta^{ji}-\beta^{j1}) \\ +2\sum_{j=1}^{M}\beta^{1j}.V^1(\beta^{1i}-\beta^{11})-2\sum_{j=1}^{M}(\beta^{ii}-\beta^{i1}).V^i\beta^{ij} \tag{61}$$

As before, we can compute variances that reflect the failure of arbitrage, or that the P3s and P4s are compromise indexes that "average" over many possible candidate indexes. Again, the Törnqvist is the more straightforward. From the CPD formulation, equation (9) or (25), the pairwise log Törnqvist indexes are

$$b^{ij}=\alpha^j-\alpha^i+\frac{1}{2}\sum_{n=1}^{N}(s_n^i+s_n^j)(\varepsilon_n^j-\varepsilon_n^i) \tag{62}$$

The log Törnqvist PPPs are, from (1),

$$a^i=\alpha^i+\frac{1}{2}\sum_{j=1}^{M}(s^i+s^j).(\varepsilon^i-\varepsilon^j)+\frac{1}{2}\sum_{j=1}^{M}(s^i+s^1).(\varepsilon^j-\varepsilon^1) \tag{63}$$

We assume that the variances of the $\varepsilon^i$ satisfy

$$E(\varepsilon^i\varepsilon^j)=\delta_{ij}\Omega^i \tag{64}$$

where $\delta_{ij}$ is the Kronecker delta and, if we follow our previous practice, $\Omega^i$ is a diagonal matrix whose elements are replaced in the calculations by the squares of the residuals for that country from the CPD regression. The variances in (64) are then obtained by squaring the expression for $a^i-\alpha^i$ in (63), and taking expectations using (64) and treating the vectors of budget shares as fixed. This "failure-of-arbitrage" variance of the EKS-Törnqvist index takes the form

$$4M^2V(a^i) = (1-2\delta_{1i})\sum_{j=1}^{M}\sum_{k=1}^{M}(s^i+s^j).\Omega^i(s^i+s^k) + \sum_{j=1}^{M}\sum_{k=1}^{M}(s^1+s^j).\Omega^1(s^1+s^k) + \sum_{j=1}^{M}(s^1-s^j).\Omega^j(s^1-s^j) + 2\sum_{j=1}^{M}(s^i+s^j).\Omega^i(s^1-s^i) - 2\sum_{j=1}^{M}(s^1-s^i).\Omega^1(s^1+s^j). \tag{65}$$

We earlier showed that, given the CPD model, the Fisher and Törnqvist indexes were identical to the first-order of approximation so that, to this order, the "failure of arbitrage" variance of the log PPP from the modified Fisher, the EKS-Fisher index, is the same as that of the modified Törnqvist. This result holds here too, so that (65) serves as the "failure of arbitrage" variance for both the EKS-Fisher and the EKS-Törnqvist. And as was the case with two countries, the sampling variances and the "failure of arbitrage" variances are independent, so that the "total" variance of the EKS-Törnqvist is given by the sum of (52) and (61), and that for the EKS-Fisher is given by the sum of (61) and (65).

## 5. Matching ICP prices with survey weights

We are now in a position to discuss how to bring together the prices of goods and services from the ICP with the budget weights from the household surveys. There are some immediate differences between the two projects. First, the ICP covers all of the countries in the world, at least in principle, while our interest here is confined to the Part II countries that are included in the global poverty count. As we shall see, this necessitates some prior screening and processing of the ICP price data. Second, not all of the relevant countries in the ICP have household surveys, and some do not allow them to be used for poverty-related analysis. Third, the surveys that we do have were not collected for the purpose of calculating international price indexes. In particular, the categories of consumption for which we have data are not uniform across countries, and none match exactly the list of consumption goods that is used for the ICP itself, some of which are not covered in the surveys at all. We discuss each of these issues in turn.

### 5.1 Consumption prices from the ICP

At its heart, the ICP is a large-scale price collection effort in which a list of commodities is priced in many countries. In practice, it is impossible to use a single list for all countries of the world, and for this and other management reasons, the 146 countries that were included in the 2005 round were broken up into six geographic regions, Africa, Asia-Pacific, Commonwealth of Independent States, South America, and Western Asia, and the OECD. (Most Central American and Caribbean countries did not participate in this round.) At a first stage, each region carried out its own regional calculations in which PPP indexes were calculated for all of the countries in each region, with one numeraire currency in each region. At a second stage, these regional estimates were linked to give a global set of PPPs with the (international) US dollar as the unit of account. At the first stage in each region, the prices for the detailed regional list in each country are combined to give prices for 155 "basic headings" of GDP, 110 of which are items of "individual consumption expenditures by households." This concept is different from "actual consumption expenditures" which includes expenditures on behalf of households by government and NGOs on such items as health and education. Since household surveys do not (and cannot) collect such expenditures, it is the "individual" concept in the national accounts that we can attempt to match to the surveys.

At the first stage then, we have a set of prices, or "parities" for (up to) 110 basic heads. These come separately by region, so that each parity gives us the price of an item in terms of the base country for the region. For example, in the South American region, where Argentina is the numeraire, the parity for pork in Bolivia is 2.16 and is 1136 in Columbia; if pork were the only good consumed in those countries, the PPP exchange rate relative to Argentina would be 2.16 for Bolivia and 1136 for Columbia. For the calculations in this paper, these regional commodity parities are the prices that we combine into P3 and P4 indices. However, before we can do so, they need to be linked to give a single numeraire, not one for each region. We need to explain how this is done in the ICP, because the linking for the ICP was somewhat different from the linking that we use here; the procedure we developed by Diewert (2008), which contains a full account, see also Hill (2007a, 2007b).

The regions are linked together through a set of "ring" countries, six in Africa, four in Asia-Pacific, two in South America, two in Western Asia, and four in the OECD. In each of these, and for each basic head, prices were collected for a global or ring list of goods and services, distinct from the lists used in each region. These were converted to the numeraire currency of each region using the parities for each basic head that each region had developed at the first stage. To take an example, the ring gives us prices for various items of pork in Cameroon, Egypt, Kenya, Senegal, South Africa and Zambia, and the African region of the ICP gives us country pork parities that allow us to convert them all to the currency units of the regional numeraire, which in Africa was a composite of countries. Similarly, the ring gives prices for fresh milk items in Jordan and Oman which are converted to the common Western Asian numeraire currency using the within region parities. Write $p_{ij}^{cr}$ for these normalized ring prices, where, as before, $i$ is a basic head, $c$ is a country, the new subscript $j$ indicates an item on the ring list within the basic head $i$, and the new superscript $r$ denotes one of the five regions. (For reasons that need not concern us, the CIS countries were treated differently, and effectively combined with OECD.) These prices are then put through a(n unweighted) CPD regression of the form (7), here written

$$\ln p_{ij}^{cr} = \phi_{ir} + \gamma_j + u_{rij} \tag{66}$$

where we have dummies for each region, each commodity within the basic head, but not for each country because all country prices are already expressed in regional currency. The estimates of $\phi_{ir}$, or rather of $\exp(\phi_{ir})$, are the scaling factors that allow us to convert, for each basic head, the numeraire of each region into a common global currency.

At this stage, we have all the elements for the final calculation of an integrated set of PPP exchange rates for all of the countries in the ICP. For each country and each basic head, there is a price in international currency for each basic head, and these can be used together with expenditures to calculate PPPs using any of the standard methods. However, the ICP itself needs to respect a politically necessary (and perhaps economically desirable) constraint, which is the "fixity" of relative PPPs within regions, which requires that the final PPPs for countries within each region are the same as the original PPPs before linking. The ICP does this by aggregating expenditures on each basic head across countries within each region so that the regions effectively become countries, each of which has an (aggregate) expenditure for each basic head and an aggregate price, $\exp(\phi_{ir})$, taken from (62). The EKS formula is then applied to the regions to give regional PPPs over all goods. These are used to scale the original, within-region PPPs, to yield a full set of international PPPs that respect the fixity constraint.

For our own calculations, we respect much but not all of this procedure. One difference is that we drop the OECD region from the CPD regression (66). The reason is that we want our calculations to be independent of any price data from the rich countries. Our global poverty line is developed entirely from information from the countries whose poverty is being measured, and neither the total number of global poor, nor of the globally poor in any poor country, should depend on commodity prices or expenditure patterns in rich countries. Dropping the OECD region accomplishes this, and the scale factors from (66) that are used to express basic head parities for each country in a common currency do not depend on OECD country information. In practice, this change makes very little difference, and the prices we use for each basic head in each country are almost identical to those used by the ICP.

A second difference between our procedures and those of the ICP is that we do not work on a regional basis nor do we impose fixity. We have survey data for 62 ICP countries in all regions except the OECD. When we calculate our P3 and P4 indexes, we treat all 62 countries simultaneously, with no regional structure, other than that incorporated into the prices for the basic headings of consumption, as discussed above. Unlike the consumption indexes for the ICP, we do not hold fixed the within-region P3s calculated for each region. We see no advantage in doing so, even if there were regional P3s that match the data structure of our surveys, on which more below.

Finally, there are a number of other differences between our calculations and those used by the ICP. One is that, for the African region, the ICP used a different aggregation procedure, a variant of the Iklé (1972) method, than in the other regions. We treat all poor countries symmetrically, using the same formulas for all. Another difference is that the published ICP calculations use data other than the standardized list of basic heads for all regions, for example more basic heads for the Eurostat countries. Although none of the Eurostat countries are included here, the Eurostat results, as well as the way in which the CIS countries were merged into Eurostat, affect the calculation of regional PPPs at the upper stage, which in turn affect the comparisons between, for example, Africa and Asia. It is effectively impossible to trace back all of the differences between our estimates and the ICP estimates to specific details of the procedure. Even so, we will be able to get close to Chen and Ravallion's estimates of the global poverty line using variants of our calculations.

### 5.2 Matching survey data to the ICP

When the survey categories are finer than the basic headings for consumption in the ICP, they can be aggregated up to match. The harder case is when the categories are larger in the survey than in the ICP, or are neither larger nor smaller, but different. For example, one basic head in the ICP consumption is "butter and margarine;" a survey might have these two separate, or part of a larger group "butter, margarine, and edible oils," or have two categories, one of which contains butter together with other items, and one of which contains margarine together with other items. In the two last cases, our procedure is to aggregate the survey categories until we have a category that contains multiple whole basic headings, and then to split the aggregate according to the proportions in the national accounts on a household by household basis. Following the same example, if we have a survey category "butter, margarine, and edible oils" and if the country's national accounts show that, in aggregate, two-thirds of the category is edible oils, we then go through the survey data, household by household, and allocate two-thirds of each household's recorded expenditure to edible oils, and one third to butter and margarine. There are clearly lots of other and potentially more sophisticated ways of synchronizing the two lists, some of which might be worth experimental calculations. However, the example of butter and margarine was deliberately chosen to illustrate a typical case. All of the surveys used here have many categories of consumption, and there is no case in which we were forced to allocate large groupings, such as cereals, let alone all food.

In all cases, we used the latest national household survey that was available to us. In the worst cases (Argentina and Djibouti in 1996 and Burundi from 1998), weights calculated from the survey were almost a decade earlier than the ICP prices (2005). All of the other surveys used here are post 2000, with 2003 the modal year; the countries, survey names, and year of data collection are listed in Appendix A.4. While it would be ideal to be able to match expenditure weights to the year of survey prices, we would expect the expenditure patterns to change slowly enough that even a lag as long as a decade is unlikely to invalidate the procedure. Indeed, most statistical offices around the world construct their domestic consumer price indexes with weights that are several years (in extreme cases several decades) older than the prices themselves.

There are a number of cases where consumption items that are basic headings in the ICP do not appear in the survey. Indeed, there is considerable diversity in survey questionnaires and methodology. The number of consumption items covered in questionnaires vary from 39 in Djibouti (recall method, with 64 out of the 105 basic headings omitted) to 6,927 in Brazil (diary method, with only 7 basic headings not covered). On average, 23 of the 105 basic headings are "missing" in survey questionnaires. In most cases, these are basic headings that represent very limited consumption shares (e.g., animal drawn vehicles). It is clear that there is an urgent need to improve and harmonize practices of household consumption measurement.

It is useful to separate items that are indeed consumed, but are not collected in the survey, from items that are not consumed but still appear in the ICP lists. The most important example of the former is owner-occupier rents, an imputed item that recognizes the flow of services from houses to their owners who happen also to be their occupiers. Such imputed flows are rarely collected directly (though in places where there is an active rental market, it is sometimes possible to ask owners how much their home could be rented for), but can be imputed ex post from housing characteristics weighted up according to the coefficients in a hedonic regression estimated on the (selected) subset of rented houses. This method is probably good enough to give an average for the national income accounts, but we doubt that it gives adequate answers at the individual level, and we were not successful in calculating satisfactory estimates to add back into our surveys. One major concern with any attempt to do so is that rental markets are often primarily urban, so that a hedonic regression will primarily reflect the value of housing amenities in towns and cities. To take those coefficients and use them to impute rents to rural housing runs the risk of attributing consumption to the poor that bears little relationship to the real rental value of their homes. The situation is further compromised by the fact that, in many of our surveys, we do not have adequate documentation of how the rental category was constructed. Given this, and some unsatisfactory early experiments, we eventually dropped the rental category from all the surveys, so that our P3s and P4s exclude this category. This is clearly unsatisfactory though, as we shall see below, there are considerable difficulties in doing better, if only because there are additional issues with the parities for housing estimated by the ICP.

A more extreme case still is financial intermediation indirectly measured (FISIM). According to current national accounting practice, the profits of banks and insurance companies which, in competitive markets, would be equal to the value of financial intermediation and risk-bearing services to their customers, are added into the estimates of consumption by households. Once again, these items do not show up in the surveys.  While we can imagine imputing FISIM to survey households according to some formula, we have chosen not to do so, in part reflecting our skepticisms about the extent to which households around the global poverty line receive much benefit from these services.

There are also a number of items that are (almost) never represented in the surveys, and which in some cases never appear in the ICP price surveys, including purchases of narcotics and prostitution, as well as “purchases by non-residential households in the economic territory of the country.” Together with rent and FISIM, we drop these items from the lists. A number of other expenditure items are also excluded, namely purchases of animal drawn vehicles, the maintenance and repair of major durables used for recreation and culture, and purchases by residential households in the rest of the world (though some of these items are probably included in other basic headings.) After all of these exclusions, our calculations are based on 102 out of the 110 consumption basic headings in the ICP.

There are also items that are included in the ICP but are not purchased in some countries. The most notable examples are pork and alcohol in Muslim countries. These cases are different from FISIM, prostitution, or narcotics, in that there are also no prices for these items in the countries where they are not consumed. We do not want to drop these items, however, because there are valid observations on both prices and expenditures for the majority of the countries in the groups, and we do not want to discard that information. For such cases, our procedure is to impute the missing price using the CPD-regressions (9) so that, for example, we impute a price for pork in

Bangladesh using the country-effect for Bangladesh (which essentially gives us the exchange rate for Bangladesh) and the "pork effects" from the other three countries, which give us a typical relative price for pork. We then leave the item in the survey expenditure files, but assign zero expenditures to all households.

One aspect of the surveys that cannot be defended is measurement error. There are good studies for a number of countries that compare national accounts and survey estimates of comparably-defined items, and that frequently find enormous differences. For example, Triplett (1997) has found such differences for the United States, even for items that are almost certainly well-measured in the national accounts. Studies in India tend to favor the accuracy of the survey estimates over those from the national accounts, at least for food and apart from some special cases, Kulshesthra and Kar (2006). Note that we are not concerned here with the increasing divergence in many countries between total expenditures in the surveys and the national accounts, documented for example in Deaton (2005). That discrepancy is important for the measurement of poverty (and of GDP), but price indexes are invariant to the scale of consumption and depend only on its distribution. Unfortunately, the plausible accounts of the survey error—selective non-response by the richest or poorest households, item-based non-response—will also affect the distribution over commodities. In consequence, differences in indexes—even aggregate plutocratic indexes—according to whether they are constructed with national accounts or survey weights will reflect both deliberate choices about the definition of goods, and accidental choices that come from poorly understood measurement errors.

Another important issue is the treatment of China. China collects household survey data from both rural and urban households and publishes summary tables annually in the Statistical

Abstract of China. However, the household level data were not made available to us for this work. Adding China to the list of countries without data is inconceivable given its importance in the poverty calculations, and to avoid this we need a method that will allow us to calculate the pattern of expenditures for Chinese households at various levels of household per capita expenditure. The published tables contain sufficient information to allow this to be done, at least approximately. We implemented this by creating a synthetic household survey for China whose overall means and means by level of per capita expenditure match the published numbers; a fuller account of this is included in the Appendix.

A final issue in matching ICP prices to the surveys is the treatment of rural and urban sectors. All of our surveys are nationally representative covering both rural and urban households. In contrast, the ICP collected only urban prices in a number of countries, including most of Latin America, but also in China while, in India, urban outlets were overrepresented in the price surveys. For the urban only countries, we need a measure of the price of consumption in rural relative to urban, and for this we follow Chen and Ravallion and use the ratio of rural to urban poverty lines in those countries. While it is a big assumption that the ratio of the poverty lines correctly measures the relative price levels, there is no other obvious source of such information, and some correction is necessary. For countries where the adjustment is made, we adjust our surveys prior to the calculations by converting all household expenditures to urban prices by scaling up per capita household expenditure for each rural household by the ratio of the urban to rural poverty line. Once this adjustment is made, the sectors are ignored, and the survey treated as a single national sample to which the global poverty line, converted at the urban PPP, can be applied to calculate expenditure weights and counts of the numbers in poverty. India is treated somewhat differently to take account of the fact that, although the ICP collected both urban and rural prices, the former were over-represented, see theAppendix.

## 6. Results

### 6.1 P3 price indexes from surveys and national accounts

Table 1 shows our calculations of the aggregate (or plutocratic) purchasing power parity exchange rates for household consumption together with those from the ICP. There are 62 countries, and they are listed regionally, Asia first, then South America, Western Asia, and Africa. The ICP numbers in the first column come from the final report, World Bank (2008a), and relate to "individual consumption expenditures by households." Our own calculations in this table, with two calculations each for EKS-Fisher, EKS-Törnqvist, and weighted CPD, use both surveys and national accounts, so that both sets of weights relate to aggregate national purchases, with one estimated from the surveys and one estimated directly from the national accounts. If the survey and national accounts consumption data were consistent, and had the same coverage of goods and services, the two calculations would give the same results. The ICP estimates in the first column are a subset of the global estimates that come from the global parities for each basic heading, which were constructed differently from our numbers, see the discussion in Section 5.1 above. Our calculations, for both national accounts and survey-based aggregate weights, treat all 62 countries symmetrically in a single calculation. We are also using parities for the basic heads that were calculated without the rich country data, see Section 5.1 above, though this made almost no difference in practice.

In Table 1 all of the P3 exchange rates are divided by the market exchange rates listed in World Bank (2008a) so that these numbers can be interpreted as the "price of consumption" in each country. This measure allows us to express all of the indexes in the same units, unobscured by differences in the "size" of currencies which leads to PPP rates that can range from 1000 to 0.001, and eases formal comparison between the indexes. The base country is India, so that all Indian figures are unity. For other countries, if the price of consumption is less than one, the P3 exchange in terms of rupees is lower than the market exchange rate in rupees, so that a rupee converted at the market exchange rate will buy more consumption than it will in India. According to the ICP numbers in column 1, Fiji (2.59), Cape Verde (2.49), Gabon (2.38), and the Maldives (2.15) have the highest consumption price levels—for comparison, the figure for the US is 2.83—and only Tajikistan (0.84), Kyrgyzstan (0.89), Bolivia (0.90), Ethiopia (0.90), Paraguay (0.97), Pakistan (0.98), and Laos (0.99) have price levels lower than India. In spite of many of the African countries being poorer than India, only one of those listed here has a lower price level.

The final six paired columns of Table 1 show our calculations of the aggregate prices of consumption according to the three aggregation formulas and the two sources of weights. The immediate impression is that, in spite of the different weighting schemes, and different procedures, our indexes are very close to the official ones. The correlation with the ICP price of consumption across the 62 countries is 0.9275 and 0.9337 for the survey and national accounts versions of the EKS-Fisher, 0.9307 and 0.9360 for the EKS-Törnqvist, and 0.9256 and 0.9346 for the weighted CPD; note that these are not correlations for the raw P3s, which would be inflated by the variation in units from country to country, but the correlations of the price of consumption, which is comparable across countries.

Table 2 explores the similarity and differences in the indexes in a more transparent, way. The top panel of the table presents distances between pairs of indexes using the root mean squared differences over countries for each pair of indexes. The first important finding is that the distances in the first row are larger than any of the others, showing that the official ICP number is further away from all of our indexes (RMSEs around 0.15 to 0.16) than any of our indexes are from one another. The ICP index and our national-accounts based indexes use the same information, but differ for two reasons. One is that our indexes are calculated in one step using a single aggregation formula, rather than different aggregation formulas by region, the ring for linking regions, the imposition of fixity of the regional PPPs, and other details. The second is that our indexes use only 102 of the 105 consumption basic heads in the ICP; we exclude rental (actual and imputed), FISIM, and prostitution in order to match our NIPA based and survey results. As we shall see in Section 6.3, these differences have substantial effects on the calculated P3s. In terms of Table 2, recalculating the NIPA based PPPs using 105 basic headings, instead of 102, reduces the MSE with the Fisher NIPA index, 0.156 in Table 2, to 0.099 (not shown), with the remainder of the discrepancy coming from the different methods of calculation.

