How Should We Measure Global Poverty in a Changing World?

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Abstract

Before effective anti-poverty policy can be designed and implemented, the extent, trend and distribution of poverty must be identified – in this sense, poverty measurement is a crucial intermediate step in public policy making and development planning. This paper asks whether the estimated proportion of the world's population with income below US $1 (adjusted according to purchasing power parity) per day is a good measure of trends in global poverty. We argue that the answer depends on three important issues in the measurement of poverty – the definition of the poverty line, how best to summarize the level of poverty and how to infer statistical estimates of poverty from sample data. In this paper, we survey the literature on poverty measurement and demonstrate the importance of considering both the poverty rate and average poverty gap ratio and the usefulness of the "poverty box" concept for simple communication. We extend our empirical work to China using the commonly accepted international poverty line definition of one half median equivalent income and we touch briefly upon statistical inference and compare the bootstrap method and the asymptotic theory based on the U-statistics.

1. Introduction

According to the UN Millennium Project,[1] the two targets of the first millennium development goal to eradicate extreme poverty and hunger" is to (1) "halve, between 1990 and 2015, the proportion of people whose income is less than one dollar a day" and (2) "halve, between 1990 and 2015, the proportion of people who suffer from hunger." The primary indicator for the former is the proportion of population below US $1 (adjusted according to purchasing power parity[2]) per day.[3] By this criterion, progress has been made. According to the United Nations (UN) Industrial Development Report (2004), the proportion of the world population who are poor has dropped from 40% in 1981 to 21% in 2001. However, the question that this paper asks is: is this a good indicator of global anti-poverty progress?

When the poverty line is set as the purchasing power parity (PPP) adjusted US $1 per day or US $ 365 per year, the proportion of population with consumption below that level is called the poverty rate or head-count ratio. As a measure of poverty, this has the enormous advantage of simplicity. The poverty line – one US dollar per day – seems immediately understandable as an indicator of absolute deprivation. The calculation of the percentage of people who are poor is similarly direct. This measure can therefore easily be used in public debates – even though it implicitly embodies the assumption that the degree of deprivation of the poor is not important.

A second possible simple indicator of poverty is the poverty gap ratio (also called the average poverty gap of the population[4] or the poverty gap index[5]), which is the mean distance of the income shortfalls below the poverty line as a proportion of the poverty line for the entire population.[6] The poverty rate and the average poverty gap ratio[7] are the

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[1] See http://millenniumindicators.un.org/unsd/mi/mi_goals.asp.
[2] Aten and Heston (2004) note that since the consumption of the poor is more heavily weighted to food than the consumption of the population as a whole, and since food is relatively highly priced in poor countries, the PPP adjustment appropriate for comparisons of GDP per capita is inappropriate for comparisons of absolute poverty – they argue that a more appropriate poverty line PPP would increase substantially the global poverty rate. However, in this paper we cannot directly address this issue.
[3] Chen and Ravallion (2001, p.285) note that initially the $1per day standard was set in 1985 prices, but they use $1.08 in 1993 prices.
[4] See Xu and Osberg (2002, p.140).
[5] See Lipton and Ravallion (1995, p. 2579).
[6] See Chen and Ravallion (2001, note for Table 3). Note that Raj (1998, p. 255) defines the poverty gap ratio differently as the average income shortfall below the poverty line as the proportion of the population mean income for the population giving the nonpoor zero income shortfalls.
[7] Two closely related ideas are the average poverty gap ratio of the population (or the poverty gap ratio – where the deprivation of the non-poor is taken to be zero) and the average poverty gap ratio of the poor (or the income gap ratio), which is defined as the average income shortfall below the poverty line as the

two most used poverty measures in many countries and international organizations - largely because they can be easily understood and, as a consequence, *actually used* in the broader public debate.

Of course, both the poverty rate and poverty gap concepts presuppose that one can identify the poverty line. Determining this threshold can be based on either the absolute or relative sense of poverty. In practice, poverty research in affluent nations typically uses an explicitly relative definition of the poverty line[8] (often defined as a fraction – usually 50% - of median income) while an absolute poverty line (such as $1 US per day) has been more common in research on poor countries. However, some poor countries are very rapidly becoming more affluent, on average. Although many researchers would agree that absolute deprivation is the important issue in countries with very low per capita incomes, this division of focus has become harder to justify in recent years, as rapid economic growth in China (and some other countries) raises the average incomes of a large fraction of the world's population. One issue this paper addresses is the extent of poverty in China, if a relative poverty line approach is used.

Sen (1985) has also noted that there is the broader question of whether a poverty line income threshold can be representative of other dimensions of capacities. As well, at the operational level, researchers need to decide which measurement units to use. The recipient unit – individuals or households – must be defined and identified, as is culturally appropriate. Researchers must also decide whether *income* or *consumption* is the most appropriate concept to use in assessing *command over resources* and how exactly each concept can be best approximated, in the real world of statistical practice. But given these research decisions, poverty still has to be summarized by some index - as an example of current practice, one can cite Chen and Ravallion (2001), who use the head-count ratio and poverty gap ratio based on the international absolute consumption poverty lines (the 1993 PPP adjusted $1.08 and $2.15 respectively).

As pointed out by Zheng (1997) many poverty measures have been proposed in the literature primarily based on the axiomatic approach advocated by Sen (1976). However, not that many of them are actually used in practice. In a survey article of the

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proportion of the poverty line for the poor [Lipton and Ravallion (1995, p. 2579) and Raj (1998, p. 255).] It is also called the average poverty gap ratio of the poor to distinguish it from the average poverty gap ratio of the population [Xu and Osberg (2002, p.140)]. Clearly, the average poverty gap ratio of the population equals the product of the average poverty gap ratio of the poor and poverty rate.

[8] Even when the rhetoric of an "absolute" poverty line is used, the redefinition over time of a "subsistence" consumption bundle in developed economies often means that the poverty line is implicitly, if periodically, drawn relative to prevailing norms of consumption [see Fisher (1995) and Osberg (2000)].

Handbook of Development Economics by Lipton and Ravallion (1995), the more communicable poverty measures such as the head-count ratio, poverty gap ratio, income gap ratio, and Foster-Greer-Thorbecke (FGT) index are explicitly discussed. Similarly, those are also introduced in well-received development economics textbooks such as Ray (1998) and Todaro and Smith (2003). More complex poverty measures such as Watts (1968) and Sen (1976), which consider the distribution of the poor and hence are distribution-sensitive, are only touched upon briefly. While the former is simple in presentation, the latter appears more complex than the prevailing poverty measures in practice. Complex poverty measures, although perhaps desirable from a theoretical perspective, are more difficult to calculate and harder to communicate. These challenges offset the shortcomings of those prevailing simpler poverty measures, in particular in their insensitivity towards distribution among the poor – which is considered important by Sen (1976), Foster, Greer, and Thorbecke (1984), Shorrocks (1995), Lipton and Ravallion (1995), among others.

In the developed countries, where the poverty rate is relatively low (typically considerably less than 20%), inequality among the poor is small and fairly constant over time [see Osberg and Xu (2001)]. Hence Osberg (2000) and Xu and Osberg (2001) advocate the "poverty box" approach, which combines the head-count ratio and the average poverty gap ratio of the poor into a two-dimension space, as a way of simplifying communication and facilitating comparative studies.[9]

A second issue this paper addresses is whether the same should be done in developing countries, where the poverty rate is much higher. Based on international data in 1987 and 1998, Chen and Ravallion (2001) note that the poverty rate based on the 1993 PPP US$ 1.08 (or 1993 PPP US$2.15) poverty line, poverty rate is higher than 40% (70%) in South Asian and Sub-Saharan Africa. In this very different context, what are useful and desirable poverty measures in studying poverty within a nation or across countries? Can these measures be made simple to compute and easy for communication?

