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Another Mere Addition Paradox?

Some Reflections on Variable Population Poverty Measurement

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Abstract

Debates about poverty relief and foreign aid often hinge on claims about how many poor people there are in the world and what constitutes poverty. Good measures of poverty are essential for addressing the world poverty problem. Measures of poverty require a basis for determining who is poor and a method of aggregation. Historically, the methods of aggregation were quite simple. The headcount index (*H*), for instance, measures the number of poor people as a percentage of the total population. The poverty gap index for the whole population (*I*) takes the total aggregate shortfall from the poverty line divided by the number of people and the poverty line itself. Recently, however, economists have suggested several more complicated alternatives including Sen's index, the Sen-Shorrocks-Thon (SST) index, and the Foster-Greer-Thorbecke (FGT) index (which, under some parameterizations is equivalent to *H* and *I*). This paper…

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critiques several of the main poverty indexes in the literature by setting out and defending its 'axiom' (intuition or desiderata) for any good poverty measure. It argues that if Sen's index, the SST, and the FGT indexes do not satisfy this 'no mere addition axiom', they do not provide compelling measures of anything that can intuitively be considered poverty. Next, it illustrates how these poverty indexes violate this no mere addition axiom. Finally, the paper illustrates one way of modifying the indexes to satisfy the no mere addition axiom with the FGT. It notes, however, that these alternatives will not do for all policy purposes. So, it is important to consider further how poverty indexes and axioms fare in variable population contexts.

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Acronyms

SST Sen-Shorrocks-Thon (SST) index
FGT Foster-Greer-Thorbecke (FGT) index

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1 Introduction

Debates about poverty relief and foreign aid often hinge on claims about how many poor people there are in the world and what constitutes poverty. Good measures of poverty are essential for addressing the world poverty problem, especially since poverty measures guide international institutions' development policies. The Millennium Development Goal's first target to 'halve, between 1990 and 2015, the proportion of people whose income is less than one dollar a day', measures its success partly in terms of the headcount index, and the poverty gap index for the total population (UNDP 2007).[1] Different measures of poverty are also used to estimate national and international policies' impact (Cranfield et al. 2007).

Measures of poverty require a basis for determining who is poor and a method of aggregation or a poverty index. Historically, the methods of aggregation were quite simple. Consider, for instance, the indexes used in the Millennium Development Goals. The headcount index (H) measures the number of poor people as a percentage of the total population. The poverty gap index for the total population (I) takes the total aggregate shortfall from the poverty line divided by the number of people and the poverty line itself. Recently, however, economists have suggested several more complicated alternatives including Sen's index, the Sen-Shorrocks-Thon (SST) index, and the Foster-Greer-Thorbecke (FGT) index (which, under some parameterizations is equivalent to H and I).

This paper critiques several of the main poverty indexes in the literature by setting out and defending its 'axiom' (intuition or desiderata) for any good poverty measure. It argues that if Sen's index, the SST, and the FGT indexes do not satisfy this 'no mere addition axiom', they do not provide compelling measures of anything that can intuitively be considered poverty. Next, it illustrates how these poverty indexes violate this no mere addition axiom.[2] Finally, the paper illustrates one way of modifying the indexes to satisfy the no mere addition axiom with the FGT. It notes, however, that these alternatives will not do for all policy purposes. So, it is important to consider further how poverty indexes and axioms fare in variable population contexts.

2 Preliminaries

2.1 Fixed and variable population contexts

Most of the work on poverty indexes has considered what properties indexes can and should satisfy in fixed populations. There are many articles establishing that several of

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1 It also uses the share of the poorest quintile in national consumption.

2 I have found no sustained discussion in the economics literature of the fact that these indexes can suggest that poverty increases when the number of non-poor increases. The only place I have come across this point is in a footnote in (Anand 1997: 254). Anand says 'Only an actual reduction in the number of poor, or an increase in their incomes, or an improvement in their income distribution, or an increase in the number of non-poor can lead to a fall in the Sen poverty index' (ibid.: 254). Anand offers no citations or evidence for this claim, nor is it technically true. Changes in distribution are inextricably linked with either changes in the number of people in a population or their income levels (if that is the appropriate basis for poverty). So, for instance, an improvement in the income distribution may not, on its own, cause Sen's index to fall. See discussion below.

the main axioms for poverty measurement in fixed populations are incompatible (Donaldson and Weymark 1986; Sen 1976; Zheng 1997).