The distances between the survey and national accounts based (102 basic heads) versions of our consumption price indexes are only 0.065 (Fisher), 0.048 (Törnqvist) and 0.078 (CPD), less than half the size of the difference between our survey based indexes and the ICPs national accounts based indexes. These differences are important, but smaller than the differences induced by the combination of dropping some basic heads and using the ICP method of calculation. The top panel of Table 2 also shows that the EKS-Fisher and EKS-Törnqvist indexes are typically close to one another—whether the weights come from surveys or from national accounts—and both are somewhat further away from either of the weighted CPD indexes, a result that is consistent with the approximation theory and so should not be taken as an endorsement of EKS versus CPD indexes. Within a weighting scheme—national accounts or surveys—different indexes tend to be closer to one another than are the same indexes across weighting schemes. The overall conclusion is that the most important difference comes from the procedures used in the ICP versus those adapted here, as well as the exclusion of three basic heads, the second most important difference is between whether the aggregate expenditure weights come from the surveys or from the national accounts, and the least important difference is the choice of formula, with Fisher and Törnqvist closer to one another than is either to the weighted CPD.

The second panel shows the means and standard deviations of the indexes. The standard deviations are very similar, but the ICP mean is about 3 percent lower than the others. Put differently, and in comparison with the direct calculations, the ring, the regional structure of the ICP, and other differences in calculation results in the Indian consumption price level being higher relative to the other countries listed here. The dropping of the three basic heads turns out not to be important; replacing them and recalculating the NIPA-based PPPs with 105 basic heads gives the same estimates as with 102 basic heads. Since India is the country with the largest numbers of poor, and the largest numbers of people near the global poverty line, this change is likely to be important for the overall poverty numbers though, as we shall see, there are other differences that have a larger effect.

The final panel of Table 2 shows a series of regressions that test for systematic differences between the national accounts and survey versions of our indexes; these help understand why the indexes differ, but will also help impute indexes for countries where we have national accounts but no survey estimates. The estimates show that survey estimates are lower in better-off countries, with the ratio falling by between one and two percent for every doubling of per capita income. Even so, the effects are barely significant. The $F$-statistics for the regional effects are typically close to significance at five percent level, but tend to be inconsistent across indexes and quite small. It is not clear whether it would be worth while using these results to estimate survey-based indexes in countries without surveys, rather than simply using the national accounts based indexes themselves.

Table 3 looks in more detail at the reasons for the differences between the national accounts and the survey-based indexes. Since both indexes use the same parities for the 102 basic headings, differences are driven entirely by the pattern of expenditures over the parities. Table 3 lists each survey, together with its date of collection, and the correlation between the (processed) survey-based estimates of the aggregate budget shares and those from the national accounts, for all categories of consumption and for the subgroup of food, drinks, tobacco and narcotics. It is not obvious what to expect of these numbers, nor how low a correlation needs to be to make it a source of concern. There are a few very low numbers, even for the somewhat easier to measure food category. In an extreme case, the budget shares from the 2003 survey of Chad correlate with the national accounts numbers at only 0.090 overall, and only 0.023 for foods. There are a number of other correlations under 0.5, and these are highlighted in the table. We have done some cross-checking of these numbers, and as is usually the case in comparing surveys and national accounts, the problems are not easily attributable to one side or the other.

Table 4 presents the standard errors associated with the plutocratic survey-based PPPs. We show only the EKS-Fisher and the weighted CPD; the results for the EKS-Törnqvist are similar to those for the EKS-Fisher, and indeed the estimates of the sampling standard errors are identical. We present the PPPs themselves here, rather than price of consumption; the former is the latter multiplied by the market rate of exchange of local currency to rupees. The standard errors are the standard errors of the logarithms of the PPPs, and so can be thought of as relative standard errors. They are also the standard errors for the logarithms of the prices of consumption in Table 1. There are two main points to note. First, the sampling errors are very small. Although some of the surveys have small sample sizes, the sampling standard errors for the PPP indexes are negligible. Second, the same is not true for the standard errors associated with failure of arbitrage. Akin to the Paasche-Laspeyres spread, these standard errors measure the uncertainty associated with picking one particular index number when relative prices are not the same in different countries. These standard errors are typically in the vicinity of eight to ten percent, as opposed to a half to a tenth of one percent for the sampling standard errors. This finding of negligible standard errors from sampling, but substantial uncertainty from variations in relative prices, characterizes all of our results.

### 6.2 Poverty-weights purchasing power parities, P4s

Table 5 shows the first set of poverty-weighted PPPs or P4s; these are calculated using all 50 poverty lines that we have available. Column 1 shows the Törnqvist approximation to the PPP that serves as the starting point for the further calculation, followed by the iteratively calculated Törnqvist indexes at bandwidths of 1, 0.5, and 0.1 standard deviations of the log per capita total expenditure. Throughout we use the bi-weight version of the kernel function in (21),

$$\begin{aligned} K(t) &= \frac{15}{16}(1-t^2)^2 \quad if\ |t| \leq 1 \\ K(t) &= 0 \quad if\ |t| > 1 \end{aligned} \tag{63}$$

The final two columns show the Fisher and weighted CPD P4s, both calculated using the smallest (0.1 standard deviation) bandwidth. The Törnqvist-approximation starting value is something of an outlier relative to the other indexes which, one again, are very similar to one another. Choosing a good bandwidth is a question of trading off bias against variance; a small bandwidth means we only use households near the poverty line, but the result is a larger sampling variance in our estimates. Tables 6 and 7 show how this works; Table 6 lists the numbers of households at each bandwidth for the indexes in Table 5, while Table 7 lists the corresponding standard errors of the log PPPs. For example, in Table 6, we see that for a country with a large survey such as Indonesia, there are 22,760 households in the band around the poverty line when the bandwidth is 1 standard deviation, which falls to 10,415 with a bandwidth of a half, and only 1,916 with a bandwidth of 0.1. The corresponding sampling standard errors in Table 7 (multiplied by 100 compared with Table 4) rise from 0.06 to 0.08 to 0.15 of one percent so that, even with the smallest bandwidth, the sampling errors are negligible. Even for countries with much smaller sample sizes in the surveys, where the standard errors are correspondingly larger, for example Paraguay, the sampling standard errors at the smallest bandwidth are not much more than one percent.

Table 8 extends Table 2 and shows the root mean square difference, of the distances between the various indexes expressed, as before, as the price of consumption. In this table, F, T, and C stand for Fisher, Törnqvist, and CPD, respectively, while N and S stand for national accounts and surveys so that, for example, F(S) and T(N) are the plutocratic Fisher index using survey weights and the plutocratic Törnqvist index using expenditure weights from the national accounts. The indexes with numbers refer to the bandwidth, so that F1, F0.5, and F0.1 are the Fisher P4 prices of consumption calculated at bandwidths of 1, 0.5, and 0.1 of a standard deviation of the logarithm of per capita household expenditure. The first row shows, as expected, that the ICP price levels of consumption are relatively far away from the other indexes, with distances around 0.15 to 0.18. Our recalculated national accounts indexes are closer to the P4 indexes, and their survey-based counterparts are closer still. The three national accounts P3 indexes are between 0.09 and 0.11 away from the Fisher and Törnqvist P4s, and 0.14 to 0.17 from the CPD version of the P4. The survey based P3 indexes, which share the same data with the P4s, are closer, about 0.05 to 0.07 away from the Fisher and Törnqvist and 0.09 and 0.12 for the CPD. The closed-form Törnqvist approximation that we use to start the iterations for the P4s is about as far away from the final P4s as the plutocratic survey based indexes, so these latter could also have been used for starting values. Once we look within the P4 indexes alone, changing the bandwidth does not move the indexes apart by much, especially within a specific index, though, as is to be expected, the adjacent bandwidths are closer than are the two extremes. Even here, the CPD P4 is not only further away from the other two indexes than they are from one another, but it also shows the largest internal changes as the bandwidth is reduced.

Table 9 looks at what happens when we calculate poverty-based purchasing power parity indexes with different global poverty lines. We consider two alternatives. In the first, we use the same procedure as before, based on national poverty lines from 50 of our 62 countries, but we multiply all of them by two before starting the calculation. This variant is motivated by the usual World Bank procedure of calculating poverty using both a one and two dollar a day global standard; if our baseline is like the dollar-a-day calculation, our variant is the two dollar a day calculation. The second variant we consider is to use, not our procedure for calculating the global poverty line, but the variant based on Chen and Ravallion (2008), see Section 3.1 above.

Table 9 shows that the different assumptions do not have much effect on the poverty-weighted indexes. Replacing the 50 lines with poverty weighting by 14 of the 15 poorest country lines used by Chen and Ravallion without weighting makes very little difference, with distances from the original consumption prices of 0.014 and 0.013 for the Fisher and Törnqvist, and of 0.036 for the CPD. Doubling the poverty lines moves the indexes somewhat further, though the distances are only 0.050 for the Fisher, 0.048 for the Törnqvist, and 0.084 for the CPD, comparable to the distance moved by shifting from the survey based P3s to P4s. The means of the original and CR consumption prices are close, with some increase when we double the underlying poverty lines; this presumably reflects the changing balance of global poverty between India and the rest of the world as the poverty lines are moved up, though the exact mechanism is not obvious. Once again the CPD indexes are not only further away from the Fisher and Törnqvist than they are from one another, but the CPD indexes are less internally stable, moving further when we vary the underlying poverty lines.

Table 10 looks for systematic patterns by income and region between the P4 and P3 indexes. In these regressions, the dependent variable is the logarithm of the ratio of the P4—using bandwidths of 0.1 standard deviations—to our calculated P3s using the national accounts weights. The reason for this choice is that these P3s are available for countries where there are no survey data, and are therefore the starting point for imputing P4s in the absence of survey data. None of the estimated regression coefficients are significant at conventional levels, so an argument could be made for simply using the P3 indexes. Even so, comparison with the results in Table 2, which compared the survey and national accounts based P3s, shows that the income effects here are similar, so that most of the difference between the P4s and P3s can be traced to differences between the surveys and the national accounts expenditure patterns, consistently with other evidence on the indexes.

**6.3 Global poverty lines and global poverty**

Table 11 lists the international poverty lines that come out of the various calculations that we have already discussed. The top half of the table uses plutocratic aggregate P3 indexes, while the bottom half uses variants of poverty-weighted P4 indexes. The first number in the top left cell is 592.88 wrupees per month which is the world rupee equivalent of the Chen and Ravallion new $1.25 a day poverty line. Their line is $38 a month in 2005 ICP dollars. The consumption PPP for India in the 2005 ICP is 15.602, which when multiplied by $38 gives 592.88. Our own simple average of the 15 poorest countries' poverty lines (Chad, Ethiopia, Gambia, Ghana, Guinea-Bissau, Malawi, Mali, Mozambique, Nepal, Niger, Rwanda, Sierra Leone, Tajikistan, Tanzania and Uganda) using ICP conversion factors gives $37.70 or 588.14 world rupees, close to CR's line. We do not have a household survey for Guinea-Bissau, so our own calculations use only 14 countries, and if we follow the same procedure for them, we get $37.15 or 579.61 world rupees, still quite close to CR's line. (Even so, it is remarkable that the exclusion of an African country of 1.6 million people should remove 36 million people from poverty, including 13 million Indians. We shall see even more remarkable examples of this sensitivity below. An accurate world poverty count is a requirement that puts great demands on the accuracy of the ICP estimates.)

The other poverty lines in the top panel of the table come from the same conceptual calculation as Chen and Ravallion's, but use different purchasing power parity exchange rates. All of these are plutocratic P3s, and there are nine variants corresponding to the three index types, EKS-Fisher, EKS-Törnqvist, and CPD, and two sources for the weights, the national accounts and the aggregates from the surveys. We also distinguish two different NIPA numbers, one with the 105 consumption basic heads that appear in the ICP and that are incorporated into Chen and Ravallion's calculations, and one with the 102 basic heads that appear in the surveys, which do not collect data on actual or imputed rentals for housing, FISIM, or prostitution. In all cases, we have derived the global poverty line using 14 of the 15 poorest country poverty lines used by Chen and Ravallion (we exclude Guinea-Bissau for which we do not have usable survey data), taking an unweighted average in international rupees, so that the only reason the six numbers are different is the nine different P3s that are used for conversion.

The main result here is that the six global poverty lines to the right of the top panel are quite close, varying in the range from 534 wrupees per month to 549 wrupees per month, but all of these are much far away from the 593 wrupees (effectively) used by Chen and Ravallion or from the three NIPA P3s that use 105 rather than 102 basic heads, which are closer to the CR number without Guinea-Bissau of 580 wrupees. The number in the first column is around 10 percent higher than the last six numbers, and about 5 percent higher than the intermediate NIPA numbers with 105 basic heads. (The Fisher and Törnqvist poverty lines in column 2 are only 1.8 and 3.1 percent less than the CR number excluding Guinea-Bissau but using their PPPs.) The big differences in the top panel are associated with the move from 105 to 102 basic headings, rather than with the type of PPP, or whether it is calculated from the national accounts or the surveys. As we shall see below, these differences are capable of making large differences in the global poverty counts.

Why do we get such differences in the global line, even within the same conceptual framework? The difference between the 593 in column 1 and the three numbers in column 2 (563 to 577) must come from the difference in aggregation procedures, and without detailed further investigation, we do not know the contribution of the fixity restrictions, the unique use of the Iklé method for the African region, of the ring linkage between Africa and Asia, or of the (irrelevant for poverty work) inclusion of the rich countries in the calculation of P3s for the poor countries. The comparison of rich countries, like the United States, with the poor countries here is inherently difficult, given the enormous differences in expenditure patterns, and subject to great uncertainty, which we will further document below. Yet such comparisons are unnecessary for the measurement of global poverty, and so introduce statistical uncertainty to no necessary purpose. There are considerable advantages to making the poverty counts depend only on information from the countries concerned.

The differences associated with the second step, from column 2 to column 3 can be traced back almost entirely to the exclusion of the rental category from the third column. At first sight, this might appear to undermine the credibility of the survey-based estimates—although note that the exclusion of rental means that its parity is implicitly set to be equal to the overall PPP—but matters are not so straightforward if only because the measurement of rent and rental equivalence in the ICP was itself problematic. In the rich countries, the ICP collected data on actual rents for standardized accommodations, and used rental equivalence to value the services of owner-occupied homes. For various reasons, this turned out to be impossible in Africa and Asia, where the *volume* of rents was assumed to be proportional to the volume of the total of consumption expenditure; this is clearly a crude assumption, but it should be born in mind that the ICP is primarily an exercise about measuring comparable *volumes* across countries, so it made sense to make a plausible assumption about the volume of rents rather than about their price. Indeed, the ICP assumption is *neutral* in the sense that it does not affect the ranking of countries real GDPs. However, for the poverty exercise, it is the prices of the basic heads that are used, not their quantities, and given the assumption about the quantity of housing, the PPP for rental was set by dividing the total of rents in each country's national accounts by the assumed quantity. This resulted in a number of implausible numbers in some African countries, perhaps because the NIPA did not in fact include any estimate for imputed rents.

Table 12 lists, for the 15 poorest countries used by Chen and Ravallion, the ratio of the PPP for rentals to the PPP for consumption as a whole; China and India are included for comparison. We would expect all of these numbers to be less than one, because housing is less tradeable than most of consumption, and because these countries are all relatively poor. But some of the ratios, such as 0.048 for Ghana, or the numbers for Gambia, Malawi, Tajikistan, and Sierra Leone, are simply not credible, and presumably come from weaknesses in the respective national accounts estimates for this item. While it is true that a low estimate of expenditure reduces the weight of rental in the calculation of the PPP indexes, the indexes are multilateral indexes that are built on pairwise comparisons between countries, in which the weights come from both countries. In consequence, in the comparison between Ghana and China, for example, rental will receive substantial weight, which accounts for the substantial fall in the global poverty lines in Table 11 when we move from 105 to 102 basic heads and drop rentals from the comparison on the assumption that the rental parity is the same as for all other items. Without rentals in the comparison, countries like Ghana, Malawi or Tajikistan have higher prices of consumption, which brings down the international value of their national poverty lines.

That the PPPs for the reference countries are artificially low has a further unfortunate effect. Understating the rental parity in Africa inflates the wrupee (or international dollar) value of the 15 national poverty lines, which are averaged to give the global line. This has only a small effect on the estimate of total poverty in Africa as a whole, because the African lines get converted back into local currency, but it inflates the value of their average in the international currency, and in particular will raise the poverty lines in India and China. And if India and China are excluded from the construction of their global line, as they are in Chen and Ravallion's calculations, this increase in the Indian and Chinese local lines will not be compensated by any need to match the local value of the global line to the actual Indian and Chinese lines. In effect then, underestimation of rents in the national accounts of sub-Saharan Africa lead directly to larger poverty counts in India and China. This hardly seems desirable.

The bottom panel of Table 11 shows nine more poverty lines, here based on poverty-weighted P4s, with three index types interacted with three treatments of the poverty line. In the first column, our P4s are calculated around the unweighted average of the 14 poor country poverty lines, converted at our calculated P4s. In the middle column, the P4s are calculated around the poverty-weighted average of the 50 countries for which we have lines. The final column is the same as the middle one, but with all the underlying poverty lines multiplied by two. The results are readily interpretable. The 50 countries include India and China, whose poverty lines are relatively low, especially India's, so that the numbers in the middle column are substantially lower than those in the first. The numbers in the last column are more than twice those in the middle column; they are not exactly twice because there is an effect associated with the recalculation of the P4s as we change the lines.

These P4 lines echo what is now a familiar theme of this paper, which is that the poverty weighting does not cause large changes in and of itself. The numbers in the first column of the bottom panel are very similar to those in the last two columns of the top panel. It is the way the PPP indexes are calculated, and the source of weights, that are more important than the poverty-weighting. The sharp difference between the P4s in the first two columns comes from including the Chinese and Indian poverty lines, which are much lower than the average of the 14 poorest countries, and because India and China get a great deal of weight corresponding to the number of poor there. Because of the low weight given to most African countries, their underestimation of rents, and the overstatement of the international value of their poverty lines, plays much less of a role than in the case in the top panel of the table. These "weighted means of 50" are our preferred global poverty lines; our preference comes from the use of P4s over P3s—though this is more a conceptual matter than a practical one, given the little difference that it makes—and from the symmetric weighting of all the poor of the world and of their national poverty lines when available. The weighting makes these numbers relatively insensitive to estimation uncertainty in African lines, and not sensitive at all to prices or consumption patterns in rich countries.

How can we think about the numbers in Table 11 in terms of dollars? How should we convert from world rupees to international dollars? While we recognize that it is inevitable that people will want to make this calculation, a good reason for not doing so is that the structure of the US—or of other advanced economies—is very different from the structures of the economies where the global poor live, so that index numbers that compare the two are subject to a great deal of uncertainty, and vary a great deal from one aggregation formula to another. It is to avoid this unnecessary uncertainty that we have computed both P3s and P4s using only information from the countries included in the global poverty count. from Part 2 countries. Table 13 lists the bilateral price indexes between each country and the US calculated using NIPA weights for the US and poverty-line weights for the countries, see Section 3.2 above. The prices for each country have first been converted to world rupees using our P4s, so that each country's index is a dollar to world rupee conversion factor. The table shows that these are almost identical across countries, so that the averaging over countries has very little effect, but vary dramatically across types of index. In terms of wrupees per dollar, the average rates shown in Table 14 are 13.68 for the weighted CPD, 17.40 for the Fisher, and 16.11 for the Törnqvist. These can be compared with the rate in the ICP which is 15.60 rupees to the dollar, so that there is a substantial spread even if we ignore the CPD index which is somewhat less well theoretically supported. The uncertainty associated with the index choice, akin to the Paasche-Laspeyres spread, or to large “failure of arbitrage standard errors” of the kind we have been calculating, reflects the difficulty of making comparisons over countries that are so far apart in income, relative prices, and tastes. So when we use these rates to turn our poverty lines into their daily dollar equivalents, we introduce a good deal of variation across the indexes that is excluded from the world rupee poverty lines. Our three numbers, shown in Table 14, correspond to the preferred numbers in the second column of the second panel of Table 11 and are $1.19 a day for the CPD, $0.92 for the Fisher, and $0.99 for the Törnqvist. Not much weight should be attached to the fact that these numbers are so close to the original dollar a day—which is around $1.45 at current (2005) prices. Moreover, the range from $0.92 to $1.19 reflects not the uncertainty in the global line itself, which varies only from 485 to 495 wrupees a month, but the difficulty of making purchasing power comparisons between the US and poor countries, comparisons which need not (and in our view should not) play any part in calculating the global line.

Table 14 also shows the dollar value of the poverty lines associated with the P4s using only the 14 lines, as well as the global lines derived from the 15 countries used by Chen and Ravallion converted, not with P4s or the ICP numbers, but with the P3s that bypass the ICP procedures, using only countries in the count, and using a uniform EKS Fisher aggregation procedure. The poverty lines in this table are the same as those in Table 11, and with each we report the associated average of the “star” bilateral price indexes with the US, and the resulting global poverty line in US dollars. Our preferred global poverty lines are the Fisher and Törnqvist lines in the top panel, which are $0.92 and $0.99. When we move to the 14 country global poverty lines—which exclude India and China—these lines rise to $1.06 and $1.12 respectively. With the 15 countries and our version of the 102 basic head NIPA, the dollar denominated lines are $1.18

and $1.16 respectively. Finally, with the inclusion of rental (and FISIM and prostitution), and the resulting inflation of the international value of the African lines, the dollar lines rise to $1.31 (Fisher) and $1.32 (Törnqvist), which are close to—although a little more than—the Chen and Ravallion rates. Once again, it is a combination of the rental problem and the exclusion of India and China that inflates the global poverty line.

### 6.4 Global poverty

Finally, we turn to calculations of global poverty in 2005 using alternative purchasing power parity exchange rates. Our procedures are designed to replicate those used by Chen and Ravallion (2008) and World Bank (2008b), and include the same countries, but with alternative purchasing power parity exchange rates, and alternative procedures for calculating the global poverty line. Otherwise, our estimates are comparable to theirs, and come from POVCALNET, the program used by the World Bank to calculate global poverty[1], but with the substitution of a new global poverty line and new PPPs. The results are shown in Tables 15 through 18.