Finally, since all poverty statistics are estimates from samples surveyed from the population, sampling variability of these estimates are a perennial concern. Particularly in

[9] Fields (1977, p. 576 or 1980, p. 26 and p. 212) study of Brazil's poverty, includes a figure in which the poverty rate and average poverty gap in local currency are shown in a coordinate system – but for international comparison one needs to use the poverty gap ratio.

a context such as China, where estimates of poverty outcomes for absolutely large numbers of people may depend on quite small numbers of raw observations, it may be important to ask – what are the statistical properties of poverty estimators?

Section 2 of the paper reviews the literature on what we have learned from affluent nations about the set of useful poverty measures. Section 3 provides some empirical evidence from China and Section 4 examines related statistical issues. Section 5 concludes.

2. What Have We Learned about Poverty Measurement?

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The most common measure of poverty is to calculate the proportion of the population whose incomes are below a designated poverty line. If we use *N* for the size of a population and *Q* for the number of the poor, then the *poverty rate* is given by

$$H = \frac{Q}{N}. \tag{2.1}$$

This "head count" measure presupposes the definition of recipient unit (individual or family or household) and income concept, and the specification of a poverty line (*z*), below which income of individual *i* (y_i) is unacceptably low. When these issues are more or less settled, another issue becomes apparent: the poverty rate cannot show the depth of poverty - in two countries (or the same country at two different points in time). With identical poverty rates, the two poor subpopulations may have very different average income levels. More disturbingly, if the poverty rate is as the main measure of the effectiveness of anti-poverty policy, policy makers may be tempted by "cream-skimming", because the most cost effective way to reduce poverty is to give a small transfer to the richest of the poor so that his or her income is lifted just above the poverty line.

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Concern with the depth of poverty motivates two closely related measures – the average poverty gap ratio of the poor and that of the total population. The former is denoted by

$$I = \frac{1}{Q}\sum_{y_i < z}\left(\frac{z - y_i}{z}\right) \tag{2.2}$$

and the latter

$$H I = \frac{Q}{N}\frac{1}{Q}\sum_{y_i < z}\left(\frac{z - y_i}{z}\right) = \frac{1}{N}\sum_{y_i < z}\left(\frac{z - y_i}{z}\right), \tag{2.3}$$

where the poverty gap ratio is set to zero for the nonpoor population because they have zero deprivations in income.

Although these measures illustrate the average depth of the poverty of the poor or the population, they cannot reveal whether their deprivations are substantially unequal. Further, the average poverty gap ratios are not sensitive to whether poverty alleviation targets the poorest of the poor and those who are only marginally poor.

In 1976 Amartya Sen proposed a set of fundamental axioms for poverty measurement. Similar to the debate in measuring inequality, where the Pigou-Dalton transfer principle becomes a guidepost for inequality measurement [see Dalton (1920) for the original work and Xu (2003) for an intuitive explanation], Sen's (1976) axioms, refined further later [see Shorrocks (1995) and Chakravarty (1997)]], formed the foundation for subsequent poverty measures. One of the key points made by Sen is that all the existing poverty measures at that time are insensitive to the distribution aspect of poverty.

Seven well-known axioms for evaluating poverty measures are:[10]

(1) Focus axiom (F): the poverty measure should be independent of the nonpoor population.
(2) Weak monotonicity axiom (WM): a reduction in a poor person's income, holding other incomes constant, must increase the value of the poverty measure.
(3) Impartiality axiom (I): A poverty measure should be insensitive to the order of incomes.
(4) Weak transfer axiom (WT): An increase in a poverty measure should occur if the poorer of the two individuals involved in an upward transfer of income is poor and if the set of poor people does not change.
(5) Strong upward transfer axiom (SUT): An increase in a poverty measure should occur if the poorer of the two individuals involved in an upward transfer of income is poor.
(6) Continuity axiom (C): The poverty measure must vary continuously with incomes.
(7) Replication invariance axiom (RI): The value of a poverty measure does not change if it is computed based on an income distribution that is generated by the k-fold replication of an original income distribution.

For some observers, these axioms are pre-conditions to judge the reasonableness of a poverty measure. Of course, as shown later, some axioms impose stronger conditions than other axioms do (WT versus SUT or with or without C).

The poverty rate H satisfies Focus, Independence, and Replication axioms but it violates the Weak Monotonicity axiom, and both the Weak and Strong Transfer axioms -

[10] See Hagenaars (1986, 1991) or Xu and Osberg (2001) in Chinese; the English version is available at http://is.dal.ca/~econhome/RePEc/dal/wparch/sensw.pdf.

which is why many economists find it unacceptable. In other words, the poverty rate captures the incidence of poverty but is insensitive to the depth of poverty. The average poverty gap ratio of the poor *I* satisfies Focus, Weak Monotonicity, and Independence axioms but neither Weak or Strong Transfer axiom - which means that *I* captures the depth of poverty but is insensitive to the distribution aspect of poverty. These observations prompted Sen (1976) to propose two version of the same poverty measure. The first is

$$S_0 = H\left[I + (1-I)\,G(y_p)\left(\frac{Q}{1+Q}\right)\right], \tag{2.4}$$

where $G(y_p)$ is the Gini index of the distribution of the poor. As the population size gets larger, $\frac{Q}{1+Q} \rightarrow 1$. Thus another version is given by

$$S = H\left[I + (1-I)\,G(y_p)\right] \tag{2.5}$$

These two versions of the Sen indices will satisfy the other axioms but not the Strong Upward Transfers and Continuity axioms. S_0 does not satisfy the Replication Invariance axiom while *S* does. Clark et al. (1981) applied equation (2.5) in their empirical study.

Immediately after Sen's work many economists proposed a wide range of poverty measures [see Zheng (1997) and Xu and Osberg (2002) and references therein]. Among those, Shorrocks (1995) proposed a modified Sen index which is identical to the limiting case of the Thon index (1979, 1983), and can be called the Sen-Shorrocks-Thon (SST) index of poverty, which is defined as

$$S_{SST} = \frac{1}{N^2}\sum_{y_i<z}(2N-2i+1)\left(\frac{z-y_i}{z}\right). \tag{2.6}$$

Note that the poverty gap ratio for the nonpoor $\left(\frac{z-y_i}{z}\right)$ is set to zero. The application of this poverty index can be found in Xu (1998).

Foster, Greer and Thorbecke (1984) proposed a class of decomposable poverty indices (the FGT indices) of the form:

$$FGT_\alpha(y;z) = \frac{1}{N}\sum_{y_i<z}\left(\frac{z-y_i}{z}\right)^{\alpha}, \tag{2.7}$$

where *y* represents the income distribution and y_i represents the income of individual *i*. within this family of indices, the FGT index with some values of α ($\alpha = 0$,) may not satisfy all of the above axioms. However, higher order FGT indices (i.e. α > 1) do satisfy axioms WM, WT, and SUT. As can be seen below, the FGT indices include those that are criticized by Sen (1976).

When $\alpha = 0$

$$FGT_0(y;z) = \frac{1}{N}\sum_{y_i<z}\left(\frac{z-y_i}{z}\right)^0 = \frac{Q}{N} = H \qquad (2.8)$$

The FGT index of order 0 is the poverty rate. When $\alpha = 1$

$$FGT_1(y;z) = \frac{1}{N}\sum_{y_i<z}\left(\frac{z-y_i}{z}\right) = H \cdot I \qquad (2.9)$$

The FGT index of order 1 is the average poverty gap ratio of the population, which equals the product of the poverty rate and the average poverty gap ratio of the poor. FGT indices of an order higher than 1 are distribution-sensitive. For example, when $\alpha = 2$

$$FGT_2(y;z) = \frac{1}{N}\sum_{y_i<z}\left(\frac{z-y_i}{z}\right)^2. \qquad (2.10)$$

In this formulation, when α > 1, a larger poverty gap ratio $\left(\frac{z-y_i}{z}\right) > 0$ receives more than proportionately higher weight in the FGT index. Schady (2002) is an example where the FGT index of order 2 is used. However, as Osberg (2004) has noted, researchers often face the question as to what value should be assigned to α. In the FGT family of indices it appears that over the range α = 2, 3, …, 6 index values tend to be clustered and there is not much additional gain of information.