This paper takes up and hopefully adds impetus to the recent move to consider poverty indexes in variable population contexts (Kundu and Smith 1983; Bossert 1990; Subramanian 2002, 2005a, 2005b; Chakravarty et al. 2006; Kanbur and Mukherjee 2007; Hassoun and Subramanian 2010). It illustrates how many common indexes are inadequate in variable populations. In doing so, it also tries to provide an accessible introduction to several of the main poverty measures and some of the significant criticism of these measures in a variable population context.

This paper articulates and defends a new axiom for poverty measurement. On this no mere addition axiom merely adding a person who is not poor to a population should *not* decrease poverty. Amongst the work that has considered poverty indexes in changing populations, Kundu and Smith's (1983) non-poverty growth axiom is basically the opposite of the no mere addition axiom.[3] Non-poverty growth asserts that poverty *decreases* just because a non-poor (henceforth rich) person is added to a population. The no mere addition axiom claims that poverty does not decrease when the only change is that a rich person is added to a population. Of course, poverty might decrease if other things happen as well. If, for instance, a poor person becomes rich, poverty may decline. The no mere addition axiom just asserts that that poverty does not decline due to the mere addition of a rich person.

Subramanian's 'strong focus axiom' entails but also requires much more than the no mere addition axiom (2002). On the strong focus axiom, poverty is invariant with respect to the size and incomes of the rich. The no mere addition axiom is even weaker than Paxton's (2003) non-poverty-invariance axiom, which says that poverty is invariant with respect to the number of rich people. The no mere addition axiom just says that poverty is not reduced by an increment in the number of rich people in a population.[4] It allows, but does not require, poverty to increase if a rich person joins a population. It says nothing about what happens to poverty when the income of the rich changes.[5]

Like Subramanian and Kundu and Smith's papers, this paper illustrates how its suggested axiom is inconsistent with some other axioms for fixed populations. In showing that many of the existing poverty indexes violate the no mere addition axiom, it also proves one of Paxton's assertions, that these indexes satisfy the non-poverty growth axiom (Paxton 2003). This paper demonstrates the importance of paying attention to how poverty axioms and indexes fare in variable populations.

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3 I owe thanks to Subbu Subramanian for help simplifying my formalization of these axioms and generalizing this paper's results.

4 Subramanian has, however, pointed out that the headcount index entails that poverty can almost be eradicated simply by increasing the number of non-poor people in a population (Subramanian 2002: 283). This problem is worse than that on which this paper focuses but the strong focus axiom he suggests that rules out the problem requires more than the no mere addition axiom.

5 If poverty is, in part, a matter of vulnerability, it may make sense to say poverty increases with the addition of people above the poverty line (though, presumably, the richer the people are, the less vulnerable they will be). It is not clearly the case, however, that rich people are vulnerable (Christensen and Subbarao 2005).

This paper is unique because of the way that it argues that it is important to consider poverty axioms and indexes in variable population contexts. For, it shows that many of the traditional poverty indexes fail to satisfy the no mere addition axiom.[6] It also provides some defence of a particular index that can satisfy this axiom. Finally, this paper goes further than much of the literature on axiomatic poverty measurement in providing a philosophical justification for the axiom it relies upon and the poverty index it advances.

2.2 The basis of poverty measurement

Although this paper follows the standard in economics and focus primarily on income and consumption, the indexes this paper will examine whether all can be used with different bases for poverty measurement. Poverty might be deprivation in the space of capabilities, functionings, resources, and so forth (Sen 1999; Pogge 2004; Nussbaum 2000; Dworkin 2002). It is, of course, important to justify the basis for an index if it is to play a constructive role in measuring poverty.[7] Furthermore, what basis is correct may influence what index is desirable (and how the parameters in the index should be set). This paper will focus only on the aggregative component of poverty indexes, however, considering the indexes on the assumption that they have the right basis.