Tables 15 and 16 show calculations for the broad regions of the world, with China and India highlighted in their regions, with Table 15 showing the absolute numbers, and Table 16 showing the poverty headcount ratios. For each region, we show the fraction of the population covered by surveys, and for which we can calculate P4s. Over all countries, this is 82.9 percent of the population, but is higher in the poor regions of East Asia and Pacific, sub-Saharan Africa, and

[1] http://go.worldbank.org/NT2A1XUWP0

South Asia; only in Europe and Central Asia and Middle East and North Africa are we largely missing surveys, and to a much lesser extent in Latin American and the Caribbean. For countries without surveys, where we cannot calculate P4s, we substitute our own P3s (calculated using 102 basic heads, and for CPD, Fisher, and Törnqvist), in the light of the comparisons earlier in the paper and of the fact that we have P4s for all of the large poor countries, this substitution is unlikely to be of any importance. Note also that the ICP itself excludes a number of countries, particularly in Latin America and the Caribbean, and imputes its own P3s using regression methods.

In Tables 15 and 16, we show the full range of alternative exchange rates and poverty line calculations. The first column shows the population for each region, so that the first cell shows that there are 5.2 billion people in the countries covered by the world poverty counts. The second column replicates the official Bank calculations, according to which there are 1.3 billion people (25.3 percent of the covered population) in poverty. The PPPs used in this column are the consumption P3s from the 2005 round of the International Comparison Program, and the poverty line is the unweighted average of the 15 poverty lines for the poorest countries in the ref+erence group discussed earlier. The next three columns show a roughly comparable set of calculations, but using P4s instead of P3s. The global poverty line is once again a simple average, taken over 14 of the 15 reference countries for which we have household surveys. The P4s are *in principle* comparable to the P3s in the Chen and Ravallion column, but differ because P4s can only be calculated using 102 out of the 105 consumption basic heads. The most important category excluded from the P4s is rentals so that, in effect, the parity for rentals is assumed to have the same value as the overall country parity. The three columns correspond to the three different aggregation methods for the P4s, CPD, EKS-Fisher, and EKS-Törnqvist, and the associated global poverty lines (in world rupees) are shown in the first row. These three columns give world poverty counts of 1.21, 1.16, and 1.13 billion depending on whether we use CPD, EKS-Fisher, or EKS-Törnqvist; the headcount ratios in Table 16 are 23.2, 22.4, and 21.7 percent. Note that for sub-Saharan Africa, the poverty estimates (353, 356, or 349 million) are very close to those of Chen and Ravallion; this is because the reference countries are mostly African, and it is in those African countries where there is a problem with the rental parity. Because the global poverty line is set with those countries as reference, their counts are more or less unaffected by the change in the P3s with the inclusion or exclusion of the rental category, Instead, the adjustments come in the non-reference countries, most importantly in India and China, for each of which there are about 50 million more poor in the first set of P4s. We shall revisit this comparison using only P3s in Table 18 below.

The second block of three columns shows the poverty estimates based on P4s and on our preferred construction of the poverty line. Here, the global poverty line is calculated as a weighted average of poverty lines from 50 countries, with weights given by the numbers of poor in each country. This gives a global poverty line that is closer to the Bank poverty lines prior to the 2005 revision because the poverty lines of India and China are now included. For these P4 based counts, the three estimates of global poverty are 867, 874, and 865 million (16.7, 16.8 and 16.6 percent), about 450 million below the Chen and Ravallion estimate, and even a little lower than they calculated prior to the latest revision, see Chen and Ravallion (2007). The reason for the difference between the global poverty counts associated with the P4s in the first block and those associated with the P4s in the second block is that the global poverty line is now much lower, for example 488 world rupees versus 557 world rupees.

The final block of results in Tables 15 and 16 shows what happens when we double the poverty lines underlying our preferred estimates. The P4s are calculated in the usual way, and the global poverty line is the poverty-weighted average over 50 countries, with the single difference that the country lines are doubled prior to the calculation. This procedure mimics the computation of a dollar-a-day and two dollar-a-day poverty counts. With the doubling of lines, the global poverty counts are more than tripled, to 2.6 billion people, or 51 percent of the covered population. Two thirds of the increase comes from India (where the count triples) and China (where it increases almost fivefold) two countries in which recent economic growth has removed large numbers of people from beneath the lower line but who are yet to cross the higher line. In Africa, where the baseline poverty counts are much higher, and there are relatively few people between the lines, the doubling of the lines causes the counts to increase by less than twofold.

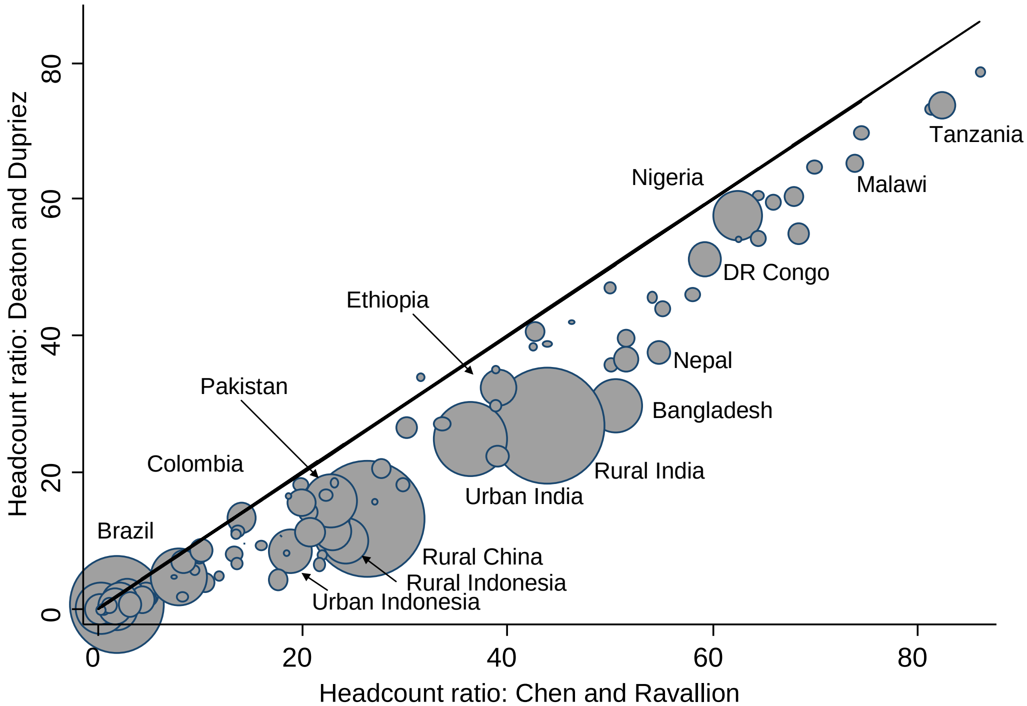


**Figure 2: Alternative headcount ratios**

Table 17 gives the complete country breakdown underlying the aggregated numbers in Tables 15 and 16. We show only the Chen and Ravallion estimates and our own preferred estimates using the EKS-Fisher P4. Countries listed in italics are countries where we do not have surveys, and where P3s have been substituted for P4s. The differences between the two sets of estimates are illustrated in Figure 2, where the CR headcount ratios are plotted on the horizontal axis, and our own headcount ratios on the vertical axis. Countries are shown as circles with diameter proportional to population, and some important countries are indicated. The most obvious feature is the correlation between the two sets of numbers, which is 0.98, so that apart from our estimates being lower than Chen and Ravallion's, there is not much reordering of countries. We provide these numbers for completeness and interest; the main differences between our procedures and those of CR were already well-illustrated in the regional estimates in Tables 15 and 16.

Table 18 further investigates the differences between our numbers and those of Chen and Ravallion. As before, the first two columns give populations and the Chen and Ravallion estimates of numbers in poverty. The third column uses P3s calculated directly from the ICP data on prices and expenditures for 105 basic heads; it also calculates the global poverty line in the same way as Chen and Ravallion, as the unweighted average of the poverty lines of the 15 reference countries, though these are now converted using our P3s, not those of the ICP. These P3s differ from the P3s from the ICP itself—as used by Chen and Ravallion—by being calculated in one step for all of the ICP countries that are included in the global poverty counts, here using the EKS-Fisher aggregation formula. The ICP estimates, in contrast, are calculated by regions at the first stage, and then combined using the ring countries at the second stage, and this second stage involves all countries in the ICP, including the rich countries. The ICP P3s also used a different aggregation procedure for Africa. Our recalculation, using a single aggregation formula, at a single stage, and excluding the rich countries, is designed to investigate whether these details of the ICP are important for the global count or its distribution over countries. Table 18 shows that this is not the case, and the numbers in the second and third columns are very close. The myriad details of the ICP calculations do not affect the global poverty counts in any important way.

The table then moves on to the calculations that do turn out to be important. Column 4 replicates the calculations in Column 3, with the one difference that we work with 102 basic heads, not 105. Because everything else is held constant—which was not the case in Table 15, where we also switched to P4s, to survey data, and dropped one country from the reference groups—columns 3 and 4 provide a clean analysis of the effects of dropping the rental category, using P3s and the same construction of the global poverty line in both cases. Making the rental correction removes 127 million people from the global count, 51 million in East Asia and Pacific (32 million of which are in China), and 59 million in South Asia (47 million of which are in India.) By contrast, the number of poor in sub-Saharan Africa falls by only 9 million, from 374 to 365 million. Given that the global poverty line is denominated in mostly African currencies, and given that the rental problem is essentially an African problem, the direction and pattern of this effect is what we would expect, with the table giving the magnitude. The Bank's method of constructing the global poverty line means that poor (or no) measurement of rental equivalence in Africa puts 110 million Asians into poverty.

The final column of Table 18 repeats our own preferred estimates from Table 15. The difference with the previous column is in the construction of the poverty line, though we have also moved to P4s. This column shows a global count of 320 million less than the previous column, which is essentially the effect of moving to a lower global poverty line when we bring in all 50 countries, and weight by numbers in poverty. In summary then, of the 445 million people that are removed from poverty according to our revision of Chen and Ravallion, about 127 million come from the treatment of rentals, and about 320 million from our construction of the poverty line. For the reasons given in Section 3, we believe that our estimates are to be preferred; they correct an error associated with the use of the rental category imputation, and they use a method for constructing the poverty line that prevents discontinuities in the global poverty line as countries grow and decline.

## 7. Summary and conclusions

Our aim in this paper is to show how to calculate purchasing power parity exchange rates that reflect the consumption patterns of poor people around the world. One important application of these purchasing power parity exchange rates for the poor (PPPPs or P4s) is to recalculate the global poverty counts. These counts are based on a global line, whose calculation is based on local poverty lines, converted at PPPs, and which is then converted back to each country's currency using PPPs in order to count the number of people below the line in each country. World Bank estimates of global poverty rely on PPPs that are designed for national income accounting purposes, not for calculating living standards of the poor, and our aim here is to calculate new P4s, to use them to recalculate global poverty, and to compare our results with the Bank's own estimates based on the recent (2005) round of the International Comparison Project.

Earlier sections of this paper lay out the theory of the calculations, and the details of its implementation. P4s, unlike P3s, require household survey information, but there are currently enough household surveys to cover the vast majority of the world's poor population. P4s, unlike P3s, need to be calculated simultaneously with the global poverty line, because the price indexes depend on the line and the line depends on the price indexes. We have shown how the fixed point can be calculated explicitly in a special case, and developed an iterative procedure that works more generally. We have developed formulas for standard errors of our estimates in order to address the concern that some of the household surveys have small samples, so that the estimates might be too noisy for use. In practice, the standard errors from sampling are very small, negligibly so relative to the more general uncertainty associated with the choice of index number formula. The design and detail of household surveys vary widely across the world, and many compromises and assumptions have to be made to adapt the survey data to match the prices from the International Comparison Project. In the end, we believe our procedures are unlikely to be a source of much error in our final estimates.

In the end, poverty-weighted purchasing power parity exchange rates look very much like the regular purchasing power parity exchange rates that use weights from the national accounts, certainly when we confine ourselves to comparisons that do not involve the rich countries of the world. These comparisons are not required for global poverty estimates—because it is assumed in advance that there are no poor people in the rich countries—and would be impossible in any case, because there are no people in those countries living near the global poverty line so that there are no weights for the indexes. Although it is true that poor people have different consumption patterns from the patterns in the national accounts, the reweighting is similar in different countries, so that the price indexes between each pair do not usually change by much. There are, of course, exceptions, but the weighting differences between P4s and P3s are probably not of great importance for estimating global poverty.

A larger source of difference between the P3s and P4s is data inconsistency between household surveys and national accounts, so that the consumption pattern in one is often different from the consumption pattern in the other, even when we use both to estimate aggregate consumption. Some of this comes from difference in definition and coverage—FISIM and owner-occupied rental equivalence are not collected in surveys, nor (usually) are narcotics or prostitution. Perhaps more important are measurement errors in either the surveys or the national accounts or both. Yet even the differences in these weights do not generate large differences between P3s and P4s.

One accounting issue that turns out to be important is the treatment of housing, or more accurately, the rental equivalent of housing. This is an important item of consumption in nearly all countries, and among such important items, is by far the most difficult to measure. In the 2005 ICP, it turned out to be impossible to measure the prices of rental equivalence in Africa and South Asia, so it was decided to impute to each country a “quantity” (international price) estimate of rental in proportion to the quantity of its GDP. Because the ICP is primarily concerned with measuring GDP in international prices, this is a neutral assumption in the sense that the imputation has no effect on the relative GDPs of the affected countries. However, many countries, especially in Africa, apparently make no imputation for rental equivalence in their national accounts. This has the consequence that the parities for rental in those countries in the ICP are very low, sufficiently so to artificially bring down their national parities. As we discuss in Section 6.3 above, the use of these low parities, together with the procedure for setting the global poverty line, has the effect of artificially inflating the global poverty count, by around 127 million people. For poverty work, it is the price that is important, not the quantity of housing, and we suggest instead that the appropriate neutral assumption for this work is to assume that the price of rental be set equal to the average of other prices, as captured in the overall PPP for the country.

The calculation of P4s requires the specification of a method for setting the global poverty line, because the line and the P4s must be calculated simultaneously. We provide estimates for a procedure that mimics the Bank procedure, taking an average of the P4 values of the poverty lines of a reference group of very poor countries. However, we also argue that this method has the disadvantage of causing discontinuities in poverty counts as countries move in and out of the reference group, and can even result in the global count *increasing* in the face of *increases* in national incomes. We propose an alternative procedure that uses lines from a larger group of countries, weighting them according to the number of poor people in each. This method generates a lower global line, and lower global poverty counts, more closely in line with the Bank's own estimates prior to the most recent revision. Our preferred global poverty count, using our preferred P4s, is more than 445 million people smaller than the latest Bank estimates.

There are a number of important issues that we do not address. Leading among these is fact that we make no attempt to use separate *prices* for the poor. Instead, we confine ourselves to reweighting the same prices to match the expenditure patterns of households near the global poverty line. The Asian Development Bank (2007) has undertaken experimental work to identify the prices paid by the poor, by collecting prices in shops and markets thought to be patronized by the poor, and specifying varieties of goods that are typically purchased by the poor. One potential weakness of these procedures is that it is unclear exactly what and where the poor buy, and the ADB's specifications were set by groups of experts. Perhaps a better source of such information is to use the unit values in household surveys, which have the advantage of relating to actual purchases by actual poor people. The corresponding disadvantage is that there is no obvious way of specifying quality, or of controlling for quality variation across poor and non-poor.

Our work also raises a number of issues that are relevant both for future work on the ICP and on household surveys. For the former, it is clear that, in some respects, the demands of national accounting and of poverty work are different. For example, for poverty work we need prices paid by consumers, not prices paid by governments on behalf of consumers, a distinction that is particularly troubling in the case of health related goods, such as pharmaceuticals. We have also seen that, when direct measurements break down or are difficult, the supplementary imputations that are suitable for estimating national accounts—for which quantities are most important—are sometimes different than those for estimating poverty—where prices are the relevant magnitudes.

On household surveys, our plea is mostly for greater harmonization across countries. We realize that surveys are used for different purposes in different countries, and that a survey that works in one country may be useless in another. Nevertheless, greater standardization is certainly possible in some cases, not only in data collection, but in the reporting and documentation of survey design.

Although we suspect that it is not of leading importance for the estimates presented here, we also want to flag the issue of quality adjustment. How to deal with quality is perhaps the leading unsolved issue in price index construction, both domestically—see for example Mackie and Schultze (2002) for the US—and internationally in the ICP. The ICP has become progressively more detailed in comparing like with like across countries, on the reasonable suspicion that price levels in poor countries were being understated by comparing lower quality goods in poor countries with higher quality goods in richer countries. The use of more precise specifications has raised price levels in poor countries in more recent rounds and, for poverty work, this has had the effect of reducing the dollar value of the global line below its original dollar value updated for inflation in the United States. It is almost certainly true that the latest ICP does a better job of the quality comparisons, though perhaps at the price in some cases of comparing representative goods in a rich country with the same goods in a poor country but which are not representative of consumption patterns there. The 2005 ICP attempted to make a representativity correction to deal with this but, for a number of reasons, the correction was not successful for poor countries. This is an active area of research for the ICP itself, and is likely to have repercussions for poverty work in the future, if only because changes in the real dollar value of the international line undermine understanding of the global poverty counts.

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**Table 1: Consumption prices using national aggregates as weights**

| | Pc ICP | Pc Fisher | | Pc Törnqvist | | Pc-CPD(W) | |
|---|---|---|---|---|---|---|---|
| | | NAS | Survey | NAS | Survey | NAS | Survey |
| India | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| Bangladesh | 1.120 | 1.091 | 1.077 | 1.079 | 1.063 | 1.098 | 1.073 |
| Bhutan | 1.183 | 1.158 | 1.139 | 1.135 | 1.128 | 1.126 | 1.142 |
| Cambodia | 1.116 | 1.111 | 1.175 | 1.092 | 1.147 | 1.057 | 1.135 |
| China | 1.411 | 1.404 | 1.354 | 1.410 | 1.389 | 1.399 | 1.361 |
| Fiji | 2.589 | 2.222 | 2.124 | 2.162 | 2.106 | 2.184 | 2.079 |
| Indonesia | 1.221 | 1.185 | 1.184 | 1.163 | 1.169 | 1.143 | 1.168 |
| Lao PDR | 0.993 | 1.043 | 1.090 | 1.048 | 1.076 | 1.033 | 1.123 |
| Malaysia | 1.577 | 1.497 | 1.440 | 1.471 | 1.439 | 1.416 | 1.379 |
| Maldives | 2.150 | 1.716 | 1.721 | 1.708 | 1.702 | 1.668 | 1.613 |
| Mongolia | 1.225 | 1.217 | 1.234 | 1.204 | 1.216 | 1.166 | 1.172 |
| Nepal | 1.048 | 0.989 | 1.003 | 0.976 | 0.999 | 0.950 | 0.999 |
| Pakistan | 0.984 | 1.038 | 1.071 | 1.029 | 1.055 | 1.005 | 1.052 |
| Philippines | 1.241 | 1.238 | 1.249 | 1.221 | 1.238 | 1.194 | 1.199 |
| Sri Lanka | 1.126 | 1.178 | 1.150 | 1.157 | 1.142 | 1.128 | 1.106 |
| Thailand | 1.227 | 1.306 | 1.299 | 1.268 | 1.273 | 1.219 | 1.232 |
| Vietnam | 1.055 | 1.031 | 1.058 | 1.044 | 1.069 | 1.028 | 1.048 |
| Argentina | 1.318 | 1.383 | 1.347 | 1.374 | 1.359 | 1.363 | 1.326 |
| Bolivia | 0.900 | 1.020 | 1.056 | 1.007 | 1.043 | 0.955 | 1.013 |
| Brazil | 1.828 | 1.992 | 1.951 | 1.912 | 1.888 | 1.956 | 1.917 |
| Colombia | 1.452 | 1.676 | 1.693 | 1.642 | 1.644 | 1.619 | 1.595 |
| Paraguay | 0.974 | 1.094 | 1.074 | 1.083 | 1.074 | 1.051 | 1.030 |
| Peru | 1.416 | 1.670 | 1.621 | 1.642 | 1.571 | 1.677 | 1.540 |
| Armenia | 1.212 | 1.146 | 1.164 | 1.142 | 1.143 | 1.140 | 1.124 |
| Azerbaijan | 1.039 | 0.961 | 0.883 | 0.968 | 0.933 | 0.987 | 0.918 |
| Kazakhstan | 1.382 | 1.070 | 1.060 | 1.100 | 1.068 | 1.122 | 1.068 |
| Kyrgyz Rep. | 0.896 | 0.789 | 0.807 | 0.823 | 0.837 | 0.822 | 0.856 |
| Tajikistan | 0.840 | 0.613 | 0.775 | 0.783 | 0.821 | 0.755 | 0.844 |
| Yemen | 1.345 | 1.201 | 1.150 | 1.166 | 1.156 | 1.139 | 1.150 |

Notes: The first column is from the ICP Final Report, and is the PPP for individual consumption expenditures by households divided by the foreign exchange rate, the "price of consumption" with India as base. The second, third, and fourth columns report are prices of consumption using the parities for 102 basic heads, but using estimates of aggregate weights first from the national accounts, then from the household surveys. The first column and the first column of each pair differ only in the aggregation formulas, the ring structure, and the merging of regional parities for the basic headings of consumption.