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It is somewhat surprising to see that the FGT indices are applied more widely in empirical poverty studies than the Sen indices, S_0, S, and S_{SS}, although the latter were proposed earlier and have been improved upon over time [see Osberg (2004)]. Fields (1980, p.170) noted the Sen indices require a lot more information and that it is sometimes impossible to compute *S* because of the unavailability of data on income inequality. Although the FGT index of order α < 2 does not satisfy many of the important axioms, the FGT indices are considered simpler by many analysts. Osberg and Xu (1999, 2001), Osberg (2000), Xu and Osberg (2001, 2002) argue that the Sen indices are not as simple to the policy analysts, but should and can be substantially simplified. Indeed, as soon as these simplifications become known, the Sen indices, in particular the SST index, become a powerful tool in policy analysis as shown by Myles and Picot (2000).

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In particular, we have argued[11] that the Sen index S and the SST index S_{SST} [given in equations (2.5) and (2.6) respectively] should, and can, be simplified into their multiplicative components - the poverty rate, average poverty gap ratio of the poor, and a measure that is related to the Gini index of poverty gap ratios of the poor (for the Sen index) or of the population (for the SST index).

Formally, let x_p represents the poverty gap ratios $\left(\frac{z-y_i}{z}\right)$ for the poor and x those of the population. The Sen index given in equation (2.5) can be written as

$$S = H\,[1+G(x_p)] \qquad (2.11)$$

Note that in order to compute $G(x_p)$, one can use the regular Gini index formula[12] with poverty gap ratios sorted in non-decreasing order [see Xu and Osberg (2002, p. 143)]. The higher value of $1+G(x_p)$, the higher the inequality the poor has. If the poor are equally poor, then $G(x_p) = 0$ and $1+G(x_p) = 1$. A more transparent expression of the above is

The Sen Index = [the poverty rate] $\times$ [the average poverty gap ratio of the poor]
$\times$ [the inequality of poverty gap ratios of the poor].

The interpretation of the above is straightforward. Poverty is high when the incidence of poverty is high (a higher poverty rate), or when the depth of poverty is increasing (a higher average poverty gap ratio), and or when the poverty gap ratios of the poor are more unequal [a higher $1+G(x_p)$]. As is clear in the above expression, when poverty gap ratios of the poor are identical, then the Sen index becomes:

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[11] See Osberg and Xu (1999, 2001), Osberg (2000), Xu and Osberg (2001, 2002).

[12] For a data set $\{y_1, y_2, \ldots, y_N\}$, the Gini index or coefficient is given by

$G(y) = 1 + \frac{1}{N} - \frac{2}{N^2 \bar{y}} \sum_{i=1}^{N} (N - i + 1) y_i$, when $\{y_1, y_2, \ldots, y_N\}$ are sorted in non-decreasing order.

Alternatively, $G(y) = \frac{\sum_{i=1}^{N}\sum_{j=1}^{N} |y_i - y_j|}{2N^2 \bar{y}}$, where $\{y_1, y_2, \ldots, y_N\}$ do not have to be sorted. Note that $\bar{y}$ is the mean of $\{y_1, y_2, \ldots, y_N\}$. See Xu (2003) for more details.

The Sen Index = [the poverty rate] $\times$ [the average poverty gap ratio of the poor]

because the poor are approximately equally deprived, $G(x_p) = 0$, so $1 + G(x_p) = 1$. The Sen Index thus collapses to the FGT index, with α = 1. Another interesting observation is that when the inequality of poverty gap ratios is a constant over time at the level *K*, the major sources of changes in poverty can be represented by the poverty rate and the average poverty gap ratio of the poor alone. Hence, when either when the poor are equally deprived or the inequality of poverty is constant, the combination of two simple concepts – the *rate* and *average depth* of poverty - leads to a powerful illustrative tool called the “poverty box”.

The “poverty box” is, in fact, related to the poverty profile [originally due to Jenkins and Lambert (1997)], which we show in Figure 1. In this coordinate system, the poverty profile draws the curve of cumulative percentage of poverty gap ratios, for the total population, from the highest to the lowest (zero ratio for the nonpoor) corresponding to the percentage of the population. The poverty profile curve rises from the origin (at point 0) at a faster rate, increases at a decreasing rate, reaches the plateau (at point a) when the last and least poor individual’s poverty gap ratio is added, and then becomes flat to the end (at point HI) when zero poverty gap ratios of the nonpoor are add to the cumulative percentage. When the inequality of poverty gap ratios is nil, the curved segment of the poverty profile becomes a straight 45-degree line.

As shown in Figure 2, the geometric interpretation of the Sen index with reference to the poverty profile curve according to Xu and Osberg (2002), is as shown in the upper-right panel. Let the triangle area of OHH’ be Area E. The Sen index is given by the sum of Areas C and D divided by Area E. Hence the Sen index will take the curvature (in relation to Area C) into account. In the lower-left panel of Figure 2, the poverty box is drawn in relation to the poverty profile. In the event that there is no curvature in the poverty profile curve or when the curved segment varies little in a relative sense, the poverty box can convey information on poverty intensity.

Figure 1 Geometry of the Poverty Profile

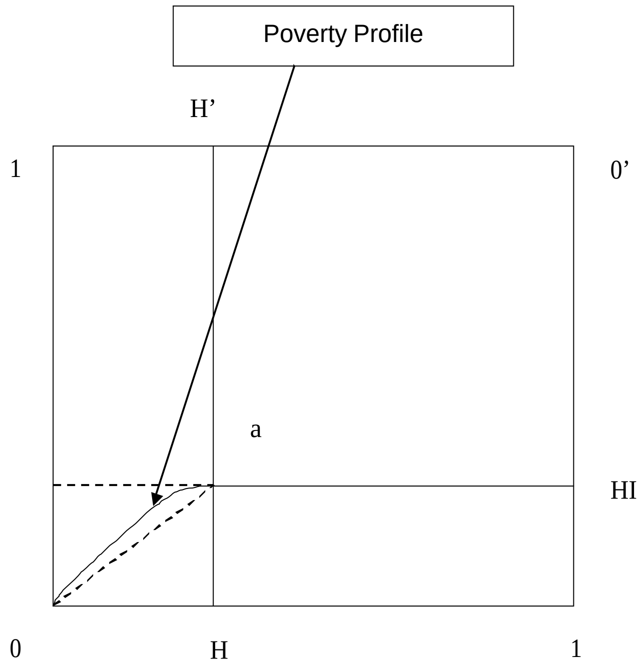
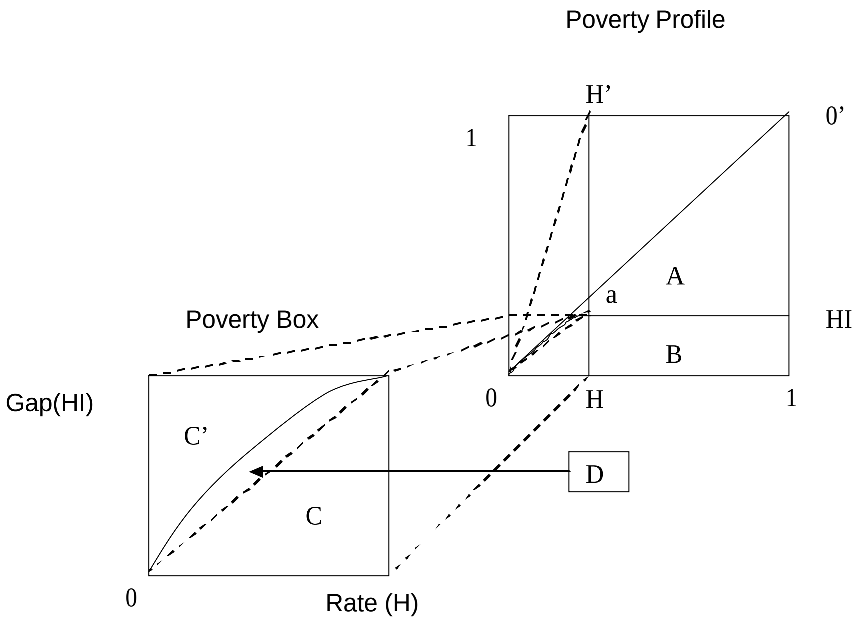