To stay neutral on the proper basis for poverty measurement, however, this paper refers to this basis as *need.* It refers to whatever alleviates need or brings someone up higher above the poverty line as a *good*. This terminology is slightly misleading as opportunities might be necessary to alleviate need, for instance, rather than hard goods or other resources (Miller 1999). This way of speaking does not, however, presuppose an answer to what distribution of *goods* (in the relevant broad sense) is best. It might, for instance, alleviate just as much need to give ten children a year of schooling as to inoculate a single child against measles.[8]

Finally, this paper is only concerned with measures of poverty simpliciter. It is not concerned with measures of the amount of poverty-in-a-country or the average depth of poverty. Nor is it concerned with a complete measure of social welfare, inequality, or other phenomena one might want to measure.

2.3 Justifying the no mere addition axiom

Recall that the no mere addition axiom states that merely adding a rich person to a population should not decrease poverty. The rich may, of course, do a lot to alleviate poverty. They might voluntarily or involuntarily give money to the poor or their money might trickle down to the poor. But, their mere existence in a population does not reduce poverty. To illustrate the import of this axiom, consider the following population:

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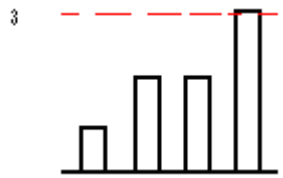
6 Its results should hold even if one rejects that the strong focus axiom and avoids Subramanian's impossibility theorems.

7 This point is well established. See, for instance, Hassoun (2009).

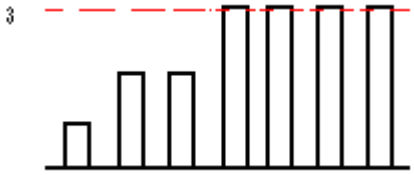
8 This paper sets aside problems that arise from the fact that some people are inefficient users of goods. It does not consider, for instance, what to say about people with unusual medical conditions who require very expensive medical care.



P1 P2 P3 P4

In this diagram, each rectangle represents a person. The dotted line denotes the level at which people can meet their needs—the poverty line. Here the poverty line is at three units of good. The height of each rectangle shows how close a person comes to being able to meet their needs. The first person, P1, has one unit of good, so needs two units to reach the poverty line. The second and third person, P2 and P3, have two units of good, so need one more unit to reach the poverty line. The last person, P4 has more than three units of good, so is not poor.

The no mere addition axiom suggests that simply adding more people who can meet their needs to the population does not reduce poverty. So, the following population does not have less poverty in it than the initial population as it simply contains three additional people P5-P7 who can meet their needs:



P1 P2 P3 P4 P5 P6 P7

Nor would poverty decline if P5-P7 were much richer:

Of course, the burden of poverty might be less in this population than in the initial population. It might be much easier to alleviate poverty by redistributing some income from the rich to the poor, for instance. There may also be some respects in which this population is better (or worse) than the initial population. But the mere addition of P5-P7 does not *in itself* reduce poverty.[9]

The intuition here is along the same lines as that Sen (1981: 190) expresses in objecting to the idea 'that some increase in the income shortfall of the poor may be compensated by a sufficiently high rise in the income of the non-poor'. He says 'poverty is a characteristic of the poor, and a reduction of the incomes of the poor must increase the measure of poverty, no matter how much the incomes of the non-poor go up at the same

9 The idea here is different from Parfit's mere addition paradox. Parfit starts by comparing two (otherwise equivalent) populations, one of which has an additional person with below average welfare but with a life worth living. He says the population with the additional person is not worse than the original population. But, then, he points out that a third population which also contains an additional person, but where everyone has a level of welfare between the additional person's level and the level of the other people in the population may be better than the second population (Parfit 1984. His worry is that merely adding poor people may compensate for decreasing welfare in a population.

time' (Sen 1981: 190). But if poverty is a characteristic of the poor, an increase in the number of rich people should not alone reduce poverty. At least a change that does not affect the poor at all should not reduce poverty.

This paper considers indexes only as measures of poverty, not as measures of how it is best to fulfil needs. Though, these things are related. The best explanation for why it is best to meet needs in a particular way may, for instance, be the fact that doing so meets the most need.