**Table 1, continued.**

| | Pc ICP | Pc Fisher | | Pc Törnqvist | | Pc CPD (W) | |
|---|---|---|---|---|---|---|---|
| | | NAS | Survey | NAS | Survey | NAS | Survey |
| Benin | 1.475 | 1.545 | 1.448 | 1.544 | 1.490 | 1.576 | 1.499 |
| Burkina Faso | 1.299 | 1.417 | 1.382 | 1.389 | 1.379 | 1.388 | 1.376 |
| Burundi | 1.168 | 1.283 | 1.214 | 1.298 | 1.212 | 1.301 | 1.163 |
| Cameroon | 1.578 | 1.690 | 1.681 | 1.674 | 1.686 | 1.665 | 1.655 |
| Cape Verde | 2.493 | 2.402 | 2.295 | 2.383 | 2.286 | 2.382 | 2.264 |
| Chad | 1.755 | 1.995 | 1.882 | 1.944 | 1.847 | 2.082 | 1.849 |
| Congo DR | 1.886 | 1.975 | 1.989 | 1.934 | 1.961 | 1.976 | 2.010 |
| Congo PR | 2.013 | 2.122 | 2.072 | 2.111 | 2.072 | 2.122 | 2.083 |
| Côte d'Ivoire | 1.746 | 1.850 | 1.828 | 1.837 | 1.846 | 1.859 | 1.850 |
| Djibouti | 1.715 | 1.950 | 2.051 | 1.935 | 2.025 | 1.796 | 1.985 |
| Ethiopia | 0.897 | 1.068 | 1.039 | 1.035 | 1.016 | 0.982 | 0.978 |
| Gabon | 2.378 | 2.505 | 2.469 | 2.507 | 2.483 | 2.565 | 2.525 |
| Gambia | 1.023 | 1.224 | 1.314 | 1.232 | 1.296 | 1.147 | 1.247 |
| Ghana | 1.394 | 1.593 | 1.540 | 1.577 | 1.540 | 1.572 | 1.516 |
| Guinea | 1.148 | 1.260 | 1.254 | 1.272 | 1.270 | 1.310 | 1.328 |
| Kenya | 1.223 | 1.380 | 1.340 | 1.370 | 1.335 | 1.377 | 1.326 |
| Lesotho | 1.523 | 1.671 | 1.726 | 1.712 | 1.721 | 1.650 | 1.677 |
| Madagascar | 1.066 | 1.111 | 1.153 | 1.132 | 1.159 | 1.171 | 1.211 |
| Malawi | 1.359 | 1.572 | 1.462 | 1.577 | 1.501 | 1.559 | 1.482 |
| Mali | 1.552 | 1.663 | 1.585 | 1.641 | 1.590 | 1.654 | 1.601 |
| Mauritania | 1.341 | 1.569 | 1.530 | 1.534 | 1.507 | 1.521 | 1.469 |
| Morocco | 1.756 | 1.929 | 1.777 | 1.897 | 1.800 | 1.901 | 1.772 |
| Mozambique | 1.409 | 1.658 | 1.471 | 1.616 | 1.477 | 1.578 | 1.395 |
| Niger | 1.433 | 1.602 | 1.575 | 1.579 | 1.570 | 1.567 | 1.575 |
| Nigeria | 1.692 | 1.836 | 1.826 | 1.827 | 1.824 | 1.874 | 1.848 |
| Rwanda | 1.200 | 1.287 | 1.352 | 1.284 | 1.375 | 1.211 | 1.331 |
| Senegal | 1.598 | 1.768 | 1.742 | 1.751 | 1.727 | 1.758 | 1.696 |
| Sierra Leone | 1.361 | 1.597 | 1.571 | 1.593 | 1.576 | 1.539 | 1.510 |
| South Africa | 2.032 | 2.172 | 2.034 | 2.129 | 2.013 | 2.168 | 2.016 |
| Swaziland | 1.657 | 1.815 | 1.709 | 1.816 | 1.726 | 1.761 | 1.590 |
| Tanzania | 1.218 | 1.304 | 1.267 | 1.269 | 1.248 | 1.284 | 1.257 |
| Togo | 1.513 | 1.644 | 1.595 | 1.631 | 1.605 | 1.681 | 1.618 |
| Uganda | 1.182 | 1.240 | 1.172 | 1.257 | 1.205 | 1.230 | 1.154 |

**Table 2: Survey based and NIPA based estimates of the price of aggregate consumption**

| | ICP | Fisher (N) | Fisher (S) | Törnqvist (N) | Törnqvist (S) | CPD (N) | CPD (S) |
|---|---|---|---|---|---|---|---|
| | | | | Root mean square distance | | | |
| ICP | 0 | 0.156 | 0.150 | 0.147 | 0.146 | 0.149 | 0.148 |
| Fisher (N) | | 0 | 0.065 | 0.033 | 0.068 | 0.050 | 0.088 |
| Fisher (S) | | | 0 | 0.054 | 0.023 | 0.078 | 0.047 |
| Törnqvist (N) | | | | 0 | 0.048 | 0.042 | 0.067 |
| Törnqvist (S) | | | | | 0 | 0.066 | 0.070 |
| CPD (N) | | | | | | 0 | 0.078 |
| CPD (S) | | | | | | | 0 |
| | | | | Summary statistics | | | |
| Mean | 1.402 | 1.463 | 1.440 | 1.453 | 1.437 | 1.445 | 1.421 |
| Standard dev. | 0.389 | 0.404 | 0.377 | 0.390 | 0.372 | 0.404 | 0.373 |
| | | Regressions of log of ratio of Survey to National Accounts basis | | | | | |
| | | Estimate | *t*-value | Estimate | *t*-value | Estimate | *t*-value |
| ln *y* | | −0.0170 | (2.1) | −0.0107 | (2.1) | −0.0200 | (2.3) |
| Asia | | 0.0055 | (0.1) | 0.0077 | (0.3) | 0.0143 | (0.3) |
| Africa | | −0.0334 | (0.7) | −0.0221 | (0.7) | −0.0345 | (0.7) |
| Latin America | | 0.0086 | (0.2) | 0.0041 | (0.1) | 0.0019 | (0.0) |
| Central Asia | | 0.0283 | (0.6) | 0.0020 | (0.0) | 0.0011 | (0.2) |
| constant | | 0.1313 | (1.5) | 0.0825 | (1.7) | 0.1542 | (1.7) |
| *F*-regions (*p*) | | 2.69 | 0.041 | 2.53 | 0.051 | 2.97 | 0.056 |

Notes: The top panel shows the root mean squared difference between pair of consumption price indexes over the 62 countries. The country price indexes are those shown in Table 1. Means and standard deviations in the second panel refer to the same indexes. The final panel shows regressions of the log of the ratio of the survey-based to national accounts based estimates on the log of per capita GDP in PPP $ (from the 2008 World Development Indicators) and dummies for the ICP regions. For these regressions, India is treated as a region, and is the base country, so that Asia refers to non-Indian Asia.

**Table 3: Household consumption shares by basic heading: correlation between national accounts and survey data (national accounts as of 2005, survey data as of survey year)**

| | All | Food, drinks, tobacco, and narcotics | Other goods and services |
|---|---|---|---|
| India 2005 | 0.603 | 0.710 | 0.558 |
| | | | |
| Bangladesh 2000 | 0.968 | 0.971 | 0.939 |
| Bhutan 2003 | 0.608 | 0.960 | *0.251* |
| Cambodia 2003 | 0.842 | 0.890 | 0.576 |
| China urban 2005 | 0.833 | 0.954 | 0.820 |
| China rural 2005 | 0.816 | 1.000 | 0.805 |
| Fiji 2002 | 0.624 | 0.616 | 0.655 |
| Indonesia 2002 | 0.874 | 0.921 | 0.874 |
| Lao PDR 2003 | 0.902 | 0.916 | 0.791 |
| Malaysia 2004 | 0.929 | 0.892 | 0.938 |
| Maldives 2004 | 0.788 | 0.836 | 0.763 |
| Mongolia 2005 | 0.898 | 0.970 | 0.868 |
| Nepal 2003 | 0.877 | 0.964 | 0.561 |
| Pakistan 2001 | 0.846 | 0.832 | 0.838 |
| Philippines 2003 | 0.857 | 0.979 | 0.733 |
| Sri Lanka 2002 | 0.651 | 0.747 | 0.725 |
| Thailand 2002 | 0.794 | 0.575 | 0.830 |
| Vietnam 2004 | 0.878 | 0.972 | 0.764 |
| | | | |
| Argentina 2006 | 0.753 | 0.942 | 0.672 |
| Bolivia 2002 | 0.536 | 0.884 | *0.467* |
| Brazil 2002 | 0.787 | 0.818 | 0.778 |
| Colombia 2003 | 0.771 | 0.633 | 0.805 |
| Paraguay 2000 | 0.682 | 0.884 | 0.570 |
| Peru 2003 | *0.468* | 0.729 | *0.460* |
| | | | |
| Armenia 2004 | 0.848 | 0.870 | 0.548 |
| Azerbaijan 2001 | *0.449* | 0.589 | 0.533 |
| Kazakhstan 2003 | *0.492* | 0.732 | 0.590 |
| Kyrgyz Republic 2003 | 0.789 | 0.714 | 0.824 |
| Tajikistan 2003 | 0.599 | 0.636 | *0.327* |
| Yemen 2005 | 0.759 | 0.720 | 0.747 |

Notes: Figures are the correlations between the (plutocratic) budget shares estimated from the surveys and those provided by the national accounts, as incorporated into the ICP calculations. The Chinese survey data are synthetic numbers created from published data for this exercise, see the main text. Correlations less than 0.5 are highlighted in italic.

**Table 3, continued**

| | All | Food, drinks, tobacco, and narcotics | Other goods and services |
|---|---|---|---|
| Benin 2003 | 0.787 | 0.903 | 0.553 |
| Burkina Faso 2003 | 0.767 | 0.787 | 0.634 |
| Burundi 1998 | 0.605 | 0.594 | *0.443* |
| Cameroon 2001 | 0.671 | 0.650 | 0.761 |
| Cape Verde 2001 | 0.699 | 0.929 | 0.657 |
| Chad 2003 | *0.090* | *0.023* | *0.095* |
| Congo DR 2005 | 0.865 | 0.864 | 0.655 |
| Congo PR 2005 | 0.563 | *0.372* | 0.858 |
| Côte d'Ivoire 2002 | 0.674 | 0.733 | 0.613 |
| Djibouti 1996 | 0.534 | *0.374* | 0.937 |
| Ethiopia 2000 | 0.955 | 0.980 | 0.729 |
| Gabon 2005 | 0.819 | 0.960 | 0.643 |
| Gambia 2003 | *0.367* | 0.933 | *0.196* |
| Ghana 2006 | 0.692 | 0.725 | 0.636 |
| Guinea 2002 | 0.721 | 0.767 | *0.460* |
| Kenya 2005 | 0.704 | 0.830 | 0.562 |
| Lesotho 2002 | 0.875 | 0.979 | 0.705 |
| Liberia 2007 | *0.490* | 0.876 | *0.436* |
| Madagascar 2001 | 0.922 | 0.956 | 0.616 |
| Malawi 2004 | *0.405* | 0.648 | *0.108* |
| Mali 2006 | 0.840 | 0.939 | *0.382* |
| Mauritania 2004 | 0.823 | 0.779 | 0.791 |
| Morocco 2001 | 0.782 | 0.889 | 0.771 |
| Mozambique 2002 | 0.821 | 0.896 | *0.424* |
| Niger 2005 | 0.843 | 0.891 | 0.603 |
| Nigeria 2003 | 0.829 | 0.860 | 0.692 |
| Rwanda 2005 | 0.544 | 0.621 | 0.607 |
| Senegal 2001 | 0.681 | 0.685 | 0.505 |
| Sierra Leone 2003 | 0.895 | 0.961 | 0.799 |
| South Africa 2000 | *0.495* | 0.529 | *0.490* |
| Swaziland 2000 | 0.764 | 0.886 | 0.519 |
| Tanzania 2000 | 0.955 | 0.970 | 0.884 |
| Togo 2006 | 0.724 | 0.826 | 0.525 |
| Uganda 2002 | 0.826 | 0.794 | 0.891 |

Note: A regression of the correlations for “all” on log $y$ and regions yields no significant effects, singly or jointly.

**Table 4: PPPs for consumption using national aggregates from surveys, and the standard errors of their logarithms**

| | Pc Fisher | | | Pc-CPD(W) | | |
|---|---|---|---|---|---|---|
| | PPP | se(1) | se(2) | PPP | se(1) | se(2) |
| India | 1.000 | --- | --- | 1.000 | --- | --- |
| Bangladesh | 1.571 | 0.0010 | 0.0836 | 1.565 | 0.0040 | 0.1048 |
| Bhutan | 1.139 | 0.0012 | 0.0693 | 1.142 | 0.0025 | 0.0828 |
| Cambodia | 109.1 | 0.0007 | 0.1040 | 105.4 | 0.0027 | 0.1308 |
| China | 0.251 | 0.0004 | 0.0975 | 0.253 | 0.0029 | 0.1293 |
| Fiji | 0.081 | 0.0011 | 0.0815 | 0.080 | 0.0038 | 0.0967 |
| Indonesia | 260.6 | 0.0004 | 0.0757 | 257.0 | 0.0026 | 0.0940 |
| Lao PDR | 263.2 | 0.0040 | 0.1000 | 271.4 | 0.0027 | 0.1370 |
| Malaysia | 0.124 | 0.0052 | 0.0862 | 0.118 | 0.0035 | 0.1128 |
| Maldives | 0.499 | 0.0062 | 0.0954 | 0.468 | 0.0038 | 0.1219 |
| Mongolia | 33.73 | 0.0007 | 0.0851 | 32.02 | 0.0031 | 0.1039 |
| Nepal | 1.622 | 0.0014 | 0.0848 | 1.616 | 0.0090 | 0.1046 |
| Pakistan | 1.446 | 0.0005 | 0.0799 | 1.420 | 0.0039 | 0.0941 |
| Philippines | 1.560 | 0.0005 | 0.0858 | 1.498 | 0.0040 | 0.1040 |
| Sri Lanka | 2.621 | 0.0006 | 0.0861 | 2.521 | 0.0032 | 0.1051 |
| Thailand | 1.185 | 0.0005 | 0.0765 | 1.124 | 0.0028 | 0.0877 |
| Vietnam | 380.6 | 0.0010 | 0.0860 | 376.9 | 0.0033 | 0.1104 |
| Argentina | 0.089 | 0.0008 | 0.0813 | 0.087 | 0.0045 | 0.0982 |
| Bolivia | 0.193 | 0.0015 | 0.0790 | 0.185 | 0.0048 | 0.0946 |
| Brazil | 0.107 | 0.0012 | 0.0986 | 0.106 | 0.0035 | 0.1196 |
| Colombia | 89.07 | 0.0011 | 0.0795 | 83.93 | 0.0034 | 0.0938 |
| Paraguay | 150.5 | 0.0017 | 0.0830 | 144.3 | 0.0034 | 0.1026 |
| Peru | 0.121 | 0.0010 | 0.0798 | 0.115 | 0.0038 | 0.0906 |
| Armenia | 12.08 | 0.0025 | 0.0791 | 11.66 | 0.0039 | 0.0894 |
| Azerbaijan | 94.62 | 0.0043 | 0.0950 | 98.37 | 0.0039 | 0.1164 |
| Kazakhstan | 3.195 | 0.0006 | 0.0809 | 3.219 | 0.0106 | 0.0921 |
| Kyrgyz Rep. | 0.751 | 0.0041 | 0.0969 | 0.796 | 0.0049 | 0.1076 |
| Tajikistan | 0.055 | 0.0026 | 0.0974 | 0.060 | 0.0052 | 0.1061 |
| Yemen | 4.993 | 0.0017 | 0.0868 | 4.991 | 0.0033 | 0.1035 |

Notes: Pc is the aggregate (plutocratic) consumption PPP expressed in local currency per Indian rupee. The Törnqvist is not shown because the results are similar to those for the Fisher index. The second and third columns of each set show (a) the standard errors associated with sampling from the household surveys and (b) the standard errors associated with the failure of arbitrage. Standard errors are standard errors of the logarithms of the PPPs shown in the first column. Standard errors for India and China are not shown; the former is the base country, while for China we are using synthetic data that matches the published tables.

**Table 4, continued: PPPs for consumption using national aggregates from surveys, and their standard errors**

| | Pc Fisher | | | Pc-CPD(W) | | |
|---|---|---|---|---|---|---|
| | PPP | se(1) | se(2) | PPP | se(1) | se(2) |
| Benin | 17.32` | 0.0014 | 0.0966 | 17.93 | 0.0057 | 0.1323 |
| Burkina Faso | 16.53 | 0.0011 | 0.0746 | 16.45 | 0.0032 | 0.0906 |
| Burundi | 29.78 | 0.0022 | 0.1077 | 28.52 | 0.0047 | 0.1544 |
| Cameroon | 20.11 | 0.0014 | 0.0715 | 19.79 | 0.0028 | 0.0855 |
| Cape Verde | 4.613 | 0.0022 | 0.0893 | 4.551 | 0.0031 | 0.1051 |
| Chad | 22.52 | 0.0012 | 0.0742 | 22.12 | 0.0023 | 0.0884 |
| Congo DR | 21.37 | 0.0008 | 0.0706 | 21.60 | 0.0033 | 0.0867 |
| Congo PR | 24.78 | 0.0012 | 0.0755 | 24.92 | 0.0027 | 0.0883 |
| Côte d'Ivoire | 21.86 | 0.0018 | 0.0741 | 22.12 | 0.0034 | 0.0906 |
| Djibouti | 8.267 | 0.0010 | 0.0774 | 7.999 | 0.0041 | 0.0970 |
| Ethiopia | 0.204 | 0.0013 | 0.0846 | 0.192 | 0.0055 | 0.0970 |
| Gabon | 29.54 | 0.0009 | 0.0805 | 30.20 | 0.0030 | 0.0942 |
| Gambia | 0.852 | 0.0025 | 0.0800 | 0.808 | 0.0030 | 0.0935 |
| Ghana | 316.8 | 0.0009 | 0.0751 | 312.0 | 0.0069 | 0.0866 |
| Guinea | 103.7 | 0.0019 | 0.0975 | 109.8 | 0.0028 | 0.1237 |
| Kenya | 2.295 | 0.0010 | 0.0703 | 2.272 | 0.0026 | 0.0847 |
| Lesotho | 0.249 | 0.0019 | 0.0752 | 0.242 | 0.0032 | 0.0900 |
| Madagascar | 52.44 | 0.0023 | 0.0817 | 55.06 | 0.0039 | 0.0984 |
| Malawi | 3.927 | 0.0031 | 0.1121 | 3.980 | 0.0037 | 0.1549 |
| Mali | 18.96 | 0.0008 | 0.0710 | 19.15 | 0.0036 | 0.0859 |
| Mauritania | 9.190 | 0.0009 | 0.0751 | 8.823 | 0.0047 | 0.0900 |
| Morocco | 0.357 | 0.0008 | 0.0923 | 0.356 | 0.0033 | 0.1095 |
| Mozambique | 777.9 | 0.0030 | 0.0989 | 737.5 | 0.0031 | 0.1317 |
| Niger | 18.84 | 0.0011 | 0.0723 | 18.83 | 0.0024 | 0.0883 |
| Nigeria | 5.435 | 0.0011 | 0.0861 | 5.500 | 0.0029 | 0.1009 |
| Rwanda | 17.10 | 0.0021 | 0.0971 | 16.83 | 0.0031 | 0.1273 |
| Senegal | 20.83 | 0.0006 | 0.0700 | 20.28 | 0.0031 | 0.0843 |
| Sierra Leone | 103.3 | 0.0025 | 0.0848 | 99.26 | 0.0077 | 0.0989 |
| South Africa | 0.293 | 0.0014 | 0.0832 | 0.291 | 0.0030 | 0.1004 |
| Swaziland | 0.246 | 0.0040 | 0.0831 | 0.229 | 0.0027 | 0.1068 |
| Tanzania | 32.15 | 0.0013 | 0.0743 | 31.91 | 0.0046 | 0.0887 |
| Togo | 19.08 | 0.0009 | 0.0775 | 19.35 | 0.0029 | 0.0912 |
| Uganda | 47.33 | 0.0019 | 0.1105 | 46.58 | 0.0033 | 0.1536 |

**Table 5: Poverty-weighted PPPs at various bandwidths**

| | Törnqvist Indexes | | | | Fisher | CPD(W) |
|---|---|---|---|---|---|---|
| Bandwidth | Approx. | 1.0 | 0.5 | 0.1 | 0.1 | 0.1 |
| India | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 |
| Bangladesh | 1.479 | 1.501 | 1.496 | 1.494 | 1.517 | 1.510 |
| Bhutan | 1.114 | 1.089 | 1.086 | 1.086 | 1.098 | 1.081 |
| Cambodia | 102.9 | 103.0 | 102.5 | 102.3 | 104.0 | 100.2 |
| China | 0.252 | 0.253 | 0.252 | 0.252 | 0.246 | 0.241 |
| Fiji | 0.082 | 0.080 | 0.080 | 0.080 | 0.081 | 0.077 |
| Indonesia | 259.3 | 252.5 | 251.5 | 251.0 | 255.3 | 245.5 |
| Lao | 260.6 | 251.8 | 251.3 | 252.7 | 256.1 | 260.3 |
| Malaysia | 0.128 | 0.124 | 0.124 | 0.123 | 0.125 | 0.117 |
| Maldives | 0.532 | 0.506 | 0.501 | 0.491 | 0.505 | 0.484 |
| Mongolia | 33.84 | 32.92 | 32.83 | 32.74 | 33.23 | 30.65 |
| Nepal | 1.487 | 1.535 | 1.532 | 1.531 | 1.539 | 1.514 |
| Pakistan | 1.490 | 1.438 | 1.440 | 1.439 | 1.457 | 1.396 |
| Philippines | 1.522 | 1.482 | 1.476 | 1.473 | 1.486 | 1.382 |
| Sri Lanka | 2.554 | 2.521 | 2.514 | 2.509 | 2.526 | 2.346 |
| Thailand | 1.183 | 1.121 | 1.113 | 1.120 | 1.156 | 0.963 |
| Vietnam | 359.0 | 357.8 | 355.4 | 354.3 | 354.7 | 336.3 |
| Argentina | 0.083 | 0.081 | 0.081 | 0.081 | 0.080 | 0.073 |
| Bolivia | 0.192 | 0.183 | 0.183 | 0.183 | 0.186 | 0.175 |
| Brazil | 0.100 | 0.101 | 0.101 | 0.102 | 0.103 | 0.106 |
| Colombia | 93.99 | 87.81 | 87.78 | 88.47 | 89.99 | 86.33 |
| Paraguay | 147.8 | 144.9 | 144.1 | 145.2 | 145.4 | 138.0 |
| Peru | 0.122 | 0.117 | 0.117 | 0.118 | 0.120 | 0.114 |
| Armenia | 12.29 | 11.56 | 11.51 | 11.51 | 11.68 | 10.97 |
| Azerbaijan | 96.61 | 95.28 | 95.34 | 96.47 | 89.41 | 90.59 |
| Kazakhstan | 2.999 | 2.998 | 2.998 | 2.998 | 3.006 | 2.890 |
| Kyrgystan | 0.799 | 0.755 | 0.744 | 0.741 | 0.740 | 0.715 |
| Tajikistan | 0.060 | 0.055 | 0.056 | 0.056 | 0.048 | 0.054 |
| Yemen | 4.885 | 4.781 | 4.750 | 4.795 | 4.631 | 4.494 |

Notes: Authors calculations using formulas described in the text. These are based on 50 local poverty lines, and use 102 basic heads. The global poverty line is calculated by weighting each country's poverty line in international wrupees by the estimated number of people below the line in that country.