Figure 2 Geometry of the Sen index and Poverty Box



As shown in Osberg and Xu (1999, 2000), the SST index [equation (2.6)] proposed by Shorrocks (1995) following Sen (1976), can be simplified into

$$S_{SST} = H\, I\, (1 + G(x)) \qquad (2.12)$$

where *x* represents the poverty gap ratios of the total population. A less mathematical expression of the above is

The SST Index = [the poverty rate] $\times$ [the average poverty gap ratio of the poor] $\times$ [the inequality of poverty gap ratios of the population].

Note that unlike $G(x_p)$ which can take value zero when all the poor are equally poor – i.e. have the same poverty gap ratio, $G(x)$ cannot be zero simply because even if the poor are equally poor the nonpoor have zero poverty gap ratios. As shown in Xu and Osberg (2002, p. 145, equation 24), $G(x) = 1 - H$ when the poor have an identical poverty gap ratio. For example, if the poverty rate is 15% and the poor are equally poor, the Gini index of poverty gap ratios of the population will be 1-0.15 = 0.85. The inequality component in the SST index will then be $1 + G(x) = 1 + 0.85 = 1.85$. Any inequality in poverty gap ratios among the poor will add to [1 + $G(x)$] but with an upper bound value 2 – so there is a fairly narrow possible range, particularly if the poverty rate is relatively low.

The "common sense" explanation for the small role that inequality among the poor plays in an aggregate measure of poverty intensity is that the differences in income among the poor are relatively small when compared to income differences among the nonpoor. The upper bound on the incomes of poor people is the poverty line. The lower bound, leaving aside measurement error aside, is subsistence. The dollar value of the difference is not large, particularly when compared to the dollar differences among the non-poor population.

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When the inequality of poverty gap ratios of the population changes little over time and across countries/regions/social groups, the value of the SST index is in proportion to ($\propto$) the product of the poverty rate and the average poverty gap ratio of the poor; that is

The SST Index $\propto$ [the poverty rate] $\times$ [the average poverty gap ratio of the poor].

The geometric interpretation of the SST index, according to Xu and Osberg (2002) is as follows. Let the lower triangle of the poverty profile box in the upper-right panel of Figure 2 surrounded by O, O', HI, 1, and H be Area A, which is the half of the unit box. The Sen index is the ratio of the sum of Areas B, C, and D to Area A. Hence, the poverty box is directly connected to the poverty profile.

For both Sen and SST indices[13], it appears that the inequality of the poor in developed countries is fairly constant, and thus plays little role in comparisons – either internationally or over time [Osberg and Xu (2000)].). Hence a two-dimensional poverty box can present poverty reasonably accurately and can be used for across country/region/social group comparisons. The "poverty box" is formed by the poverty rate *H* and the average poverty gap ratio of the poor *I* [see Xu and Osberg (2001) and Osberg (2004)].

What does the "poverty box" add to the debate? Figure 3, which is taken from Osberg (2004) illustrates its potential usefulness for comparisons of poverty in the United Kingdom over time, since the average poverty gap ratio and the poverty rate moved in different directions. An assessment of poverty policy in the UK which looked only at the poverty *rate* would score the 1979 to 1986 period as a success, since the poverty rate fell (from 9 % to 8.4 %), but would miss completely the significant increase in the average poverty gap of the poor (which rose from 21.8 % of the poverty line to 27.8 %). This divergence between trends in the poverty rate and average poverty gap ratio is not uncommon in developed nations [see Osberg (2002, p.18)]], but is crucial for the assessment of poverty policy "success". However, although the "poverty box" idea replaces a misleadingly simple focus (on the poverty rate alone) with a slightly more complex picture (that trends in both the poverty rate and average poverty gap should be considered), it is based on a generalization (that inequality among the poor varies so little that it can safely be ignored – at least for comparative purposes). The question for

[13] The Sen and SST indices are closely related. According to Xu and Osberg (2002),

$$S_{SST} = HS + 2H(1-H)I$$

That is, given H and I, it is always possible to compute S_{SST} from S and vice versa. For example, if we know S_{SST}, H, and I based on the data, we can compute S using

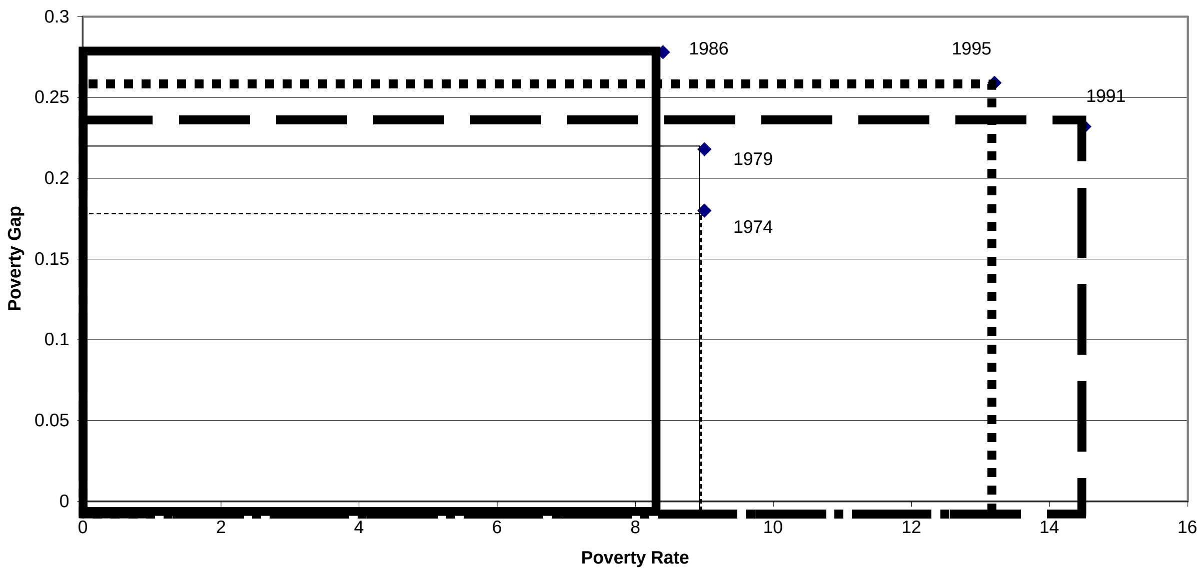
$$S = \frac{S_{SST} - 2H(1-H)I}{H} = \frac{S_{SST}}{H} - 2(1-H)I$$

this paper is whether or not similar assumptions should be made in the context of developing countries – and to assess this issue we turn to evidence from China.

Figure 3 The Poverty Box for the United Kingdom in 1974, 79, 86, 91, and 95

Poverty Line = ½ Median Equivalent Disposable Income

Source: Osberg (2004).