Relying on this connection, one might object to the no mere addition axiom by adapting an argument first advanced by political scientist Miller in a slightly different context. Miller is concerned with distribution according to need and claims that it is important in deciding who to help to consider not only P1's claims vs. P2 and P3's claims but P1's claims against P4-P7's claims. So one could argue that people in the middle of the stack are worse off the closer to the bottom they fall. Perhaps it is important to consider 'the relative position of everyone' in determining how much poverty there is in a population (Miller 1999: 219). This might support the intuition that it is best to 'equalize degrees of unmet need, which means distributing in favour of those in greater need until they are brought up to the same level as others' (Miller 1999: 74).

One might follow Miller in suggesting that this intuition underlies some empirical evidence regarding how people think about distributing according to need in the social psychology literature. In one experiment, there were two students one of whom needed extra money for books. Subjects had to decide how to split a set amount of money between them. Most subjects wanted to give the needy student enough to buy the textbooks before splitting the rest equally (Miller 1999: 74). In another experiment, intended to mimic Rawls' original position, subjects had to choose the rules for remuneration for work they were to perform. Most subjects chose to maximize income subject to a floor constraint.

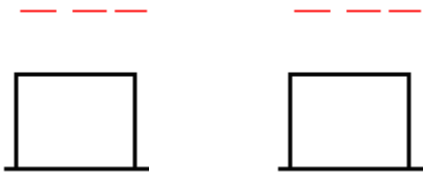
The first experiment, however, only provides evidence that sometimes people will try to help others meet their needs before distributing the remaining goods equally. The second experiment only provides evidence that most people want to provide a flat minimum for everyone (Frohlich and Oppenheimer 1992; Miller 1999: 79). The evidence does not support Miller's intuition about what distribution according to need requires. The results just show that people are concerned about need, not that 'people will aim to equalize degrees of unmet need' (Miller 2001: 74).[10] Hence, one cannot argue that the best explanation for why people share Miller's intuition about how it is best to meet need, is that poverty in a population decreases when the only change is that more people who can meet their needs are added to the population. The empirical evidence suggests that people do not share Miller's intuition.

A different objection is that the no mere addition axiom is incompatible with the idea that poverty should be sensitive to the proportion of people in poverty. One might argue that large countries with a relatively small proportion of poor people are poorer than small countries with a relatively large proportion of poor people. Or, more generally, one might endorse what Subramanian calls the 'likelihood principle', on which (at least

10 Miller suggests subjects are balancing a concern for giving people their just deserts against a concern for need fulfilment. But, it is not clear that the evidence supports this contention.

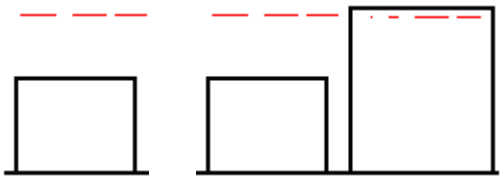
ceteris perabus) a population in which one is more likely to encounter a poor person is poorer (Subramanian 2006). On the likelihood principle, large populations with a relatively small proportion of poor people are poorer than small populations with a relatively large proportion of poor people.[11]

We can consider the relevance of proportions by holding the numbers of the poor people in a population constant and just manipulating the number of rich people in the population. Suppose that at time t1 there are two populations that have one-hundred poor people each, so 100 per cent of each population is poor (the width of the boxes that follow can be used to represent the size of the populations).



Population 1 t1 Population 2 t1

At t2, the first population has stayed the same and the second population has gained one-hundred rich people. So, the proportion of poor people in the second population has decreased drastically to 50 per cent, but it has the same number of poor people.



Population 1 t2 Population 2 t2

Considering these cases, I hope no one will think poverty has decreased in the second population when all that has happened is that it has gained rich people.[12]

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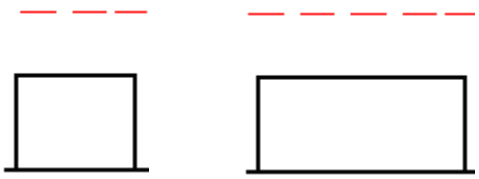
11 One could not even use a relative conception of poverty to support the likelihood principle (at least on the most common measures of relative poverty).