**Table 5, continued, poverty-weighted PPPs at various bandwidths**

| | Törnqvist Indexes | | | | Fisher | CPD(W) |
|---|---|---|---|---|---|---|
| Bandwidth | Approx. | 1.0 | 0.5 | 0.1 | 0.1 | 0.1 |
| Benin | 18.26 | 17.70 | 17.68 | 17.64 | 17.14 | 16.87 |
| Burkina Faso | 16.12 | 15.97 | 15.93 | 15.91 | 15.90 | 15.40 |
| Burundi | 30.07 | 29.19 | 29.17 | 29.10 | 29.20 | 26.63 |
| Cameroon | 20.08 | 19.69 | 19.68 | 19.65 | 19.59 | 18.62 |
| Cape Verde | 4.308 | 4.297 | 4.273 | 4.303 | 4.354 | 4.067 |
| Chad | 23.17 | 22.12 | 22.11 | 22.10 | 22.48 | 21.46 |
| Congo DR | 21.30 | 20.93 | 20.91 | 20.88 | 21.10 | 20.81 |
| Congo PR | 26.19 | 24.68 | 24.66 | 24.67 | 24.52 | 23.89 |
| Côte d'Ivoire | 22.20 | 21.62 | 21.58 | 21.52 | 21.47 | 21.16 |
| Djibouti | 8.169 | 7.999 | 7.974 | 8.024 | 8.122 | 7.913 |
| Ethiopia | 0.200 | 0.194 | 0.194 | 0.193 | 0.197 | 0.178 |
| Gabon | 29.91 | 29.47 | 29.56 | 29.77 | 29.57 | 30.67 |
| Gambia | 0.912 | 0.855 | 0.855 | 0.853 | 0.859 | 0.785 |
| Ghana | 350.4 | 322.8 | 323.0 | 322.2 | 321.8 | 302.3 |
| Guinea | 111.3 | 105.8 | 105.8 | 105.8 | 104.2 | 109.0 |
| Kenya | 2.287 | 2.242 | 2.239 | 2.237 | 2.256 | 2.141 |
| Lesotho | 0.253 | 0.242 | 0.242 | 0.241 | 0.241 | 0.226 |
| Madagascar | 54.38 | 53.06 | 52.98 | 52.97 | 52.33 | 56.57 |
| Malawi | 3.993 | 3.909 | 3.903 | 3.887 | 3.782 | 3.622 |
| Mali | 19.29 | 18.73 | 18.70 | 18.71 | 18.60 | 18.38 |
| Mauritania | 9.466 | 8.942 | 8.919 | 8.875 | 9.066 | 8.415 |
| Morocco | 0.351 | 0.336 | 0.330 | 0.326 | 0.324 | 0.292 |
| Mozambique | 707.9 | 718.9 | 715.7 | 714.7 | 709.6 | 637.6 |
| Niger | 19.02 | 18.51 | 18.49 | 18.48 | 18.56 | 17.99 |
| Nigeria | 6.217 | 5.604 | 5.610 | 5.621 | 5.604 | 5.352 |
| Rwanda | 17.32 | 16.93 | 17.00 | 16.99 | 16.64 | 15.73 |
| Senegal | 21.13 | 20.28 | 20.24 | 20.24 | 20.45 | 19 45 |
| Sierra Leone | 107.8 | 103.5 | 103.5 | 103.2 | 102.9 | 96.47 |
| South Africa | 0.265 | 0.265 | 0.264 | 0.262 | 0.266 | 0.246 |
| Swaziland | 0.257 | 0.247 | 0.247 | 0.249 | 0.248 | 0.225 |
| Tanzania | 32.00 | 31.22 | 31.17 | 31.15 | 31.39 | 30.46 |
| Togo | 19.89 | 19.16 | 19.14 | 19.15 | 19.04 | 18.70 |
| Uganda | 46.74 | 46.15 | 46.04 | 45.76 | 44.34 | 40.90 |

**Table 6: Numbers of observations within the bandwidth around the poverty lines (first column is total number of households in the survey)**

| | Sample size | T(1.0) | T(0.5) | T(0.1) | F(0.1) | CPD(0.1) |
|---|---|---|---|---|---|---|
| India | 124644 | 78724 | 45623 | 9670 | 9761 | 10003 |
| Bangladesh | 7448 | 5595 | 3049 | 616 | 631 | 638 |
| Bhutan | 4007 | 1047 | 469 | 84 | 82 | 81 |
| Cambodia | 14984 | 7014 | 3392 | 641 | 683 | 650 |
| *China** | *2000* | *721* | *363* | *74* | *71* | *71* |
| Indonesia | 64422 | 22760 | 10415 | 1916 | 2098 | 1918 |
| Fiji | 5244 | 1761 | 807 | 158 | 158 | 149 |
| Lao | 8071 | 5589 | 3197 | 658 | 678 | 686 |
| Malaysia | 14084 | 363 | 76 | 11 | 14 | 8 |
| Maldives | 2728 | 157 | 42 | 11 | 11 | 7 |
| Mongolia | 11162 | 4112 | 1913 | 339 | 371 | 334 |
| Nepal | 3912 | 2329 | 1349 | 301 | 305 | 305 |
| Pakistan | 15839 | 6993 | 3198 | 573 | 613 | 547 |
| Philippines | 42094 | 17839 | 8998 | 1814 | 1882 | 1673 |
| Sri Lanka | 16924 | 4484 | 1785 | 342 | 360 | 258 |
| Thailand | 34785 | 414 | 80 | 8 | 13 | 5 |
| Vietnam | 9189 | 4224 | 1938 | 345 | 353 | 340 |
| Argentina | 27245 | 2304 | 798 | 135 | 136 | 109 |
| Bolivia | 5732 | 1125 | 415 | 77 | 77 | 72 |
| Brazil | 48466 | 8446 | 3138 | 568 | 593 | 635 |
| Colombia | 22949 | 2357 | 880 | 166 | 169 | 163 |
| Paraguay | 2682 | 580 | 260 | 51 | 47 | 52 |
| Peru | 18911 | 3464 | 1227 | 219 | 217 | 214 |
| Armenia | 6816 | 873 | 322 | 62 | 63 | 60 |
| Azerbaijan | 7820 | 1038 | 338 | 64 | 43 | 51 |
| Kazakhstan | 11986 | 128 | 44 | 6 | 6 | 6 |
| Kyrgystan | 1081 | 210 | 81 | 14 | 16 | 14 |
| Tajikistan | 4160 | 768 | 290 | 51 | 23 | 52 |
| Yemen | 13136 | 1327 | 460 | 67 | 71 | 73 |

* A synthetic dataset was used for China (see Appendix).

**Table 6, continued: Numbers of observations within the bandwidth around the poverty lines (first column is total number of households in the survey)**

| | Sample Size | T(1.0) | T(0.5) | T(0.1) | F(0.1) | CPD(0.1) |
|---|---|---|---|---|---|---|
| Benin | 5350 | 3552 | 2008 | 422 | 427 | 430 |
| Burkina Faso | 8494 | 5795 | 3330 | 674 | 677 | 685 |
| Burundi | 6668 | 3807 | 2124 | 444 | 436 | 463 |
| Cameroon | 10992 | 5111 | 2603 | 522 | 524 | 482 |
| Cape Verde | 4584 | 1967 | 965 | 186 | 197 | 173 |
| Chad | 6697 | 4279 | 2318 | 445 | 469 | 448 |
| Congo DR | 11959 | 6626 | 3508 | 713 | 709 | 714 |
| Congo PR | 5002 | 2742 | 1389 | 284 | 284 | 276 |
| Côte d'Ivoire | 10800 | 5473 | 2769 | 562 | 564 | 567 |
| Djibouti | 2380 | 794 | 344 | 45 | 49 | 49 |
| Ethiopia | 16672 | 7966 | 4206 | 898 | 956 | 697 |
| Gabon | 6379 | 1070 | 424 | 74 | 74 | 93 |
| Gambia | 2238 | 1326 | 737 | 167 | 171 | 137 |
| Ghana | 8687 | 4513 | 2335 | 443 | 442 | 442 |
| Guinea | 7095 | 4901 | 2755 | 571 | 568 | 569 |
| Kenya | 13154 | 8055 | 4534 | 942 | 966 | 932 |
| Lesotho | 5992 | 3532 | 1876 | 404 | 404 | 418 |
| Madagascar | 5078 | 996 | 391 | 56 | 60 | 82 |
| Malawi | 11280 | 7428 | 4048 | 838 | 855 | 889 |
| Mali | 4494 | 3065 | 1843 | 401 | 400 | 406 |
| Mauritania | 9385 | 2991 | 1335 | 245 | 279 | 219 |
| Morocco | 14243 | 5508 | 1085 | 96 | 93 | 70 |
| Mozambique | 8700 | 5931 | 3400 | 679 | 668 | 698 |
| Niger | 6689 | 4419 | 2438 | 528 | 521 | 532 |
| Nigeria | 19158 | 13019 | 7350 | 1572 | 1565 | 1574 |
| Rwanda | 6900 | 3326 | 1496 | 266 | 268 | 297 |
| Senegal | 6594 | 4095 | 2266 | 483 | 490 | 464 |
| Sierra Leone | 3719 | 2717 | 1574 | 352 | 353 | 353 |
| South Africa | 26215 | 10039 | 4772 | 948 | 959 | 913 |
| Swaziland | 3794 | 2907 | 1739 | 343 | 344 | 385 |
| Tanzania | 22178 | 13996 | 7670 | 1601 | 1587 | 1604 |
| Togo | 7500 | 5218 | 3011 | 616 | 616 | 616 |
| Uganda | 9711 | 6295 | 3641 | 755 | 755 | 737 |

**Table 7. Estimates of standard errors of log P4s from sampling, percentages**

| | T(1.0) | T(0.5) | T(0.1) | F(0.1) | CPD(0.1) |
|---|---|---|---|---|---|
| India | --- | 0.00 | 0.00 | 0.00 | 0.00 |
| Bangladesh | 0.07 | 0.09 | 0.15 | 0.18 | 0.32 |
| Bhutan | 0.15 | 0.17 | 0.33 | 0.54 | 0.69 |
| Cambodia | 0.15 | 0.18 | 0.30 | 0.28 | 0.61 |
| *China* | *0.05* | *0.06* | *0.13* | *0.13* | *0.30* |
| Indonesia | 0.06 | 0.08 | 0.15 | 0.13 | 0.29 |
| Fiji | 0.16 | 0.24 | 0.58 | 0.87 | 1.25 |
| Lao PDR | 0.17 | 0.19 | 0.32 | 0.27 | 0.65 |
| Malaysia | 0.25 | 0.62 | 0.64 | 0.87 | 2.76 |
| Maldives | 0.52 | 0.83 | 1.59 | 1.49 | 3.24 |
| Mongolia | 0.18 | 0.21 | 0.38 | 0.30 | 0.79 |
| Nepal | 0.14 | 0.16 | 0.25 | 0.23 | 0.51 |
| Pakistan | 0.10 | 0.13 | 0.22 | 0.19 | 0.49 |
| Philippines | 0.09 | 0.12 | 0.20 | 0.20 | 0.37 |
| Sri Lanka | 0.10 | 0.13 | 0.26 | 0.25 | 0.62 |
| Thailand | 0.65 | 1.02 | 2.10 | 0.54 | 0.78 |
| Vietnam | 0.11 | 0.15 | 0.29 | 0.27 | 0.61 |
| Argentina | 0.19 | 0.32 | 1.09 | 1.13 | 1.06 |
| Bolivia | 0.24 | 0.29 | 0.76 | 0.74 | 1.27 |
| Brazil | 0.24 | 0.36 | 0.83 | 0.66 | 1.18 |
| Colombia | 0.19 | 0.31 | 0.65 | 0.61 | 1.25 |
| Paraguay | 0.36 | 0.48 | 1.28 | 1.06 | 2.01 |
| Peru | 0.20 | 0.29 | 0.63 | 0.45 | 1.33 |
| Armenia | 0.16 | 0.23 | 0.47 | 0.62 | 0.92 |
| Azerbaijan | 0.33 | 0.52 | 0.92 | 3.11 | 2.95 |
| Kazakhstan | 0.37 | 0.66 | 0.45 | 0.34 | 1.27 |
| Kyrgystan | 0.57 | 0.83 | 1.56 | 1.39 | 2.28 |
| Tajikistan | 0.28 | 0.46 | 1.42 | 0.65 | 2.28 |
| Yemen | 0.52 | 0.76 | 2.05 | 0.90 | 2.24 |

Note: The figures shown have been multiplied by 100, and are already standard errors of logs. Hence, for example, the estimated standard error of the log of the Törnqvist P4 for the Maldives with bandwidth 1 is 0.0052, or a little over half of one percent. For Armenia, Azerbaijan, Fiji, Ghana, Kazakhstan, Tajikistan, Kyrgyzstan, and Morocco, we do not have information on the survey design and have assumed that the surveys are unstratified simple random samples, so that the standard errors shown are almost certainly too small. A synthetic dataset was used for China (see Appendix).

**Table 7, continued. Estimates of standard errors of log P4s from sampling, percentages**

| | T(1.0) | T(0.5) | T(0.1) | F(0.1) | CPD(0.1) |
|---|---|---|---|---|---|
| Benin | 0.16 | 0.18 | 0.33 | 0.36 | 0.55 |
| Burkina Faso | 0.09 | 0.11 | 0.22 | 0.24 | 0.46 |
| Burundi | 0.24 | 0.27 | 0.46 | 0.44 | 1.04 |
| Cameroon | 0.25 | 0.28 | 0.41 | 0.53 | 0.74 |
| Cape Verde | 0.31 | 0.40 | 0.56 | 0.62 | 1.18 |
| Chad | 0.10 | 0.12 | 0.24 | 0.27 | 0.46 |
| Congo DR | 0.12 | 0.16 | 0.30 | 0.21 | 0.51 |
| Congo PR | 0.13 | 0.18 | 0.30 | 0.32 | 0.61 |
| Côte d'Ivoire | 0.12 | 0.15 | 0.28 | 0.34 | 0.53 |
| Djibouti | 0.19 | 0.29 | 0.53 | 0.68 | 1.02 |
| Ethiopia | 0.13 | 0.15 | 0.26 | 0.26 | 0.55 |
| Gabon | 0.20 | 0.30 | 0.68 | 0.70 | 1.15 |
| Gambia | 0.32 | 0.37 | 0.62 | 0.63 | 1.38 |
| Ghana | 0.08 | 0.11 | 0.23 | 0.26 | 0.47 |
| Guinea | 0.21 | 0.26 | 0.47 | 0.51 | 0.86 |
| Kenya | 0.08 | 0.09 | 0.17 | 0.22 | 0.34 |
| Lesotho | 0.14 | 0.18 | 0.33 | 0.41 | 0.62 |
| Madagascar | 0.20 | 0.26 | 0.54 | 0.57 | 1.12 |
| Malawi | 0.14 | 0.17 | 0.34 | 0.41 | 0.59 |
| Mali | 0.09 | 0.12 | 0.25 | 0.29 | 0.47 |
| Mauritania | 0.15 | 0.19 | 0.35 | 0.35 | 0.68 |
| Morocco | 0.13 | 0.26 | 0.79 | 0.87 | 1.68 |
| Mozambique | 0.20 | 0.22 | 0.34 | 0.43 | 0.69 |
| Niger | 0.08 | 0.10 | 0.18 | 0.21 | 0.36 |
| Nigeria | 0.09 | 0.11 | 0.21 | 0.22 | 0.40 |
| Rwanda | 0.19 | 0.23 | 0.39 | 0.47 | 0.88 |
| Senegal | 0.08 | 0.10 | 0.16 | 0.17 | 0.31 |
| Sierra Leone | 0.20 | 0.22 | 0.34 | 0.44 | 0.68 |
| South Africa | 0.09 | 0.12 | 0.23 | 0.21 | 0.44 |
| Swaziland | 0.21 | 0.28 | 0.60 | 0.79 | 1.03 |
| Tanzania | 0.15 | 0.19 | 0.31 | 0.36 | 0.62 |
| Togo | 0.09 | 0.11 | 0.19 | 0.25 | 0.37 |
| Uganda | 0.17 | 0.21 | 0.41 | 0.41 | 0.70 |

**Table 8: Comparing distances between pairs of alternative indexes**
(Root mean squared differences over 62 countries of price of consumption.)

| | T0 | F1.0 | F0.5 | F0.1 | T1.0 | T0.5 | T0.1 | C1.0 | C0.5 | C0.1 |
|---|---|---|---|---|---|---|---|---|---|---|
| ICP | 0.179 | 0.154 | 0.155 | 0.158 | 0.153 | 0.156 | 0.157 | 0.171 | 0.176 | 0.178 |
| F(N) | 0.105 | 0.101 | 0.104 | 0.104 | 0.102 | 0.106 | 0106 | 0.158 | 0.164 | 0.167 |
| T(N) | 0.093 | 0.090 | 0.093 | 0.093 | 0.086 | 0.089 | 0.090 | 0.144 | 0.150 | 0.153 |
| C(N) | 0.107 | 0.103 | 0.105 | 0.105 | 0.099 | 0.102 | 0.102 | 0.144 | 0.149 | 0.152 |
| F(S) | 0.073 | 0.054 | 0.057 | 0.057 | 0.056 | 0.060 | 0.060 | 0.114 | 0.120 | 0.123 |
| T(S) | 0.073 | 0.058 | 0.061 | 0.062 | 0.052 | 0.056 | 0.057 | 0.112 | 0.119 | 0.121 |
| C(S) | 0.084 | 0.062 | 0.064 | 0.065 | 0.055 | 0.057 | 0.057 | 0.092 | 0.098 | 0.102 |
| T0 | 0 | 0.062 | 0.064 | 0.064 | 0.058 | 0.061 | 0.062 | 0.121 | 0.126 | 0.127 |
| F1 | -- | 0 | 0.006 | 0.011 | 0.023 | 0.024 | 0.026 | 0.075 | 0.081 | 0.084 |
| F0.5 | | -- | 0 | 0.010 | 0.023 | 0.022 | 0.024 | 0.072 | 0.077 | 0.080 |
| F0.1 | | | -- | 0 | 0.027 | 0.026 | 0.026 | 0.074 | 0.079 | 0.081 |
| T1 | | | | -- | 0 | 0.006 | 0.012 | 0.073 | 0.079 | 0.082 |
| T0.5 | | | | | -- | 0 | 0.008 | 0.069 | 0.075 | 0.078 |
| T0.1 | | | | | | -- | 0 | 0.069 | 0.074 | 0.077 |
| C1 | | | | | | | -- | 0 | 0.011 | 0.023 |
| C0.5 | | | | | | | | -- | 0 | 0.019 |
| C0.1 | | | | | | | | | -- | 0 |

Notes: ICP stands for the price of consumption expenditures by individual households, i.e. the PPP divided by the exchange rate. F(p), T(p), and C(p) are the aggregate (plutocratic) indexes computed from the surveys, Fisher, Törnqvist, and CPD(W) respectively, again divided by the foreign exchange rate. The other indexes are indicated by their first letter, and by the bandwidths in terms of standard deviations of log PCE, 1.0, 0.5, or 0.1.