3. How Should We Measure Poverty Trends in China?

In assessing the level and trend of global poverty, a crucial variable stands out in importance – the rate of growth of the Chinese economy. With 1.29 billion citizens, roughly 20% of the world's population, China dominates global poverty trends – and in recent years, the Chinese economy has been growing strongly.[14] In 1980, GDP per capita in China was $708, (PPP, constant 1995 international $[15]), but by 2003 that had risen six-fold to $4,344. [To put this in context, the comparable per capita PPP GDP of Portugal was at $7,499 in 1975.] Over the 1995-2003 period, the average annual growth rate of per capita GDP was 7.55 %. Extrapolation of these recent trends would imply that in twenty years, in 2023, per capita GDP in China would be about $20,000 in PPP terms, and in thirty years, it would be approximately $42,000– which would be well in excess of the GDP per capita (PPP, constant 1995 international $) of Canada ($23,842) or the USA ($32,482) in 2003.

At current exchange rates, the US dollar value of China's per capita GDP is far lower – at $1,024 in 2003 – and one conclusion of this paper will be that the uncertainties of PPP calculations can heavily affect calculations of the extent of absolute global poverty. As well, it should be obvious that simple extrapolation – for twenty or thirty years – of the trends of the recent past is not a serious forecast. Nevertheless, the point of these calculations is to indicate that China is moving rapidly from the group of nations in which absolute poverty is the key issue to the group of countries in which a relative poverty line is usually used.

At some point, it will therefore become appropriate to calculate the rate and depth of poverty in China using the same methodology as is now commonly used in affluent OECD nations. The usual methodology for international comparisons of poverty among affluent nations is to use micro-data on the incomes of individual households (from a data set such as the Luxembourg Income Study) in order to compute the equivalent income of individuals and to draw the poverty line relative to median equivalent income –most commonly at 50% of median individual equivalent income. Typically, household income is measured assuming that all individuals within households share equally in household resources, and have no claim on

[14] India's 1.06 billion inhabitants (and faster rate of population growth), and lower level of average income (in 2003, GDP per capita of $2529 – PPP, constant 1995 international $) mean that India's growth rate is also crucial to global poverty trends – between 1995 and 2003, growth in GDP per capita in India averaged 4.3 %, with strong acceleration in most recent years (8% GDP growth in 2003).

[15] Unless otherwise noted, all aggregate data in this section are PPP constant 1995 $, drawn from the World Bank web site - http://devdata.worldbank.org/dataonline/

the resources of other households.[16] The LIS definition of total family money income after tax (disposable income)[17] is often used as the basis for calculation of the after tax money income "equivalent income" of all individuals within families. In the literature, a number of equivalence scales have been used to account for the economies of scale of household consumption [Burkhauser et al. (1996), and Phipps and Garner (1994), among others] have examined some of the implications of alternative choices] but recent literature[18] has predominantly used the LIS equivalence scale, which calculates the equivalent income of each household member as:

$$y_i = \frac{y_f}{n_f^{0.5}} \tag{3.1}$$

where y_f is total household income after tax,[19] and n_f is the number of persons in the household.[20]

This methodology lies behind the poverty estimates for the UK discussed in Section 2, but this paper started with a discussion of global poverty trends using an absolute poverty line concept (specified as the local currency equivalent, in purchasing power parity terms, of US $1 per day). How does the relative poverty line methodology compare with the absolute US $1 standard for China in 1995, if we use official exchange or if we use a PPP exchange rate?

To assess this we use data from the 1995 CHINESE HOUSEHOLD INCOME PROJECT (1995 CHIP)[21] whose purpose was to measure and estimate the distribution of personal

[16] Admittedly, these are strong assumptions about the social context of income flows since the effective resources available to each person depend on the degree of inequality in the intra-household distribution of consumption. See Phipps and Burton (1995, p. 194)

[17] Disposable income consists of the sum of gross wages and salaries, farm self-employment income, non-farm self-employment income, cash property income, sick pay, disability pay, social retirement benefits, child or family allowances, unemployment compensation, maternity pay, military/veteran/war benefits, other social insurance, means-tested cash benefits, near cash benefits, private pensions, public sector pensions, alimony or child support, other regular private income, and other cash benefits; minus mandatory contributions for self employed, mandatory employee contribution, and income tax.

[18] See, for example, Buhmann et al. (1988), Coulter et al. (1992), Burkhauser et al. (1996), and Figini (1998) for comparison of the LIS, OECD and other equivalence scales. Figini (1998, p. 2) notes that "OECD and other two-parameter equivalence scales empirically used show a similarity of results [in measurement of inequality] to one parameter equivalence scales with elasticity around 0.5."

[19] "Disposable Personal Income" in the LIS data sets.

[20] Two important special cases of the "equivalent income" calculation: $y_i = \frac{y_f}{n^{\alpha}}$ assigns household income to each individual if α = 0 and per capita income if α = 1.

[21] Riskin, Carl, Zhao Renwei, and Li Shi. CHINESE HOUSEHOLD INCOME PROJECT, 1995 [computer file]. ICPSR version. Amherst, MA: University of Massachusetts, Political Economy Research Institute [producer], 2000. Ann Arbor, MI: Inter-university Consortium for Political and Social Research [distributor], 2000. The

income in both rural and urban areas of the People's Republic of China. The concept of "income" used was considerably broader than that used in most studies of OECD nations - it included both cash payments and a broad range of additional components: payments in kind valued at market prices, agricultural output produced for self-consumption valued at market prices, the value of food and other direct subsidies, and the imputed value of housing services.[22]/[23] Although calculation of the value of in kind or own account self-production is arguably an appropriate adjustment to the context of rural China, none of the nations whose data is included in the Luxembourg Income Study make an imputation of the rental value of owner occupied housing.[24] Thus, maintaining a comparable estimate of poverty implies similarly disregarding the imputed value of housing services.

The 1995 CHIP dataset is based on a survey of 7,998 rural households (together representing 34,739 individual household members) in 19 provinces plus 6,931 urban households (with 21,698 members) in 11 provinces. Eliminating observations with negative incomes produces 7,988 rural and 6,929 urban households. Table 1 presents estimates, based on one half the median equivalent income (in local currency) as the poverty line, of the SST index, poverty rate, average poverty gap ratio, and inequality of poverty gap ratios. The top panel uses the comprehensive definition of income, while the bottom panel excludes the imputed value of owner occupied housing.

If the comprehensive definition of income is adopted, then half the median equivalent income is 2,555 Yuan (Renminbi). At the official exchange rate of 8.28 Yuan per US $1, this is equivalent to a poverty line of US $308.57, or US $0.85 per day. However, excluding the imputed value of owner occupied housing implies that half the median

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Chinese Household Income Project is a joint research effort sponsored by the Institute of Economics, Chinese Academy of Social Sciences, the Asian Development Bank and the Ford Foundation. Additional support was provided by the East Asian Institute, Columbia University.

[22] Disposable rural household income = Income from wages pensions and other compensations received by individual members of the household + Household income from township, village, collective and other types of enterprise (other than compensation for labor) + Cash income from farming and industrial and subsidiary activities + Gross value of self-consumption of farm products + Income from property + Rental value of housing equity + Net transfer from/to collective and state entities + Miscellaneous income (including private transfer) + Net cash income from the sale of farm products + Net income from non-farm subsidiary activities.

[23] Disposable urban household income = Cash income of the working members + Income of the retired members + Income of the non-working members + Income from private/individual enterprises + Income from property + Miscellaneous income (including private transfer and special income) + Subsidies less taxes (except housing subsidy and ration coupon subsidy) and income in kind + Ration coupon subsidy + Housing subsidy + Rental value of owner occupied housing equity.