**Table 9: Comparing distances between P4s under different poverty lines**
(Means, s.d.'s, and root mean squared differences over 62 countries of price of consumption.)

| | Mean | Standard Deviation | Distance from P4 with PL x 2 | Distance from P4 with CR PL |
|---|---|---|---|---|
| Fisher | | | | |
| Original | 1.404 | 0.379 | 0.057 | 0.014 |
| PL times 2 | 1.455 | 0.384 | 0 | 0.050 |
| CR PL | 1.410 | 0.376 | -- | 0 |
| Törnqvist | | | | |
| Original | 1.402 | 0.372 | 0.053 | 0.013 |
| PL times 2 | 1.448 | 0.378 | 0 | 0.048 |
| CR PL | 1.406 | 0.372 | -- | 0 |
| CPD | | | | |
| Original | 1.347 | 0.373 | 0.101 | 0.036 |
| PL times 2 | 1.437 | 0.381 | 0 | 0.084 |
| CR PL | 1.362 | 0.364 | -- | 0 |

Notes: Original indexes are the prices of consumption based on the P4 index with bandwidth of 0.1 standard deviation; the global poverty line is calculated by weighting by the number of poor people in each of the 50 countries. The PL times 2 uses the same 50 country poverty lines as in the original calculation, but multiplied by two; again, the global line is weighted by the number of people below the line in each countries. This alternative is intended to mimic the comparison between dollar-a-day poverty and two dollar-a-day poverty. The consumption price indexes with CR PL, are intended to mimic Chen and Ravallion's (2008) global poverty line. They are calculated using the poverty lines for 14 of their 15 countries–we do not have data for Guinea-Bissau which is excluded–and without weighting, so that the global poverty line is the unweighted average of the P4 converted value of the 14 lines.

**Table 10: Income and regional effects in poverty PPPs versus PPPs and the ICP consumption PPP**

| | Fisher | | Törnqvist | | CPD(W) | |
|---|---|---|---|---|---|---|
| | Log of ratio of P4 with bandwidth 0.1 to P3 with NAS weights | | | | | |
| ln *y* | −0.0166 | (1.6) | −0.0140 | (1.7) | −0.0241 | (1.8) |
| Asia | −0.0202 | (0.3) | −0.0206 | (0.4) | −0.0366 | (0.5) |
| Africa | −0.0556 | (1.0) | −0.0459 | (1.0) | −0.0943 | (1.2) |
| Latin America | −0.0275 | (0.4) | −0.0218 | (0.4) | −0.0351 | (0.4) |
| Western Asia | −0.0353 | (0.6) | −0.0429 | (0.9) | −0.0826 | (1.0) |
| Constant | 0.1280 | (1.3) | 0.1079 | (1.4) | 0.1858 | (1.1) |
| *F* regions (*p*) | 0.99 | 0.42 | 0.89 | 0.48 | 1.75 | 0.15 |

Note: India is the omitted "region". The last row shows the *F*-statistic for the omission of the regions, together with the associated *p*-value.

**Table 11: International poverty lines in world rupees**

| | P3 Indexes: Plutocratic Purchasing Power Parities using unweighted mean of 14 poorest countries as international poverty line | | | |
|---|---|---|---|---|
| Source for weights | ICP: NIPA | NIPA 105 | NIPA 102 | Surveys |
| ICP/Chen-Ravallion | 592.88 | -- | -- | -- |
| Fisher | -- | 577.4 | 549.1 | 541.8 |
| Törnqvist | -- | 570.1 | 534.0 | 537.5 |
| CPD | -- | 563.1 | 546.3 | 546.2 |
| | P4 Indexes: Poverty weighted Purchasing Power Parities | | | |
| Poverty line selection | Unweighted mean of 14 | Weighted mean of 50 | | 2x weighted mean of 50 |
| Fisher | 557.0 | 487.9 | | 1020.0 |
| Törnqvist | 547.8 | 485.0 | | 1015.8 |
| CPD | 576.9 | 495.1 | | 1022.2 |

Notes: The first number in the top panel, 592.88, is the CR global poverty line of $38 a month ($1.25 a day) converted into Indian rupees using the conversion factor of 15.602 which is the PPP for household individual consumption for India relative to the US taken from the final report. If we calculate this number directly, using the poverty lines of the 15 poorest countries, converted to international dollars using their PPPs for household individual consumption, and taking an unweighted average, we get 37.70 international dollars or 588.13 world rupees. If we exclude Guinea-Bissau from the 15 poorest countries, so as to make the calculations comparable with our own calculations for which we do not have a survey for Guinea-Bissau, we get 37.15 international dollars or 579.62 world rupees. The column headed NIPA 105 shows the simple average of poverty lines converted at the PPP for household individual consumption on a NIPA basis directly calculated in one step according to the aggregation formula indicated, and using all 105 basic heads. The column headed NIPA 102 is the same as NIPA 105, but with three basic heads dropped: FISIM, prostitution, and actual and imputed household rents. The column labeled surveys also uses 102 basic heads, and also uses an aggregate PPP, but uses surveys to estimate aggregate expenditures instead of the national accounts. The bottom panel shows three sets of poverty lines that use P4s (bandwidth 0.5) for conversion to international rupees; in all cases, the global poverty line is calculated simultaneously with the P4s. In the first column, the global line is calculated as the simple average of the 14 poorest country poverty lines at the final estimates of the P4s. The second column uses poverty lines from 50 countries, and weighted by the number of poor in each country at the final global poverty line. The final column also uses 50 countries, and is weighted by the number of poor, but starts from the 50 national poverty lines multiplied by two.

**Table 12: Ratio of parity for actual and imputed rental to parity for household individual consumption**

| Country | Ratio of parities | Country | Ratio of parities |
|---|---|---|---|
| Chad | 0.176 | Niger | 0.318 |
| Ethiopia | 0.520 | Rwanda | 0.846 |
| Gambia | 0.110 | Sierra Leone | 0.184 |
| Ghana | 0.048 | Tanzania | 0.607 |
| Guinea-Bissau | 0.259 | Tajikistan | 0.119 |
| Malawi | 0.150 | Uganda | 0.581 |
| Mali | 0.525 | | |
| Mozambique | 0.215 | China | 0.832 |
| Nepal | 0.904 | India | 0.602 |

Notes: The numbers shown are the ratios of the parity for actual and imputed rents to the parity for household individual consumption. The first 15 countries are the poorest countries whose national poverty lines are used by Chen and Ravallion in their calculation of the global poverty line. China and India are shown for comparison.

**Table 13: Bilateral index comparisons to US, country by country**
(Wrupees per US dollar)

| Country | CPD | Fisher | Törnqvist |
|---|---|---|---|
| India | 13.6 | 17.3 | 16.0 |
| Bangladesh | 13.8 | 17.5 | 16.3 |
| Bhutan | 13.3 | 17.5 | 16.2 |
| Cambodia | 13.7 | 17.5 | 16.2 |
| China | 13.7 | 17.4 | 16.2 |
| Fiji | 13.7 | 17.5 | 16.1 |
| Indonesia | 13.8 | 17.5 | 16.3 |
| Lao | 13.8 | 17.5 | 16.2 |
| Malaysia | 13.7 | 17.5 | 16.2 |
| Maldives | 13.6 | 17.4 | 16.3 |
| Mongolia | 13.8 | 17.5 | 16.2 |
| Nepal | 13.6 | 17.5 | 16.2 |
| Pakistan | 13.6 | 17.5 | 16.1 |
| Philippines | 13.7 | 17.5 | 16.2 |
| Sri Lanka | 13.7 | 17.5 | 16.2 |
| Thailand | 13.8 | 17.5 | 16.3 |
| Vietnam | 13.8 | 17.5 | 16.3 |
| Argentina | 13.8 | 17.5 | 16.2 |
| Bolivia | 13.7 | 17.4 | 16.1 |
| Brazil | 13.7 | 17.4 | 16.0 |
| Colombia | 13.7 | 17.4 | 16.2 |
| Paraguay | 13.7 | 17.4 | 16.3 |
| Peru | 13.6 | 17.4 | 16.1 |
| Armenia | 13.7 | 17.4 | 16.2 |
| Azerbaijan | 13.8 | 17.5 | 16.2 |
| Kazakhstan | 13.7 | 17.5 | 16.2 |
| Kyrgyz Rep. | 13.7 | 17.5 | 16.4 |
| Tajikistan | 13.7 | 17.4 | 16.2 |
| Yemen | 13.7 | 17.5 | 16.3 |

Notes: The numbers shown are bilateral price indexes based on 102 basic heads comparing the United States to each country. The prices from each of the countries are first converted to wrupees using the corresponding P4s from Table 5 with bandwidth 0.5 so that all numbers are expressed in world rupees per dollar.

**Table 13, continued**

| Country | CPD | Fisher | Törnqvist |
|---|---|---|---|
| Benin | 13.7 | 17.4 | 16.2 |
| Burkina Faso | 13.8 | 17.5 | 16.2 |
| Burundi | 13.7 | 17.4 | 16.1 |
| Cameroon | 13.7 | 17.4 | 16.2 |
| Cape Verde | 13.8 | 17.5 | 16.3 |
| Chad | 13.7 | 17.5 | 16.2 |
| Congo DR | 13.7 | 17.5 | 16.2 |
| Congo PR | 13.7 | 17.4 | 16.2 |
| Côte d'Ivoire | 13.7 | 17.4 | 16.2 |
| Djibouti | 13.7 | 17.4 | 16.2 |
| Ethiopia | 13.7 | 17.4 | 16.2 |
| Gabon | 13.7 | 17.5 | 16.1 |
| Gambia | 13.8 | 17.4 | 16.1 |
| Ghana | 13.7 | 17.4 | 16.1 |
| Guinea | 13.6 | 17.4 | 16.1 |
| Kenya | 13.7 | 17.5 | 16.2 |
| Lesotho | 13.7 | 17.4 | 16.2 |
| Madagascar | 13.6 | 17.4 | 16.1 |
| Malawi | 13.7 | 17.4 | 16.2 |
| Mali | 13.8 | 17.4 | 16.2 |
| Mauritania | 13.7 | 17.4 | 16.2 |
| Morocco | 13.8 | 17.5 | 16.5 |
| Mozambique | 13.7 | 17.5 | 16.3 |
| Niger | 13.7 | 17.5 | 16.2 |
| Nigeria | 13.6 | 17.4 | 16.1 |
| Rwanda | 13.7 | 17.4 | 16.0 |
| Senegal | 13.7 | 17.4 | 16.2 |
| Sierra Leone | 13.7 | 17.4 | 16.1 |
| South Africa | 13.7 | 17.5 | 16.3 |
| Swaziland | 13.5 | 17.4 | 16.2 |
| Tanzania | 13.7 | 17.5 | 16.2 |
| Togo | 13.8 | 17.4 | 16.2 |
| Uganda | 13.7 | 17.4 | 16.2 |

**Table 14: Global poverty lines in US dollars using star conversion factors**

| | CPD | Fisher | Törnqvist |
|---|---|---|---|
| *P4s based on 50 poverty lines* | | | |
| Mean World rupees per US$ : | 13.675 | 17.395 | 16.108 |
| Poverty line (wrupees per capita per month): | 495.1 | 487.9 | 485.0 |
| Poverty line (US$ per capita per day): | 1.190 | 0.922 | 0.990 |
| *P4s based on 14 poverty lines* | | | |
| Mean World rupees per US$ | 13.575 | 17.211 | 16.047 |
| Poverty line (wrupees per capita per month): | 576.9 | 557.0 | 547.8 |
| Poverty line (US$ per capita per day): | 1.397 | 1.064 | 1.122 |
| *P3s based on NIPA 102 basic heads:* | | | |
| Mean World rupees per US$ | 13.755 | 15.366 | 15.169 |
| Poverty line (wrupees per capita per month): | 546.3 | 549.1 | 534.0 |
| Poverty line (US$ per capita per day): | 1.306 | 1.175 | 1.157 |
| *P3s based on NIPA 105 basic heads:* | | | |
| Mean World rupees per US$ | 12.952 | 14.504 | 14.250 |
| Poverty line (wrupees per capita per month): | 563.1 | 577.4 | 570.1 |
| Poverty line (US$ per capita per day): | 1.429 | 1.309 | 1.315 |

Notes: The first row in each panel shows the poverty-weighted averages of the bilateral price indexes listed in Table 13. The second row gives the poverty lines in world rupees from the middle column of the bottom panel of Table 11. The last row is the second row divided by the first row and multiplied by 12/365 to convert to a per day amount. The first panel, which contains our preferred results, uses a global poverty line calculated as the weighted average of the poverty lines of 50 countries, converted using the associated P4s, and weighted using the number of people in poverty in each country. The second panel calculates the poverty line as the simple average over the 14 reference countries of each country's poverty line converted to world rupees using the associated P4s. The third and fourth panels use P3s, rather than P4s, and follow Chen and Ravallion by calculating a global poverty line as the simple average over the original 15 reference countries. We differ from CR in calculating our own NIPA based P3s within the poor countries, rather than using the numbers from the ICP, and in using either 102 basic heads in panel three, and 105 basic heads in panel 4.

**Table 15**

**Numbers of poor people in 2005 by region using different poverty lines and purchasing power parities (millions)**

| | Popu-lation | $38 15 PL P3 ICP | 576.86 14 PL P4 CPD | 557.00 14 PL P4 Fisher | 547.83 14 PL P4 Törn. | 495.06 50 PL P4 CPD | 487.94 50 PL P4 Fisher | 484.96 50 PL P4 Törn | 1022.17 50 PL P4 CPD | 1019.99 50 PL P4 Fisher | 1015.79 50 PL P4 Törn |
|---|---|---|---|---|---|---|---|---|---|---|---|
| World | 5,202 | 1,319 | 1,209 | 1,164 | 1,129 | 867 | 874 | 865 | 2,645 | 2,647 | 2,643 |
| P4 only | 4,311 | 1,259 | 1,154 | 1,113 | 1,078 | 824 | 831 | 823 | 2,505 | 2,510 | 2,506 |
| EAP | 1,811 | 308 | 243 | 234 | 231 | 149 | 155 | 159 | 764 | 764 | 773 |
| P4 only | 1,804 | 306 | 241 | 233 | 229 | 148 | 154 | 158 | 761 | 761 | 767 |
| China | 1,305 | 212 | 170 | 160 | 163 | 106 | 107 | 114 | 524 | 517 | 528 |
| S Asia | 1,451 | 585 | 550 | 516 | 493 | 380 | 370 | 361 | 1,140 | 1,140 | 1,135 |
| P4 only | 1,451 | 585 | 550 | 516 | 493 | 380 | 370 | 361 | 1,140 | 1,140 | 1,135 |
| India | 1,095 | 456 | 431 | 400 | 386 | 300 | 288 | 284 | 872 | 871 | 868 |
| LAC | 535 | 44 | 42 | 40 | 38 | 31 | 31 | 30 | 104 | 106 | 102 |
| P4 only | 310 | 27 | 27 | 26 | 25 | 20 | 20 | 18 | 69 | 71 | 68 |
| ECA | 465 | 17 | 14 | 11 | 12 | 9 | 9 | 9 | 44 | 42 | 42 |
| P4 only | 38 | 3 | 2 | 2 | 2 | 1 | 1 | 1 | 8 | 8 | 8 |
| SSA | 698 | 355 | 353 | 356 | 349 | 294 | 306 | 303 | 544 | 547 | 545 |
| P4 only | 657 | 333 | 331 | 334 | 327 | 274 | 286 | 284 | 513 | 516 | 514 |
| MENA | 242 | 9 | 6 | 5 | 5 | 3 | 3 | 3 | 50 | 48 | 49 |
| P4 only | 52 | 5 | 2 | 2 | 2 | 1 | 1 | 1 | 14 | 15 | 15 |

Notes: See Tabl1 16.

**Table 16**
**Fractions of poor people in 2005 by region using different poverty lines and purchasing power parities (percent)**

| | Population | $3815 PL P3 ICP | 576.8614 PL P4 CPD | 557.0014 PL P4 Fisher | 547.8314 PL P4 Törn. | 495.0650 PL P4 CPD | 487.9450 PL P4 Fisher | 484.9650 PL P4 Törn | 1022.1750 PL P4 CPD | 1019.9950 PL P4 Fisher | 1015.7950 PL P4 Törn |
|---|---|---|---|---|---|---|---|---|---|---|---|
| World | 5,202 | 25.3 | 23.2 | 22.4 | 21.7 | 16.7 | 16.8 | 16.6 | 50.8 | 50.9 | 50.8 |
| P4 only | 4,311 | 29.2 | 26.8 | 25.8 | 25.0 | 19.1 | 19.3 | 19.1 | 58.1 | 58.2 | 58.1 |
| EAP | 1,811 | 17.0 | 13.4 | 12.9 | 12.8 | 8.3 | 8.6 | 8.8 | 42.2 | 42.2 | 42.6 |
| P4 only | 1,804 | 17.0 | 13.4 | 12.9 | 12.7 | 8.2 | 8.5 | 8.8 | 42.2 | 42.2 | 42.5 |
| China R | 777 | 26.1 | 21.0 | 19.8 | 20.1 | 13.2 | 13.3 | 14.1 | 59.7 | 59.0 | 60.1 |
| China U | 527 | 1.7 | 1.2 | 1.1 | 1.2 | 0.7 | 0.7 | 0.8 | 11.3 | 11.0 | 11.6 |
| S Asia | 1,451 | 40.3 | 37.9 | 35.6 | 34.0 | 26.2 | 25.5 | 24.9 | 78.6 | 78.6 | 78.2 |
| P4 only | 1,451 | 40.3 | 37.9 | 35.6 | 34.0 | 26.2 | 25.5 | 24.9 | 78.6 | 78.6 | 78.2 |
| India R | 780 | 43.8 | 41.4 | 38.3 | 36.8 | 28.1 | 27.0 | 26.5 | 83.5 | 83.4 | 83.2 |
| India U | 314 | 36.2 | 34.5 | 32.4 | 31.4 | 25.7 | 24.9 | 24.5 | 70.0 | 69.9 | 69.7 |
| LAC | 535 | 8.2 | 7.8 | 7.6 | 7.1 | 5.8 | 5.8 | 5.6 | 19.4 | 19.8 | 19.1 |
| P4 only | 310 | 8.7 | 8.9 | 8.6 | 7.9 | 6.3 | 6.3 | 6.0 | 22.3 | 22.9 | 22.1 |
| ECA | 465 | 3.6 | 3.0 | 2.4 | 2.7 | 2.0 | 1.9 | 2.0 | 9.4 | 9.0 | 9.0 |
| P4 only | 38 | 7.4 | 4.8 | 4.1 | 4.6 | 2.6 | 2.3 | 2.9 | 20.9 | 19.7 | 20.5 |
| SSA | 698 | 50.9 | 50.6 | 51.0 | 50.0 | 42.1 | 43.8 | 43.5 | 77.9 | 78.3 | 78.0 |
| P4 only | 657 | 50.7 | 50.4 | 50.9 | 49.8 | 41.7 | 43.5 | 43.2 | 78.1 | 78.5 | 78.2 |
| MENA | 242 | 3.6 | 2.5 | 2.2 | 2.1 | 1.3 | 1.2 | 1.2 | 20.5 | 19.9 | 20.1 |
| P4 only | 52 | 9.1 | 4.2 | 4.2 | 4.2 | 2.2 | 2.4 | 2.5 | 27.5 | 27.9 | 28.2 |

Notes: The first row gives details of the basis for the calculations. The first number is the global poverty line expressed in world rupees, except in for the Chen and Ravallion calculations in the second column. The second number is the number of national poverty lines that go into the construction of the global poverty line. For CR, there are 15 countries in this reference group. The first three P4 indices that follow use the 14 of these for which we have associated household surveys. In the last six columns, the global line is the weighted average of the poverty lines for 50 Part II countries, with numbers of poor people as weights. In the last three columns, the 50 poverty lines are doubled prior to the calculations. The top row also identifies the purchasing power parity exchange rates used as either P3s, based on national accounts, or P4s, based on surveys, and as calculated in this paper. Finally, in the first row, the source of the P3 or P4 is identified, the ICP final report for CR, and the aggregation method, CPD, EKS-Fisher, or EKS-Törnqvist for the P4s. World refers to the Part 2 world, excluding rich countries, which is the basis for the global poverty calculations. The regions are EAP for East Asia and Pacific, S Asia for South Asia, LAC for Latin American and the Caribbean, ECA for Europe and Central Asia, SSA for sub-Saharan Africa, and MENA for Middle-East and North Africa. The row labeled" P4 only" shows comparable results for the 60 countries for which we have household surveys, and which are included in previous sections of this paper. For China and India, in Table 16, rural and urban are shown separately, labeled "U" and "R". Some part II countries were not included in the 2005 ICP, and their P3s were imputed by the Bank using regression methods. For the P4s, we use our own calculations for the 60 countries with surveys, and otherwise use imputed P3s. Poverty counts were calculated using POVCAL.