[24] The method used in the 1995 CHIP is to assume an 8% return on the respondent-estimated value of home equity.

income is 2289 Yuan, which is equivalent to $276.44 per year ($ 0.76 per day) at official exchange rates. Clearly, however, the official exchange rate is a poor guide to relative purchasing power. If the PPP exchange rate is 1.9 Yuan per US $1,[25] this implies that calculating a relative poverty line of half the median equivalent income produces a poverty line equivalent to $1,344 per year ($3.68 per day) using the comprehensive income concept, or $1,204 per year ($3.30 per day) excluding the imputed value of home ownership.

Of course, *if* incomes at the bottom end of the income distribution in China were to have grown over the period 1995 to 2003 at the same 7.55 % rate as per capita GDP, a person earning $1 in 1995 would be making $1.83 in 2003, and someone making $2 per day in 1995 would make $3.66 in 2003. Hence, a relative poverty line of one half median equivalent income in 1995 is, in absolute terms, about what somebody who was just at the $2 per day income level in 1995 would now be making, *if* their incomes had grown at the national average rate. One clear concern on the path of China's development is precisely this assumption – that people at the bottom of the income distribution are sharing in the benefits of economic growth.

Implicitly, the use of a common national poverty line criterion for poverty measurement in affluent countries is based on the idea that the nation as a whole is the relevant comparison group for the assessment of interpersonal equity. The motivation for this idea is not really a sociological presumption that individuals in all parts of the nation actually compare themselves with each other – there is far too much survey evidence on the highly local nature of interpersonal comparisons to make such a presumption credible. However, the nation state is the political entity within which redistribution of income, or other forms of anti-poverty policy might conceivably occur – and it is the political unit within which any expressions of political discontent with poverty outcomes will primarily be managed.

If a common national poverty line is used, one clear implication of Table 1 is the concentration of poverty in China in rural areas. Focussing on the lower panel of Table 1, we see that by this definition of the poverty line, the SST index of poverty in urban areas is approximately 28 times larger in rural areas than in urban China (0.180 compared to 0.0065) – not primarily because the depth of poverty in rural areas is so much greater (the average rural poverty gap is 0.31, compared to an average urban poverty gap of

25 See 2003 World Development Indicators, Pages 282-285 World Bank

0.255) but because the rate of poverty is so very much higher (32.3 % in rural areas, compared to just 1.3% in urban areas).

Table 2 shows that if rural and urban China are analyzed as if they were separate countries, and if the urban poverty line were drawn at half the median equivalent income *of urban areas* , while the rural poverty line is similarly drawn at half the median equivalent income *of rural areas* , the poverty line would be set over twice as high in urban areas (3862 Yuan) as in rural China (1527 Yuan). Interestingly, the level of poverty in rural China would still be twice as high as in urban areas (a rural SST index of 0.072, compared to an urban index of 0.036).

However, since the CHIP data go to some lengths to account for possible sources of in-kind income that might reduce the money cost of living in rural areas, there seems to be little technical reason why rural and urban incomes cannot be compared. If Chinese society comprises a common polity, the application of a common national poverty line to both urban and rural China therefore seems defensible. Table 3 therefore compares the SST index of poverty across the rural areas of the sampled provinces of China. Even leaving aside Beijing, because of its absolutely low fraction of rural dwellers, there is a huge range of variation in the SST index of poverty – with large differences across provinces in all three components of the SST index. As Table 3 indicates, the rural poverty rate (excluding Beijing) is as high as 38.9 % and as low as 7%. The average rural poverty gap ranges from about 62% to about 10% of the poverty line. These differences – of the order of a 5:1 ratio – are huge, so large as to swamp the observed differences in inequality of the poverty gap in the population – which varies between 1.56 and 1.95. Hence, although the variation in $(1+G(x))$ across the rural areas of Chinese provinces are relatively large compared to the variation observed across other data sets in affluent countries, it is small compared to the variation in head count ratio and average poverty gap ratio – which implies that the “poverty box” is a useful expository tool in China, as it is elsewhere.

Table 1
SST and Components
China 1995
Poverty Line = 1/2 the Median for the Country

	Poverty line (½ median equivalent income)	SST	Poverty Rate	Relative Poverty Gap	1 + Gini of Gap	Number of poor observations
Income includes imputed return owner occupied housing						
All	2555	0.100	0.189	0.282	1.886	2474
Urban	2555	0.0063	0.014	0.225	1.993	94
Rural	2555	0.154	0.298	0.283	1.818	2380
Income excludes home wealth						
All	2289	0.118	0.204	0.309	1.875	2677
Urban	2289	0.0065	0.013	0.255	1.993	86
Rural	2289	0.180	0.323	0.310	1.801	2591

Table 2
SST and Components
China 1995
Poverty Lines: 1/2 the Urban Median for the Urban; 1/2 Rural Median for the Rural

	Poverty line (½ median equivalent income)	SST	Poverty Rate	Relative Poverty Gap	1 + Gini of Gap	Number of poor observations
Income includes imputed return owner occupied housing						
Urban	4159	0.033	0.073	0.230	1.958	494
Rural	1753	0.057	0.120	0.245	1.931	974
Income excludes home wealth						
Urban	3862	0.036	0.076	0.238	1.956	515
Rural	1527	0.072	0.133	0.281	1.924	1084

Table 3
SST and Components
Rural China 1995 by Province
Poverty Line = 1/2 the Median for the Country (including urban)
Income Excludes Home Wealth

Province	Poverty line (½ median equivalent)	SST	Poverty Rate	Relative Poverty Gap	1 + Gini of Gap	Number of poor observations
11-Beijing	2289	0.023	0.558	0.021	1.985	2
13 - Hebei	2289	0.184	0.328	0.312	1.801	159
14 Shanxi	2289	0.342	0.373	0.559	1.643	166
21- Liaoning	2289	0.166	0.316	0.288	1.820	92
22 - Jilin	2289	0.146	0.312	0.253	1.848	75
32 – Jiangsu	2289	0.303	0.070	0.220	1.962	36
33 – Zhejiang	2289	0.052	0.210	0.129	1.918	53
34 – Anhui	2289	0.117	0.256	0.247	1.853	112
36 – Jiangxi	2289	0.108	0.231	0.252	1.852	88
37 – Shandong	2289	0.142	0.307	0.249	1.850	178
41- Henan	2289	0.129	0.258	0.271	1.847	203
42 – Hubei	2289	0.194	0.381	0.279	1.828	111
43 – Hunan	2289	0.229	0.319	0.412	1.741	204
44 – Guangdong	2289	0.059	0.310	0.097	1.946	46
51 – Sichuan	2289	0.248	0.301	0.485	1.697	388
52 – Guizhou	2289	0.272	0.301	0.547	1.657	165
53 – Yunnan	2289	0.215	0.268	0.472	1.701	146
61 – Shanxi	2289	0.308	0.328	0.578	1.625	177
62 – Gansu	2289	0.378	0.389	0.619	1.567	190

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4. Statistical Issues

However, observant readers may have noted the right hand side column of Table 3, which reports the number of poor observations, by province. In many provinces, the sample is absolutely small – and it is being used to portray the outcomes experienced by millions. For a theoretical desirable poverty measure to be applied in the real world where we rely on sample data, it is necessary to examine the statistical properties of the sample in order to implement appropriate statistical procedures.[26] In this subsection, asymptotic theoretical results are reviewed first and then the bootstrap method is discussed.

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The poverty measures advocated in this paper include the Sen and SST indices of poverty and their components - the poverty rate (the FGT index of order zero), the average poverty gap ratio of the population (the FGT index of order one), the poverty gap ratio of the poor (the ratio of the FGT index of order one to that of order zero), the Gini index of poverty gap ratios of the poor or of the population (and hence 1 plus the Gini index of poverty gap ratios of the poor or of the population). These measures, whether used as an aggregate (the Sen or SST index) or as a component (the poverty rate, or the average poverty gap, or 1 plus the Gini index), have desirable statistical properties. For income or poverty data, we will primarily rely on the asymptotic theories although some of the measures have good finite sample properties.

The poverty rate *H* is essentially a proportion of a distribution. If we use the sample to estimate *H* assuming that *q* is the number of the poor in the sample of size *n*,[27] then the point estimator,

$$\hat{H} = \frac{q}{n}, \tag{4.1}$$

is a consistent estimator of the true, but unknown, *H*.[28] The large sample variance of $\hat{H}$ is

$$Var(\hat{H}) = \frac{H(1-H)}{n}. \tag{4.2}$$

Since *H* can be consistent, $Var(\hat{H})$ can be estimated consistently as well. In addition, with some minor modification, equations (4.1) and (4.2) can be used for a sample with sampling weights.

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26 See Osberg and Xu (2001) for the bootstrap illustration. The statistical procedures proposed here will be implemented in another project.

27 For simplicity, we use $\{y_1, y_2, \ldots, y_n\}$ as the sample and *z* as the poverty line for the sample data.

28 Note that under the binomial distribution, the estimator is unbiased and has the same variance.

The average poverty gap ratio of the poor is a mean concept, which can be estimated by

$$\hat{I} = \frac{1}{q}\sum_{x_i>0} x_i = \frac{1}{q}\sum_{y_i<z}\left(\frac{z-y_i}{z}\right). \tag{4.3}$$

This estimator $\hat{I}$ is also consistent with a variance

$$Var(\hat{I}) = \frac{1}{(q-1)}\sum_{x_i>0}\left(x_i - I\right)^2 \tag{4.4}$$

Again, $Var(\hat{I})$ can be estimated consistent given $\hat{I}$ is a consistent estimator. Equations (4.3) and (4.4) can be modified for a sample with sampling weights. Sometimes, researchers are interested in the average poverty gap ratio of the population. It can be estimated by $\hat{HI} = \frac{1}{n}\sum_{x_i>0} x_i = \frac{1}{n}\sum_{y_i<z}\left(\frac{z-y_i}{z}\right)$ with $Var(\hat{HI}) = \frac{1}{(n-1)}\sum_{x_i>0}\left(x_i - HI\right)^2$ The above results can be found in Kakwani (1993).

For the term of 1 plus the Gini index, we can discuss the Gini index first. The probably the earliest contribution was made by Hoeffding (1948) based on the U-statistics. Following Glasser (1962) developed the variance for the Gini index based on the definition of the Gini index based on the Gini's relative mean difference [Xu (2003)]. Note that this paper contains two versions of the Gini index: one is the Gini index of poverty gap ratios of the poor, $G(x_p)$ and the other is the Gini index of poverty gap ratios of the population, $G(x)$. Since these two indices are closely related by

$$G(x) = (1-H) + H\,G(x_p) \tag{4.5}$$

we can simply focus on $G(x_p)$. Among many other approaches, Glasser (1962) proposed the Gini index estimator and its variance estimator. Let the poverty gap ratios of the poor be $\{x_1, x_2, \ldots, x_q\}$,

$$d_i = \frac{1}{q-1}\sum_{i=1}^{q}\left|x_i - x_j\right| \quad \text{for } i \neq j \tag{4.6}$$

and

$$d = \frac{1}{q}\sum_{i=1}^{q} d_i. \tag{4.7}$$

Let $\bar{x}_p$ be the sample mean of the poverty gap ratios of the poor $\{x_1, x_2, \ldots, x_q\}$. Based on these definitions, the Gini index of poverty gap ratios of the poor can be estimated by the following estimator

$$\hat{G}(x_p) = \frac{d}{2\bar{x}_p}. \tag{4.8}$$

The large sample variance of the above estimator is given by

$$Var\left(\hat{G}(x_p)\right) = \frac{(N-n)}{N\bar{n}_p x} Var\left[\left(\hat{r}_i - \left(1+G(x_p)\right)\right) x_i\right]. \tag{4.9}$$

The term $1+G(x_p)$ can be estimated by $1+\hat{G}(x_p)$. The variance of $1+\hat{G}(x_p)$ is the same as given in equation (4.9). The estimator of the Gini index of poverty gap ratios of the population, $G(x)$, and its variance can be developed similarly. Based on equation (4.5) and the assumption that *H* is fixed, $Var\left(\hat{G}(x)\right) = H^2\, \widehat{Var}\left(G(x_p)\right)$ can be employed.[29]

However, as may be noted, the above discussion is limited to the components of the Sen and SST indices (that is, the FGT indices of order 0 and 1 and the Gini indices of different kinds). In order to explain the statistical inference issues of the Sen and SST index one needs to look beyond the above basic statistical results. Following Hoeffding (1948), Zheng (1993), Bishop et al. (1997, 1998, and 2001), and Zheng et al. (2000) employed the U-statistics to develop the statistical inference for the Sen index and some other extensions. Xu (2004) also worked the statistical inference for the SST index and a uniform framework for all statistics discussed above. The following is a brief presentation of the relevant results in Xu (2004).

In order to apply the U-statistics to the Sen and SST indices, first introduce some U-statistics. Let *I*(*A*) be an indicator function: $I(A)=1$ if *A* is true, $I(A)=0$ otherwise. Let

$$U_1 = \frac{1}{n}\sum_{i=1}^{n} I(y_i < z) = \hat{H}, \tag{4.10}$$

and

$$U_2 = \frac{1}{n}\sum_{i=1}^{n} y_i I(y_i < z) \tag{4.11}$$

Then the mean of *x* and that of x_p can be computed from U_1 and U_2:

[29] Note that for simplified methods to estimate the standard error of the Gini index, please see Ogwang (2000), Giles (2004), and Ogwang (2004).

$$\bar{x} = U_1\left(1 - \frac{U_2}{z U_1}\right) \tag{4.12}$$

and

$$\bar{x}_p = \left(1 - \frac{U_2}{z U_1}\right). \tag{4.13}$$

Now define the U-statistics for the Gini's mean difference:

$$U_3 = \frac{1}{n(n-1)} \sum_{i=1}^{n}\sum_{j=1}^{n} |y_i - y_j| \, I(y_i < z)\, I(y_j < z) . \tag{4.14}$$

According to Xu (2004), the estimator of the Sen index is given by

$$\hat{S} = \frac{2z^3 U_1^2 - 2z U_1 U_2 + U_3 U_1}{2z^3 U_1}. \tag{4.15}$$

The estimator of the SST index is defined as

$$\hat{S}_{SST} = \frac{2z^3 U_1 - 2z^2 U_2 + U_3}{2z^3}. \tag{4.16}$$

According to Hoeffding (1948, Theorem 7.5), the estimators U_1, U_2, and U_3 are consistent for their population counterparts θ_1, θ_2 and θ_3, respectively. If F_y is the continuous distribution function with finite variance, then the joint distribution function of

$$n^{\frac{1}{2}}(U - \theta) = \left[n^{\frac{1}{2}}(U_1 - \theta_1), n^{\frac{1}{2}}(U_2 - \theta_2), n^{\frac{1}{2}}(U_3 - \theta_3) \right]^T \tag{4.17}$$

is asymptotically normal with mean **0** and variance

$$\Sigma = \begin{bmatrix} \theta_1(1-\theta_1) & \theta_2(1-\theta_1) & 2\theta_3(1-\theta_1) \\ \theta_2(1-\theta_1) & \varsigma_2 - \theta_2^2 & 2(\varsigma_{23} - \theta_2\theta_3) \\ 2\theta_3(1-\theta_1) & 2(\varsigma_{23} - \theta_2\theta_3) & 4(\varsigma_3 - \theta_3^2) \end{bmatrix}, \tag{4.18}$$

where

$$\varsigma_2 = \int_0^z y^2 \, dF(y), \tag{4.19}$$

$$\varsigma_3 = \int_0^z \left(\int_0^z |y_1 - y_2| \, dF(y_2) \right)^2 dF(y_1), \tag{4.20}$$

and

$$\varsigma_{23} = \int_0^z y_1 \int_0^z |y_1 - y_2| \, dF(y_2)\, dF(y_1), \tag{4.21}$$

respectively. Since $\hat{S}$ and $\hat{S}_{SS}$ are functions of U_1, U_2, U_3, their variances can be derived from suitable functions of Σ. Due to the space limitation, we refer the interested readers to Xu (2004).