**Table 17**
**Country by country counts of number in poverty and headcount ratios, 2005 (percentages, and thousands)**

| | | Chen-Ravallion: ICP P3s | | EKS-Fisher PPPs using 50 PLs | |
|---|---|---|---|---|---|
| | Population | Number poor | Headcount ratio | Number poor | Headcount ratio |
| ***East Asia Pacific*** | | | | | |
| Cambodia | 13,956 | 5,609 | 40.2 | 3,942 | 28.3 |
| China-Rural | 777,482 | 203,001 | 26.1 | 103,327 | 13.3 |
| China-Urban | 527,018 | 9,012 | 1.7 | 3,795 | 0.7 |
| Indonesia-Rural | 114,470 | 27,484 | 24.0 | 11,527 | 10.1 |
| Indonesia-Urban | 106,088 | 19,807 | 18.7 | 8,964 | 8.5 |
| Lao PDR | 5,664 | 2,021 | 35.7 | 1,479 | 26.1 |
| Malaysia | 25,653 | 139 | 0.5 | 15 | 0.1 |
| Mongolia | 2,554 | 572 | 22.4 | 364 | 14.3 |
| *Papua N. Guinea** | 6,070 | 1,803 | 29.7 | *1,102* | *18.2* |
| Philippines | 84,566 | 19,129 | 22.6 | 11,053 | 13.1 |
| Thailand | 63,003 976 | 252 | 0.4 | 19 | 0.0 |
| *Timor Leste** | 83,105 | 425 | 43.6 | *256* | *26.3* |
| Vietnam | | 18,956 | 22.8 | 9,474 | 11.4 |
| ***South Asia*** | | | | | |
| Bangladesh | 153,281 | 77,361 | 50.5 | 45,739 | 29.8 |
| Bhutan | 637 | 171 | 26.8 | 100 | 15.8 |
| India-Rural | 780,438 | 342,066 | 43.8 | 210,328 | 27.0 |
| India-Urban | 314,145 | 113,595 | 36.2 | 78,097 | 24.9 |
| Nepal | 27,094 | 14,820 | 54.7 | 10,206 | 37.7 |
| Pakistan | 155,772 | 35,189 | 22.6 | 24,783 | 15.9 |
| Sri Lanka | 19,668 | 2,032 | 10.3 | 781 | 4.0 |
| ***LAC*** | | | | | |
| Argentina-Urban | 35,415 | 1,594 | 4.5 | 698 | 2.0 |
| Bolivia | 9,182 | 1.,802 | 19.6 | 1,677 | 18.3 |
| Brazil | 186,831 | 14,498 | 7.8 | 8,874 | 4.8 |
| *Chile* | 16,295 | 116 | 0.7 | *80* | *0.5* |
| Colombia | 44,946 | 6,243 | 13.9 | 5,991 | 13.3 |
| Costa Rica* | 4,327 | 103 | 2.4 | *38* | *0.9* |
| Dominican Rep.* | 9,470 | 472 | 5.0 | *137* | *1.5* |
| Ecuador | 13,061 | 1,277 | 9.8 | *1,021* | *7.8* |
| El Salvador* | 6,668 | 899 | 13.5 | *761* | *11.4* |
| Guatemala* | 12,710 | 1,666 | 13.1 | *1,008* | *7.9* |
| Guyana* | 739 | 54 | 7.3 | *35* | *4.8* |
| Haiti* | 9,296 | 5,387 | 58.0 | *4,291* | *46.2* |
| Honduras* | 6,834 | 1,516 | 22.2 | *1,141* | *16.7* |
| Jamaica* | 2,655 | 6 | 0.2 | *1* | *0.0* |
| Mexico | 103,089 | 1,773 | 1.7 | *72* | *0.1* |
| Nicaragua* | 5,463 | 864 | 15.8 | *511* | *9.4* |

Table 17, *continued*

| | Population | Chen-Ravallion: ICP P3s | | EKS-Fisher PPPs using 50 PLs | |
|---|---|---|---|---|---|
| | | Number poor | Headcount ratio | Number poor | Headcount ratio |
| ***LAC*** (cont.) | | | | | |
| *Panama** | 3,232 | 297 | 9.2 | *183* | *5.7* |
| Paraguay | 5,899 | 549 | 9.3 | 440 | 7.5 |
| Peru | 27,274 | 2,231 | 8.2 | 1,863 | 6.8 |
| *St. Lucia** | 165 | 29 | 17.8 | *18* | *10.7* |
| *Surinam** | 452 | 64 | 14.2 | *43* | *9.5* |
| *Trinidad & Tob.** | 1,324 | 7 | 0.5 | *4* | *0.3* |
| *Uruguay-Urban* | 3,041 | 3 | 0.1 | *1* | *0.0* |
| *Venezuela* | 26,577 | 2,652 | 10.0 | *2,256* | *8.5* |
| ***Europe & C Asia*** | | | | | |
| *Albania* | 3,154 | 27 | 0.9 | *9* | *0.3* |
| Armenia | 3,018 | 143 | 4.7 | 41 | 1.4 |
| Azerbaijan | 8,392 | 3 | 0.0 | *0* | *0.0* |
| *Belarus* | 9,776 | 0 | 0.0 | *0* | *0.0* |
| *Bosnia & Herzeg.* | 3,781 | 6 | 0.2 | *0* | *0.0* |
| *Bulgaria* | 7,740 | 0 | 0.0 | *0* | *0.0* |
| *Croatia* | 4,443 | 0 | 0.0 | *0* | *0.0* |
| *Czech R.* | 10,234 | 0 | 0.0 | *0* | *0.0* |
| *Estonia* | 1,346 | 0 | 0.0 | *0* | *0.0* |
| *Georgia* | 4,473 | 601 | 13.4 | *298* | *6.7* |
| *Hungary* | 10,087 | 0 | 0.0 | *0* | *0.0* |
| Kazakhstan | 15,147 | 174 | 1.2 | 11 | 0.1 |
| Kyrgyz R. | 5,144 | 1,122 | 21.8 | 408 | 7.9 |
| *Latvia* | 2,301 | 0 | 0.0 | *0* | *0.0* |
| *Lithuania* | 3,414 | 15 | 0.4 | *0* | *0.0* |
| *Macedonia* | 2,034 | 6 | 0.3 | *3* | *0.2* |
| *Moldova* | 3,877 | 316 | 8.1 | *69* | *1.8* |
| *Poland* | 38,165 | 38 | 0.1 | *19* | *0.1* |
| *Romania* | 21,634 | 162 | 0.8 | *0* | *0.0* |
| *Russia* | 143,150 | 229 | 0.2 | *86* | *0.1* |
| *Slovak R.* | 5,387 | 0 | 0.0 | *0* | *0.0* |
| *Slovenia* | 2,001 | 0 | 0.0 | *0* | *0.0* |
| Tajikistan | 6,550 | 1,408 | 21.5 | 428 | 6.5 |
| *Turkey* | 72,065 | 1,960 | 2.7 | *1,312* | *1.8* |
| *Turkmenistan** | 4,833 | 566 | 11.7 | *238* | *4.9* |
| *Ukraine* | 47,105 | 47 | 0.1 | *0* | *0.0* |
| *Uzbekistan** | 26,167 | 10,156 | 38.8 | *5,861* | *22.4* |

Table 17, *continued*

| | Population | Chen-Ravallion: ICP P3s | | EKS-Fisher PPPs using 50 PLs | |
|---|---|---|---|---|---|
| | | Number Poor | Headcount ratio | Number Poor | Headcount ratio |
| ***Sub-Saharan Africa*** | | | | | |
| *Angola* | 16,095 | 6.845 | 42.5 | *6,541* | *40.6* |
| Benin | 8,490 | 4,244 | 50.0 | 3,050 | 35.9 |
| *Botswana* | 1,836 | 423 | 23.1 | *341* | *18.6* |
| Burkina Faso | 13,933 | 7,669 | 55.0 | 6,128 | 44.0 |
| Burundi | 7,859 | 6,391 | 81.3 | 5,757 | 73.3 |
| Cameroon | 17,795 | 4,895 | 27.5 | 3,657 | 20.6 |
| Cape Verde | 507 | 93 | 18.4 | 42 | 8.2 |
| *C. African R.* | 4,191 | 2,701 | 64.4 | *2,538* | *60.6* |
| Chad | 10,146 | 5,952 | 58.7 | 5,196 | 51.2 |
| *Comoros* | 600 | 277 | 46.1 | *252* | *42.0* |
| Congo, D.R. | 58,741 | 34,786 | 59.2 | 30,134 | 51.3 |
| Congo, Rep. | 3,610 | 1,953 | 54.1 | 1,649 | 45.7 |
| Côte d'Ivoire | 18,585 | 3,788 | 20.4 | 2,635 | 14.2 |
| Ethiopia | 75,173 | 29,348 | 39.0 | 24,311 | 32.3 |
| Gabon | 1,291 | 62 | 4.8 | 31 | 2.4 |
| Gambia | 1,617 | 506 | 31.3 | 551 | 34.1 |
| Ghana | 22,535 | 6,758 | 30.0 | 5,983 | 26.6 |
| Guinea | 9,003 | 6,287 | 69.8 | 5,838 | 64.9 |
| *Guinea-Bissau* | 1,597 | 678 | 42.5 | *612* | *38.4* |
| Kenya | 35,599 | 7,020 | 19.7 | 5,564 | 15.6 |
| Lesotho | 1,981 | 767 | 38.7 | 695 | 35.1 |
| *Liberia* | 3,442 | 2,962 | 86.1 | *2,716* | *78.9* |
| Madagascar | 18,643 | 12,645 | 67.8 | 11,262 | 60.4 |
| Malawi | 13,226 | 9,769 | 73.9 | 8,649 | 65.4 |
| Mali | 11,611 | 5,972 | 51.4 | 4,618 | 39.8 |
| Mauritania | 2,963 | 396 | 13.4 | 327 | 11.0 |
| Mozambique | 20,533 | 14,009 | 68.2 | 11,293 | 55.0 |
| *Namibia* | 2,020 | 884 | 43.8 | *785* | *38.9* |
| Niger | 13,264 | 8,738 | 65.9 | 7,905 | 59.6 |
| Nigeria | 141,356 | 88,192 | 62.4 | 81,492 | 57.7 |
| Rwanda | 9,234 | 6,873 | 74.4 | 6,444 | 69.8 |
| Senegal | 11,770 | 3,943 | 33.5 | 3,198 | 27.2 |
| Sierra Leone | 5,586 | 2,789 | 49.9 | 2,624 | 47.0 |
| South Africa | 46,892 | 9,636 | 20.6 | 5,261 | 11.2 |
| Swaziland | 1,131 | 705 | 62.4 | 613 | 54.2 |
| Tanzania | 38,478 | 31,706 | 82.4 | 28,401 | 73.8 |
| Togo | 6,239 | 2,413 | 38.7 | 1,853 | 29.7 |
| Uganda | 28,947 | 14,916 | 51.5 | 10,606 | 36.6 |
| *Zambia* | 11,478 | 7,379 | 64.3 | *6,226* | *54.2* |

Table 17, *concluded*

| | | Chen-Ravallion: ICP P3s | | EKS-Fisher PPPs using 50 PLs | |
|---|---|---|---|---|---|
| | Population | Number poor | Headcount ratio | Number poor | Headcount ratio |
| ***Middle East & N Africa*** | | | | | |
| *Algeria** | 32,854 | 1,400 | 4.3 | *437* | *1.3* |
| Djibouti | 804 | 149 | 18.6 | 135 | 16.7 |
| *Egypt* | 72,850 | 1,450 | 2.0 | *903* | *1.2* |
| *Iran* | 69,087 | 1,002 | 1.5 | *256* | *0.4* |
| *Jordan* | 5,412 | 21 | 0.4 | *5* | *0.1* |
| Morocco | 30,143 | 892 | 3.0 | 229 | 0.8 |
| *Tunisia* | 10,029 | 101 | 1.0 | *62* | *0.6* |
| Yemen | 21,096 | 3,698 | 17.5 | 907 | 4.3 |

* Based on regression PPP.

Notes: POVCALNET calculations for individual countries included in Tables 15 and 16. Countries shown in italics are countries where we had no survey to calculate P4s, and where imputed P3 was substituted in its place.

**Table 18**

**Numbers of poor people in 2005 by region using P3s under different assumptions**
(millions)

| | Population | $38<br>15 PL<br>P3<br>ICP | 588.27<br>15 PL<br>P3<br>EKS-Fisher<br>105 BH | 557.80<br>15 PL<br>P3<br>EKS-Fisher<br>102 BH | 487.94<br>50 PL<br>P4<br>Fisher |
|---|---|---|---|---|---|
| World | 5,202 | 1,319 | 1,321 | 1,194 | 874 |
| EAP | 1,811 | 308 | 304 | 253 | 155 |
| China | 1,305 | 212 | 209 | 177 | 107 |
| South Asia | 1,451 | 585 | 574 | 515 | 370 |
| India | 1,095 | 456 | 449 | 402 | 288 |
| LAC | 535 | 44 | 48 | 42 | 31 |
| ECA | 465 | 17 | 13 | 12 | 9 |
| SSA | 698 | 355 | 374 | 365 | 306 |
| MENA | 242 | 9 | 9 | 6 | 3 |

Note: The poverty lines shown in the third and fourth columns in the table (588.27 and 557.80 wrupees) differ slightly from the Fisher NIPA 105 and 102 poverty lines presented in Table 11 (577.4 and 549.1 wrupees). The reason is that poverty lines presented in Table 11 are based on PPPs calculated for a set of 62 countries only (the ones for which we have household surveys), while the poverty lines in Table 18 are based on similar PPPs calculated using 111 countries for which we had parities.

## Appendix

### A1. Adjusting Indian prices

We follow Chen and Ravallion (2008) and assume that 72 percent of the outlets for food, clothing, and footwear are urban, and 28 percent are rural. For other goods, everything is urban. Suppose first that everything is food, clothing, and footwear, with a budget share of 100 percent. We deal with the more general case below. Then the All Indian price in the ICP is 0.72 urban and 0.28 rural, so we can write

$$p_I = 0.72 p_u + 0.28 p_r \tag{A.1}$$

Chen and Ravallion take the ratio of the official urban to total poverty lines as a measure of the ratio of urban to rural prices in India. However, a long literature on Indian poverty has established that this ratio overstates actual price differences; it was originally established as a result of an accounting error but, given the difficulty of changing official procedures in India, it has never been corrected. Here we use an urban to rural price ratio of 1.15, which is in line with old Indian practice, and close to the empirical results reported in Deaton and Tarozzi (2000) and Deaton (2004). Hence,

$$p_u = 1.15 p_r \tag{A.2}$$

If we solve those two equations together, we get

$$p_u = \frac{p_I}{0.72 + 0.28/1.15} = 1.0379 p_I \tag{A.3}$$

Hence, we take 1.0379 times the ICP price and treat it as the price for urban India, just as we treat the ICP prices as urban for other countries where we have no rural price collection, the only difference being the scaling by 1.0379.

The correction above does not allow for goods other than food, clothing, and footwear, though it is probably reasonably accurate. The final report of the ICP lists an overall household consumption PPP (in international dollars) for India of 15.60, with food and non-alcoholic beverages 21.13, alcoholic beverages and tobacco 31.53, and clothing and footwear 16.72. So non-food items are relatively cheap in India, which is what we would expect. We start from some overall (All India) budget share weights for food and beverages, alcohol and tobacco, and clothing and footwear, as well as for the three together. These are the plutocratic (NIPA) weights in total expenditure for those three items and for their sum, and are taken from the ICP. We then derive a PPP for the three together, and a PPP for the rest of consumption, by weighting the individual PPPs by the plutocratic weights. For the three categories together we get a weighted average of 21.13, 31.53, and 16.72.

$$p_{I1} = \frac{w_a 21.13 + w_b 31.53 + w_c 16.72}{w_a + w_b + w_c} \quad \text{(A.4)}$$

where 1 is the combined group of food, drinks, and clothing, and *a*, *b*, and *c* refer to the three categories separately. Write

$$w_1 = w_a + w_b + w_c \quad \text{(A.5)}$$

We also have the PPP for the rest of consumption $p_{I2}$ which is defined directly from the ICP, or from

$$p_I = 15.60 = w_1 p_{I1} + (1 - w_1) p_{I2} \quad \text{(A.6)}$$

All of these quantities are known without further calculation.

For the urban and rural adjustment, we have

$$p_{I1} = 0.72 p_{u1} + 0.28 p_{r1} \quad \text{(A.7)}$$

because the food, clothing and footwear PPP is 72 percent urban and 28 percent rural. For the other category

$$p_{I2} = p_{u2} \quad \text{(A.8)}$$

because all of the other prices were collected in urban areas. We then have the relation between the urban and the rural prices. For the first aggregate, we know that the ratio is about 1.15, so we have

$$p_{r1} = p_{u1} / 1.15 \quad \text{(A.9)}$$

For the other category, we don't know anything, but the ratio is likely a good deal larger, because there is housing and transportation in there, so perhaps

$$p_{r2} = p_{u2} / 1.50 \quad \text{(A.10)}$$

Given this arbitrary assumption, we have everything we need. The urban price is

$$p_u = w_{u1} p_{u1} + (1 - w_{u1}) p_{u2} = w_{u1}(1.0379 p_{I1}) + (1 - w_{u1}) p_{I2} \quad \text{(A.11)}$$

where the weights are now taken from the survey data. To get the rural price, we use

$$p_r = w_{r1} p_{r1} + (1 - w_{r1}) p_{r2} = w_{r1} \frac{p_{u1}}{1.15} + (1 - w_{u1}) \frac{p_{u2}}{1.5} \quad \text{(A.12)}$$

In the calculations, for India as for the other countries, we scale the household per capita expenditure before we start, in order to express all amounts in the same units as the ICP prices, urban, a mixture as here, or national.

**A2. Procedures for China**

In our calculations, household survey data are used for (i) defining the consumption shares by basic heading at the poverty line, and (ii) estimating the number of poor to calculate our poverty-weighted international poverty line. For the 62 countries included in our calculations except China, we had access to the necessary survey microdata. For China, survey microdata were not made available to us. Given its importance in the overall calculations, dropping China was not an option.

Although not as detailed as one may have wished, useful data are published in an aggregated form which provide us with the basic information we needed, i.e. the cumulative consumption function and a set of Engel curves. In its 2006 Statistics Yearbook (http://www.stats.gov.cn/tjsj/ndsj/2006/indexeh.htm), the National Bureau of Statistics of China publishes tables on urban and rural 2005 consumption patterns by income group. Table 10.7 of the Yearbook provides urban household consumption shares for 8 income groups and 17 classes of products and services. Similar information is provided by income quintile for rural China in Table 10.24, for 8 classes of products and services.[2] As for the cumulative consumption distribution of urban and rural households, it can be found in POVCALNET (available on the World Bank's website). Both the tables from the Yearbook and the POVCALNET data are based on the 2005 Urban Household Survey and Rural Household Survey of China. Combining data from these two sources, supplemented by unpublished data on the values of per capita consumption at the limits of the grouped data, we created with the help of Yuri Dikhanov a synthetic survey dataset of 2,000 households (1,000 for urban, and 1,000 for rural). This synthetic dataset was designed to match as closely as possible the data available in the Yearbook and on POVCALNET.

Producing the synthetic dataset was a two-step process. In a first step, data from POVCALNET were used to calculate an approximation to the cumulative distribution function of Chinese household per capita consumption. We converted the grouped data from POVCALNET, separately by urban and rural, into a continuous functional form for

[2] The published tables provide consumption distribution by household –not population- deciles or quintiles. We used information on average household size by income group to calculate the proportion of population corresponding to these deciles and quintiles.

the cdf using a quasi-exact polynomial interpolation technique, described in Dikhanov (2005) as follows.

A set $\{F(X_i)\}$ of $M$ elements is provided, which describes values that a cumulative distribution function takes at $X_i$. All other points of the distribution need to be approximated. Within each interval $[X_{i+1},X_i]$, the distribution function is interpolated by a polynomial of the order 3 (cubic polynomial) in the form:

$$F_{i,i+1}(x) = \sum_{n=0}^{3} \alpha_i^n \left( \frac{x - X_i}{X_{i+1} - X_i} \right)^n \qquad \text{(A.13)}$$

At the boundaries the polynomials are exact, and are not interpolations. The polynomials are chosen to be twice continuously differentiable across the boundaries. This property allows for differential and integral operations with $F$ and its derivatives in explicit analytical form. For example, the mean of the distribution would be calculated as:

$$\mu = \int xdF = \sum_{i=0}^{M} \sum_{n=1}^{3} \alpha_i^n \frac{nX_{i+1} + X_i}{n+1} \qquad \text{(A.14)}$$

where $M$ is the number of intervals. Both tails of the distribution, i.e., the last and first group, are forced to be log-normal. We used these approximations to the cdf to estimate the minimum and maximum per capita expenditure corresponding to each income group (8 in urban areas, 5 in rural areas) for which expenditure shares are published.

Synthetic samples were then generated for 1,000 urban and 1,000 rural households. In each sample, all households were given a similar weight representing 0.1 percent of the 2005 population as published in the China Statistics Yearbook, so that extrapolation of the data would result in the 2005 urban and rural population. The total per capita expenditure of each household was calculated using the approximated cdf. Having generated the total expenditure variable, we could then generate variables providing household expenditure by class of product and services (17 for urban households, 8 for rural households), following the published consumption patterns and using Engel curves fitted to those data. In this second step, we also split the classes of products and services into ICP basic headings using data from national accounts, as we did for all other countries.

Although this procedure involves data creation, and the substitution of simulation for actual data, it gives us a set of Engel curves for urban and rural China and a consumption distribution that match the patterns in the publications. As shown in the tables below, the synthetic survey data replicate closely the tables with which we began. A major advantage of generating such a micro-dataset was that China could then be treated as any other country in our calculations.

**Lorenz curves of total household consumption distribution, and mean per capita expenditure (Yuan per year): POVCALNET and the synthetic survey**

| Urban | | | | Rural | | | |
|---|---|---|---|---|---|---|---|
| Povcalnet | | Synthetic | | Povcalnet | | Synthetic | |
| Mean per capita expenditure: 7915.2 * | | Mean per capita expenditure: 7915.8 | | Mean per capita expenditure: 2557.8 * | | Mean per capita expenditure: 2553.3 | |
| Cumulative Population share (%) | Cumulative Consumption share (%) | Cumulative Population shae (%) | Cumulative Consumption share (%) | Cumulative Population share (%) | Cumulative Consumption share (%) | Cumulative Population share (%) | Cumulative Consumption share (%) |
| 6.051 | 1.553 | 6.100 | 1.532 | 0.100 | 0.014 | 0.100 | 0.013 |
| 11.681 | 3.605 | 11.700 | 3.571 | 0.400 | 0.068 | 0.400 | 0.062 |
| 17.242 | 6.021 | 17.200 | 5.962 | 1.199 | 0.242 | 1.200 | 0.230 |
| 22.622 | 8.686 | 22.600 | 8.634 | 4.795 | 1.244 | 4.800 | 1.210 |
| 27.953 | 11.612 | 28.000 | 11.597 | 10.689 | 3.334 | 10.700 | 3.234 |
| 33.153 | 14.736 | 33.200 | 14.723 | 18.382 | 6.651 | 18.400 | 6.420 |
| 38.264 | 18.068 | 38.300 | 18.054 | 22.577 | 8.702 | 22.600 | 8.383 |
| 43.344 | 21.655 | 43.300 | 21.582 | 30.969 | 13.293 | 31.000 | 12.767 |
| 48.345 | 25.457 | 48.300 | 25.381 | 39.061 | 18.352 | 39.100 | 17.592 |
| 53.295 | 29.509 | 53.300 | 29.474 | 50.150 | 26.353 | 50.100 | 25.176 |
| 58.206 | 33.825 | 58.200 | 33.786 | 64.735 | 39.094 | 64.700 | 37.455 |
| 63.036 | 38.386 | 63.000 | 38.319 | 74.825 | 49.875 | 74.800 | 47.933 |
| 67.847 | 43.280 | 67.800 | 43.199 | 81.818 | 58.712 | 81.800 | 56.611 |
| 72.567 | 48.469 | 72.600 | 48.478 | 86.513 | 65.564 | 86.500 | 63.405 |
| 77.298 | 54.132 | 77.300 | 54.102 | 89.910 | 71.187 | 89.900 | 69.039 |
| 81.968 | 60.269 | 82.000 | 60.274 | 92.208 | 75.446 | 92.200 | 73.368 |
| 86.579 | 66.996 | 86.600 | 67.000 | 100.000 | 100.000 | 100.000 | 100.000 |
| 91.139 | 74.629 | 91.100 | 74.538 | | | | |
| 95.590 | 83.720 | 95.600 | 83.701 | | | | |
| 100.000 | 100.000 | 100.000 | 100.000 | | | | |

* The 2005 mean per capita expenditure published in the 2006 China Yearbook are respectively 7,942.88 Yuan (urban) and 2555.395 Yuan (rural).

## Urban China, Consumption shares - Table 10.7 of the 2006 Statistics Yearbook

| | All | first decile | first 5 percent | second decile | second quintile | third quintile | fourth quintile | ninth decile | tenth decile |
|---|---|---|---|---|---|---|---|---|---|
| **Total Consumption Expenditures** | **1.000** | **1.000** | **1.000** | **1.000** | **1.000** | **1.000** | **1.000** | **1.000** | **1.000** |
| Food | 0.367 | 0.474 | 0.486 | 0.448 | 0.419 | 0.388 | 0.364 | 0.343 | 0.280 |
| Grain | 0.030 | 0.070 | 0.080 | 0.053 | 0.042 | 0.033 | 0.027 | 0.022 | 0.014 |
| Meat, Poultry and Their Products | 0.071 | 0.110 | 0.112 | 0.101 | 0.092 | 0.080 | 0.070 | 0.059 | 0.039 |
| Eggs | 0.009 | 0.017 | 0.017 | 0.015 | 0.012 | 0.010 | 0.008 | 0.007 | 0.004 |
| Aquatic Products | 0.024 | 0.023 | 0.022 | 0.024 | 0.024 | 0.024 | 0.025 | 0.026 | 0.021 |
| Milk and Its Products | 0.017 | 0.016 | 0.015 | 0.019 | 0.020 | 0.019 | 0.018 | 0.017 | 0.013 |
| *Food others* | *0.215* | *0.238* | *0.240* | *0.237* | *0.229* | *0.222* | *0.216* | *0.212* | *0.189* |
| Clothing | 0.101 | 0.078 | 0.071 | 0.095 | 0.101 | 0.107 | 0.107 | 0.104 | 0.092 |
| Garments | 0.073 | 0.052 | 0.047 | 0.065 | 0.071 | 0.076 | 0.078 | 0.077 | 0.069 |
| *Others* | *0.028* | *0.026* | *0.024* | *0.030* | *0.030* | *0.031* | *0.030* | *0.027* | *0.023* |
| Household Facilities, Articles and Services | 0.056 | 0.035 | 0.034 | 0.040 | 0.048 | 0.054 | 0.058 | 0.062 | 0.067 |
| Durable Consumer Goods | 0.027 | 0.010 | 0.010 | 0.014 | 0.021 | 0.026 | 0.029 | 0.031 | 0.035 |
| *Others* | *0.029* | *0.025* | *0.024* | *0.026* | *0.027* | *0.029* | *0.029* | *0.031* | *0.033* |
| Medicine and Medical Services | 0.076 | 0.075 | 0.078 | 0.072 | 0.073 | 0.077 | 0.081 | 0.082 | 0.067 |
| Transport, Post and Communication Services | 0.125 | 0.073 | 0.068 | 0.088 | 0.096 | 0.105 | 0.114 | 0.131 | 0.197 |
| Education, Culture and Recreation Services | 0.138 | 0.117 | 0.110 | 0.121 | 0.129 | 0.135 | 0.142 | 0.140 | 0.152 |
| Consumer Goods for Recreational Use | 0.035 | 0.014 | 0.013 | 0.020 | 0.027 | 0.032 | 0.039 | 0.041 | 0.046 |
| *Education and others* | *0.103* | *0.103* | *0.098* | *0.101* | *0.102* | *0.103* | *0.103* | *0.100* | *0.106* |
| Residence | 0.102 | 0.123 | 0.128 | 0.110 | 0.104 | 0.102 | 0.098 | 0.099 | 0.099 |
| Housing | 0.031 | 0.019 | 0.017 | 0.018 | 0.020 | 0.027 | 0.030 | 0.037 | 0.047 |
| *Others* | 0.070 | 0.105 | 0.111 | 0.092 | 0.084 | 0.075 | 0.068 | 0.061 | 0.052 |
| Miscellaneous Commodities and Services | 0.035 | 0.024 | 0.025 | 0.027 | 0.029 | 0.031 | 0.035 | 0.038 | 0.046 |

## Urban China, Consumption shares – Synthetic survey data

| | All | first decile | first 5 percent | second decile | second quintile | third quintile | fourth quintile | ninth decile | tenth decile |
|---|---|---|---|---|---|---|---|---|---|
| **Total Consumption Expenditures** | **1.000** | **1.000** | **1.000** | **1.000** | **1.000** | **1.000** | **1.000** | **1.000** | **1.000** |
| Food | 0.360 | 0.474 | 0.484 | 0.451 | 0.423 | 0.393 | 0.367 | 0.345 | 0.293 |
| Grain | 0.029 | 0.071 | 0.079 | 0.054 | 0.043 | 0.034 | 0.028 | 0.023 | 0.015 |
| Meat, Poultry and Their Products | 0.068 | 0.110 | 0.111 | 0.103 | 0.093 | 0.082 | 0.071 | 0.061 | 0.043 |
| Eggs | 0.009 | 0.017 | 0.017 | 0.015 | 0.013 | 0.010 | 0.009 | 0.007 | 0.005 |
| Aquatic Products | 0.024 | 0.023 | 0.022 | 0.024 | 0.024 | 0.024 | 0.025 | 0.026 | 0.022 |
| Milk and Its Products | 0.017 | 0.016 | 0.015 | 0.019 | 0.020 | 0.019 | 0.019 | 0.017 | 0.014 |
| *Food others* | 0.213 | 0.238 | 0.240 | 0.237 | 0.230 | 0.223 | 0.217 | 0.212 | 0.194 |
| Clothing | 0.101 | 0.078 | 0.072 | 0.093 | 0.101 | 0.106 | 0.108 | 0.104 | 0.094 |
| Garments | 0.073 | 0.052 | 0.048 | 0.063 | 0.071 | 0.076 | 0.078 | 0.077 | 0.070 |
| *Others* | 0.028 | 0.026 | 0.025 | 0.030 | 0.030 | 0.031 | 0.030 | 0.027 | 0.024 |
| Household Facilities, Articles and Services | 0.057 | 0.035 | 0.034 | 0.039 | 0.047 | 0.054 | 0.058 | 0.062 | 0.066 |
| Durable Consumer Goods | 0.028 | 0.010 | 0.010 | 0.013 | 0.020 | 0.025 | 0.028 | 0.031 | 0.034 |
| *Others* | 0.030 | 0.025 | 0.025 | 0.026 | 0.027 | 0.028 | 0.029 | 0.031 | 0.032 |
| Medicine and Medical Services | 0.076 | 0.075 | 0.077 | 0.072 | 0.073 | 0.076 | 0.081 | 0.083 | 0.070 |
| Transport, Post and Communication Services | 0.130 | 0.073 | 0.069 | 0.086 | 0.095 | 0.103 | 0.113 | 0.129 | 0.184 |
| Education, Culture and Recreation Services | 0.139 | 0.117 | 0.111 | 0.122 | 0.127 | 0.135 | 0.141 | 0.141 | 0.149 |
| Consumer Goods for Recreational Use | 0.036 | 0.014 | 0.013 | 0.019 | 0.026 | 0.032 | 0.038 | 0.041 | 0.044 |
| Education and others | 0.103 | 0.103 | 0.099 | 0.103 | 0.101 | 0.103 | 0.103 | 0.100 | 0.105 |
| Residence | 0.101 | 0.123 | 0.127 | 0.112 | 0.104 | 0.102 | 0.099 | 0.099 | 0.099 |
| Housing | 0.033 | 0.019 | 0.017 | 0.019 | 0.020 | 0.027 | 0.030 | 0.037 | 0.045 |
| *Others* | 0.069 | 0.105 | 0.110 | 0.093 | 0.085 | 0.076 | 0.069 | 0.062 | 0.054 |
| Miscellaneous Commodities and Services | 0.036 | 0.024 | 0.025 | 0.026 | 0.029 | 0.031 | 0.035 | 0.038 | 0.044 |

## Rural China, Consumption shares - Table 10.24 of the 2006 Statistics Yearbook

| | **Total (*)** | first quintile | second quintile | third quintile | fourth quintile | fifth quintile |
|---|---|---|---|---|---|---|
| **Consumption Expenditure** | **1.000** | **1.000** | **1.000** | **1.000** | **1.000** | **1.000** |
| Food | 0.455 | 0.514 | 0.497 | 0.482 | 0.451 | 0.394 |
| Clothing | 0.058 | 0.057 | 0.057 | 0.057 | 0.058 | 0.060 |
| Residence | 0.145 | 0.133 | 0.131 | 0.135 | 0.143 | 0.165 |
| Household Appliances and Services | 0.044 | 0.038 | 0.040 | 0.041 | 0.044 | 0.049 |
| Transport and Telecommunications | 0.096 | 0.072 | 0.080 | 0.089 | 0.098 | 0.117 |
| Education, Cultural and Recreation and Services | 0.116 | 0.100 | 0.109 | 0.113 | 0.120 | 0.124 |
| Health Care and Medical Services | 0.066 | 0.069 | 0.067 | 0.064 | 0.064 | 0.066 |
| Other Goods and Services | 0.021 | 0.016 | 0.019 | 0.021 | 0.023 | 0.024 |

*(*) Calculated; not found in Table 10.24*
*Quintiles are household quintiles*

## Rural China, Consumption shares – Synthetic survey

| | **Total** | first quintile | second quintile | third quintile | fourth quintile | fifth quintile |
|---|---|---|---|---|---|---|
| **Consumption Expenditure** | **1.000** | **1.000** | **1.000** | **1.000** | **1.000** | **1.000** |
| Food | 0.442 | 0.514 | 0.497 | 0.485 | 0.456 | 0.397 |
| Clothing | 0.058 | 0.057 | 0.057 | 0.057 | 0.058 | 0.060 |
| Residence | 0.148 | 0.133 | 0.131 | 0.134 | 0.141 | 0.163 |
| Household Appliances and Services | 0.045 | 0.038 | 0.040 | 0.041 | 0.044 | 0.049 |
| Transport and Telecommunications | 0.100 | 0.072 | 0.080 | 0.087 | 0.096 | 0.116 |
| Education, Cultural and Recreation and Services | 0.118 | 0.101 | 0.109 | 0.112 | 0.119 | 0.125 |
| Health Care and Medical Services | 0.066 | 0.069 | 0.067 | 0.064 | 0.064 | 0.066 |
| Other Goods and Services | 0.022 | 0.017 | 0.019 | 0.020 | 0.022 | 0.024 |

*Quintiles are population quintiles*

## A3. Imputation of consumption PPPs for non-benchmark countries

We estimated private household consumption P3s and P4s for the 62 countries for which both household consumption and ICP data were available to us. The World Bank global poverty estimates are calculated for 109 countries (60 of our 62 countries, and 69 additional ones). In order to generate global poverty estimates that can be compared with the World Bank's estimates, we imputed P3s for the 69 countries for which no P4s were calculated (as shown in our calculations, P3s and P4s are very close to each other; we therefore estimated P3s and used them in our poverty estimates). These 69 countries include countries that participated in the 2005 ICP round but for which we did not obtain household survey data, and other countries that did not participate in the 2005 ICP round. The 69 countries represent 17 percent of the total population over all 109 countries, but account for a much smaller share of the global poor (4.5 percent, based on the World Bank's estimates at the $1.25 poverty line).

The ICP 2005 itself generated P3 estimates for countries that did not participate in the ICP, using a regression model presented in the ICP Final Report. A search for a better regression model had been undertaken by Changqing Sun and Eric Swanson after publication of the ICP Final Report. This alternative model was found to yield better estimates. We used this model, adapted to take India as reference country. The model description presented below is adapted from Sun and Swanson (2009).

The model works with the price level index (*PLI*), defined as the ratio of a PPP for consumption to the corresponding market exchange rate. The regressions take the form

$$\ln(PLI_i / PLI_0) = a + b(X_i - X_0) + e_i \qquad \text{(A.15)}$$

where India, country 0, is the base. The explanatory variables include GDP per capita in US$ at market prices, the age dependency ratio, dummy variables for Sub-Saharan African economies, island economies, and landlocked developing economies, as well as the interaction terms of GDP per capita and dummy variables. All continuous variables are expressed in natural log. Data came from the ICP 2005 and WDI databases, supplemented by other official data sources in a small number of cases.

We ran the regression model for each one of our P3 calculation methods (CPD, Fisher, Tornqvist), and for both the 102 and 105 basic headings options; the results were then used to calculate the poverty rates and other statistics in the tables in the main text. The results are presented in the following table for the Fisher, 102 BH option.

**Summary results of the regression model used for estimating Fisher PLI at private household consumption level (102 basic headings)**

| Number of observations | 113 | |
|---|---|---|
| **Dependent variable** | **Coefficient** | **Std Error** |
| Log GDP per capita (US$) | 0.268 | 0.017 |
| Age dependency ratio (log) | 0.409 | 0.111 |
| Log GDP per capita (US$)*island economy dummy | -0.046 | 0.035 |
| Log GDP per capita (US$)*Sub-Saharan Africa dummy | -0.082 | 0.028 |
| Log GDP per capita (US$)*landlocked developing economy dummy | -0.009 | 0.006 |
| Sub-Saharan Africa dummy | 0.928 | 0.187 |
| Island economy dummy | 0.516 | 0.294 |
| **Regression summary** | **$R^2$ : 0.885** | **RMSE : 0.174** |

## A4. List of household surveys used in PPPP calculations

### East Asia and Pacific

| | |
|---|---|
| Cambodia | *Household Socio-economic Survey*, 2003, National Institute of Statistics (NIS) |
| China | *Synthetic data file, generated based on aggregated data obtained from the Survey of Urban Households and the Survey of Rural Households,* 2005, National Bureau of Statistics |
| Fiji | *Household Income and Expenditure Survey*, 2002, Fiji Islands Bureau of Statistics (FIBos) |
| Indonesia | *National Social Economics Survey* (SUSENAS), 2002, Statistics-Indonesia (BPS) |
| Lao, PDR | *Lao Expenditure and Consumption Survey*, 2003, National Statistics Centre (NSC) |
| Malaysia | *Household Expenditure Survey*, 2004, Department of Statistics Malaysia |
| Mongolia | *Household Income and Expenditure Survey*, 2005, National Statistics Office (NSO) |
| Philippines | *Family Income and Expenditure Survey*, 2003, National Statistics Office (NSO) |
| Thailand | *Household Socio-economic Survey*, 2002, National Statistics Office (NSO) |
| Vietnam | *Vietnam Household Living Standard Survey* (VHLSS), 2004, General Statistics Office (GSO) |

### South Asia

| | |
|---|---|
| Bangladesh | *Household Income and Expenditure Survey*, 2000, Bangladesh Bureau of Statistics (BBS) |
| Bhutan | *Bhutan Living Standards Survey*, 2003, Central Statistical Organization (CSO) (now the National Statistics Bureau) |
| India | *National Sample Survey, 61th Round of the Socio-economic Survey*, 2005, National Sample Survey Organization (NSSO) |
| Maldives | *Vulnerability and Poverty Assessment Survey*, 2004, Ministry of Planning and National Development |
| Nepal | *Nepal Living Standards Survey*, 2003, Central Bureau of Statistics (CBS) |
| Pakistan | *Pakistan Integrated Household Survey*, 2001, Federal Bureau of Statistics (FBS) |
| Sri Lanka | *Household Income and Expenditure Survey*, 2002, Department of Census and Statistics (DCS) |

## Latin America

| | |
|---|---|
| Argentina | *Encuesta Nacional de Gastos de los Hogares*, 1996, Instituto Nacional de Estadística y Censos, Dirección de Estudios de Ingresos y Gastos de los Hogares |
| Bolivia | *Encuesta Continua de Hogares* (Encuestas y Medición sobre Condiciones de Vida (MECOVI)), 2002, Instituto Nacional de Estadistica (INE) |
| Brazil | *Pesquisa de Orçamentos Familiares*, 2002, Instituto Brasileiro de Geografia e Estatística (IBGE) |
| Colombia | *Encuesta Nacional de Calidad de Vida*, 2003, Departamento Administrativo Nacional de Estadística (DANE) |
| Paraguay | *Encuesta Integrada de Hogares*, 2000, Direción General de Estadísticas, Encuestas y Censos (DGEEC) |
| Peru | *Encuesta Nacional de Hogares*, 2003, Instituto Nacional de Estadística e Informática (INEI) |

## Europe and Central Asia

| | |
|---|---|
| Armenia | *Integrated Living Standards Survey*, 2004, National Statistical Service |
| Azerbaijan | *Household Budget Survey*, 2001, State Statistics Committee |
| Kazakhstan | *Household Budget Survey*, 2003, Statistical Agency |
| Kyrgyz Republic | *Household Budget Survey*, 2003, National Statistical Committee |
| Tajikistan | *Living Standards Measurement Survey*, 2003, State Statistical Agency |

## Sub Saharan Africa

| | |
|---|---|
| Benin | *Questionnaire des Indicateurs de Base du Bien-être*, 2003, Institut National de la Statistique et de l'Analyse Economique (INSAE) |
| Burkina Faso | *Enquête Burkinabé sur les Conditions de Vie des Ménages*, 2003, Institut National de la Statistique et de la Démographie (INSD) |
| Burundi | *Enquête Prioritaire* - *Etude Nationale sur les Conditions de Vie des Populations*, 1998, Institut de Statistiques et d'Etudes Economiques du Burundi (ISTEEBU) |
| Cameroon | *Enquête Camerounaise auprès des Ménages II*, 2001, Direction de la Statistique et de la Comptabilité Nationale (DSCN) |
| Cape Verde | *Inquérito ás Despesas e Receitas Familiares*, 2001, Instituto Nacional de Estatística (INE) |
| Chad | *Enquête sur la Consommation et le Secteur Informel au Tchad*, 2003, Institut National de la Statistique, des Etudes Economiques et Démographiques (INSEED) |
| Congo, DR | *Enquête 1-2-3 sur l'emploi, le secteur informel et les conditions de vie des Ménages*, 2005, Institut National de la Statistique (INS) |
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| Côte d'Ivoire | *Enquête Niveau de Vie des Ménages*, 2002, Institut National de la Statistique (INS) |
| Ethiopia | *Welfare Monitoring Survey and Household Income and Expenditure Survey*, 2000, Central Statistical Agency (CSA) |
| Gabon | *Enquête Gabonaise pour l'Evaluation et le Suivi de la Pauvreté*, 2005, Direction Générale de la Statistique et des Etudes Economiques (DGSEE) |
| Gambia (The) | *Integrated Household Survey*, 2003, Central Statistics Department (CSD) |
| Ghana | *Ghana Living Standards Survey*, 2006, Ghana Statistical Service (GSS) |
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| Kenya | *Kenya Integrated Household Budget Survey*, 2005, Kenya National Bureau of Statistics (KNBS) |
| Lesotho | *Household Budget Survey*, 2002, Bureau of Statistics of Lesotho (BoS) |
| Madagascar | *Enquête Permanente auprès des Ménages*, 2001, Direction des Statistiques des Ménages (DSM), Institut National de la Statistique (INSTAT) |
| Malawi | *Integrated Household Survey*, 2004, National Statistical Office (NSO) |
| Mali | *Enquête Malienne sur l'Evaluation de la Pauvreté*, 2006, Direction Nationale de la Statistique et de l'Informatique (DNSI) |
| Mauritania | *Enquête Permanente sur les Conditions de Vie des Ménages*, 2004, Institut National des Statistiques (INS) |
| Mozambique | *Inquérito aos Agregados Familiares sobre Orçamento Familiar*, 2002, Instituto Nacional de Estatística (INE) |

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| Rwanda | *Enquête Intégrale sur les Conditions de Vie des Ménages*, 2005, Direction de la Statistique |
| Senegal | *Enquête Sénégalaise auprès des Ménages*, 2001, Direction de la Prévision et de la Statistique (DPS) |
| Sierra Leone | *Sierra Leone Integrated Household Survey*, 2003, Statistics Sierra Leone (SSL) |
| South Africa | *Household Income and Expenditure Survey*, 2000, Statistics South Africa (Stats SA) |
| Swaziland | *Household Income and Expenditure Survey*, 2000, Central Statistical Office (CSO) |
| Tanzania | *Household Budget Survey*, 2000, National Bureau of Statistics (NBS) |
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