While the asymptotic results discussed above are desirable, the computation of the standard error of the Sen or SST index estimate can be complex. Osberg and Xu (2001) have proposed the bootstrap method for computing the standard error for the SST index estimate. This method is also applicable to the Sen index estimates and to estimates of other poverty measures. In a recent study, Davidson and Flachaire (2004) find that the bootstrap method can generate accurate variance estimates for poverty measures but not for inequality measures because the latter are extremely sensitive to the data in the upper-tail of a distribution. This finding assures that the bootstrap method is suitable for poverty measures.

The bootstrap method can be described as follows: Resample randomly from the sample $y^* = \{y_1^*, y_2^*, \ldots, y_n^*\}$ with replacement, compute the poverty measure of interest using the random sample $P(y^*)$, and repeat this process *B* times (typically *B* is a large number say 200). Then we can compute the bootstrap standard error using

$$se(P) = \sqrt{\frac{\sum_{b=1}^{B}\left(P(y^{*b}) - P(\bullet)\right)^2}{B-1}}, \qquad (4.22)$$

where $P(\bullet) = \frac{1}{B}\sum_{b=1}^{B} P(y^{*b})$. In this case, *P* can be $\hat{H}$, $\hat{I}$, $\hat{G}(x_p)$, $\hat{G}(x)$, $\hat{S}$, and $\hat{S}_{SS}$.

A practical example of this methodology was provided by Osberg and Xu (1999) who compared Canadian provinces – and since the provinces of China are an order of magnitude larger in population than Canadian provinces, while the sample size from which inference is made is considerably smaller, the importance of computing bootstrap standard errors is likely to be considerably greater in the context of China.

5. Summary and Conclusion

This paper started by asking whether the estimated proportion of the world's population with income below US $1 (adjusted according to purchasing power parity) per day is a good measure of trends in global poverty. We have argued in this paper that the answer depends on three important issues in the measurement of poverty – the definition of the poverty line, how best to summarize the level of poverty and how to statistically infer estimates of poverty from sample data.

5.1 What Poverty Line?

The disciplinary perspective of economists is to prefer quantitative comparisons, and to avoid the definition of qualitative categories, wherever possible – but even among economists there does seem to be a widespread recognition that there is "something different" about being poor. In common language usage, poverty is about deprivation of necessities - the primary dictionary definition of "poverty" is the deprivation of "the necessities of life"[see Oxford (1998, p. 1135)]. Adam Smith's views on this were drafted at a time when all nations had much lower incomes than presently and are now more than 200 years old, but they continue to be quoted extensively:

"Under necessaries, therefore, I comprehend not only those things which nature, but those things which the established rules of decency have rendered necessary to the lowest rank of people." (Vol. 2, Bk. V, Ch. II, Pt II, Art IV – 1961, p. 400)

In thinking about what "the established rules of decency" might be, on a global scale, the criterion of $1 per day – US$, PPP– has the enormous virtue of seeming simplicity, and hence communicability to a global public. However, a good deal of technical complexity sits behind the calculation of $1 per day in Purchasing Power Parity terms – and the issue is crucial to the evaluation of the level of global poverty. As we have already noted, in the case of China, the ratio between PPP and the exchange rate is of the order of 4:1, so adjustment for PPP has an enormous impact on the estimated level of average real income of 1.28 billion people.

Exchange rates are easily observable data derived from actual transactions involving just one good (currency) which are available in comparable terms for a wide range of countries. In calculating the Purchasing Power Parity adjustment to observed exchange rates, analysts are answering a hypothetical question about what a comparable vector of commodities would cost in different countries. Calculating such an index number of relative costs requires analysts to face the conceptual problems of deciding (1) which goods, in which relative amounts, to use and (2) how to incorporate relative price information. When PPP values are being calculated for a wide range of countries with a great deal of variance in quality and comprehensiveness of statistical data, there are also great practical problems of estimation and inference.

As we have already noted, food items are a more important component of the budgets of poor people than for the affluent and food is relatively expensive in poor nations (partly because many foods – e.g. rice – are internationally tradable). Hence, a PPP adjustment for "all output" or even "all consumption" will tend to underestimate the local currency equivalent income necessary to maintain $ 1 of consumption daily, at US prices [see Aten and Heston (2004)]. However, even leaving this aside, the calculation of PPP values can be done in a number of ways – each with its own advantages and disadvantages. Hill (2000, p.294) has compared the range of estimates of PPP adjusted average income levels that these methodologies imply. He concluded, for example, that although (when evaluated at observed exchange rates) the ratio of per capita income in the USA in 1990 to that of Turkey was 8.1 to 1, the range of PPP income ratios was between 3.3 to1 and 6.4 to 1 (with the Geary-Khamis price index method favoured by the ICP project generating a ratio of 3.7 to 1). When calculated average income ratios can nearly double, depending on PPP methodology chosen, one has to worry that estimates of the extent of global poverty are inordinately sensitive to very technical choices about PPP methodology – particularly since the income distribution is typically very dense in the region of the poverty line, implying that small movements in the poverty line can shift fairly large fractions of the population into, or out of, poverty.

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As well, the rapidity of economic growth in China, and in India and South East Asia, means that, for a very substantial fraction of the world's population, the problem of absolute deprivation of commodities is being replaced by a more subtle type of poverty. As Sen has put it:

"*Relative* deprivation in the space of *incomes* can yield *absolute* deprivation in the space of *capabilities.* In a country that is generally rich, more income may be needed to buy enough commodities to achieve the *same social functioning* , such as 'appearing in public without shame'. The same applies to the capability of 'taking part the life of the community'." (1992, p. 115)

In international poverty comparisons among affluent countries, the norm is to calculate the poverty line as a fraction of median income, and to use local currency units throughout – which avoids entirely the problem of the uncertain value of PPP conversions. Both for this reason, and because of the rapid growth of average affluence in China and elsewhere, this paper argues that more attention should be given to *relative deprivation* (i.e. equivalent incomes less than half the median) as well as *absolute deprivation* (i.e. incomes below $1 or $2 US per day).

5.2 The Summarization of Poverty Outcomes

We have shown that Sen and SST indices of poverty intensity can be calculated easily and their components are commonly used poverty and inequality measures such as the poverty rate, average poverty gap ratios of the poor/population, the Gini index of poverty gap ratios of the poor/population. Both Sen and SST indices measure the incidence, depth and inequality of poverty and have simple geometric interpretations that are related directly to an illustrative tool called the "Poverty Box".

The authors of this paper have argued in other work that since there is little variation in the inequality of poverty gaps across affluent economies, the "Poverty Box" idea is a useful graphical tool, in that context, to summarize and compare the two principal components of the level of poverty – the poverty rate and the average poverty gap ratio. Although there is more variation within a country like China in inequality among the poor, it is swamped by the variation in poverty rate and average poverty gap ratio – hence we conclude that the "Poverty Box" concept is a useful tool in this context as well.

5.3 Statistical Inference

When we implement the desirable poverty measures discussed in this paper, we must apply them to the sample data. Hence a full understanding of the statistical properties of the corresponding poverty estimators becomes important. In addition to the common knowledge about the poverty rate and average poverty gap ratios, this paper also shows the desirable statistical properties of the Sen and SST index estimators and explains how to use the bootstrap method in this context.

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