12 Alternately, it is possible to change the number of poor people in a population, but hold the proportion of poor people constant. Suppose that the first society looks like this at t3 with twice as many poor people as it had at t2:



Society 1 t2 Society 1 t3

I hope everyone can agree that there is more poverty in the first society at t3 than at t2, though the proportions are the same. At least the number of poor people in a population seems relevant to how much poverty there is.

In light of cases like these, those who think proportions are relevant to the amount of poverty in a population must at least say more. They must explain exactly how proportions matter relative to

Proponents of the likelihood principle might argue, however, that these simple diagrams decontextualize our judgements about the amount of poverty in a population too much. If one thinks that it is impermissible to discriminate against smaller countries in deciding which to aid, for instance, it might make sense to look at the proportion of the population in the country that is poor. (Though, it is debatable whether it is best to treat countries rather than individuals equally.) Alternately, if one thinks that it should be easier to alleviate poverty in countries with less poverty, one might want to say that there is more poverty in a country with a greater proportion of poor people.

It is possible, however, to account for the force of the motivating intuitions in these examples without granting that proportions are relevant to how much poverty there is in a population. First, it is important to distinguish clearly between how much poverty there is in a population and what is best to do (even about that poverty). It might not be important to alleviate the most poverty if other things of value are at stake. A measure of the amount of poverty in a population is descriptive and is different from an index that provides a (partial or complete) measure of how it is best to (for example) promote social welfare. So if it is good to give more aid to smaller countries with larger proportions but smaller numbers of poor people in them, that may not be because they are poorer but because they are smaller (and, say, have fewer resources with which to combat poverty). Second, it is important to distinguish between the potential for a population to ameliorate poverty and the amount of poverty in that population. Or, as Sen puts it, between descriptive indexes which are concerned with 'the state of the poor' and indexes intended to measure a population's 'potential ability to meet the challenge of poverty' (Sen 1981: 190). Indexes sensitive to the proportion of a population in poverty may capture the potential for the population to ameliorate poverty or the average depth of poverty in that population, rather than the amount of poverty in that population.[13] More generally, it is important to distinguish between the amount of poverty in a population and other features of a population (e.g., those that constrain how easy it is to ameliorate that poverty).[14]

Proponents of the likelihood principle might argue, however, that poverty is sensitive to the proportion of a population that is poor in at least some cases. The proportion of people in a population who are poor can change for many reasons—migration, birth, and death. Each of these reasons may also be explained by many factors, some endogenous to a population and some exogenous. Changing internal conditions may, for instance, alter economic or population growth rates amongst different segments of a population. Alternately, changing external conditions may increase immigration or encourage emigration. If the proportion of a population that is poor depends on endogenous factors, one might say poverty should be sensitive to proportions.

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numbers (e.g., provide a weighting on proportions and numbers that generates a composite measure of poverty) and can generate their desired judgements about particular cases.

13 Some standard tools in economics for distributional, welfare, and poverty analyses (such as Lorenz dominance, generalized Lorenz dominance, and stochastic dominance) may require one to reject the no mere addition axiom. The desire to be able to use these tools may drive intuitions about the relevance of proportions (Hassoun and Subramanian 2010).

14 One reason to think that potential matters (even if it does not map onto the amount of poverty in a population) is this: If one were behind a Rawlsian veil of ignorance and did not know who one would be in a society, one might reasonably choose to enter a society with a smaller proportion of poor people.

It is not clear *why* the fact that good internal conditions let a population support a greater number of rich people is supposed to decrease poverty on this proposal. Perhaps the motivating intuition is that endogenous changes that allow a population to support additional rich people suggest that the population is better in some way—so it is fair to say it is less poor. Populations can, however, be better in many ways without containing less poverty. A population might be better because it can support a greater number of rich people, even if it contains more poverty. Furthermore, it may be important to clearly distinguish between a population's poverty and how much poverty there is in a population. When internal features allow a population to support more rich people, the population may be poorer without there being less poverty in the population. Swaziland might be poorer than China, for instance, if it has a higher proportion of poor people, even if it contains fewer poor people and, so, has less poverty. Unless there is a better justification for the likelihood principle, there is reason to reject it.[15]

The next section shows how many of the most common poverty indexes fail to satisfy the no mere addition axiom. On these indexes, adding people who can meet their needs to a population can, on its own, decrease poverty. It suggests that some of the main poverty indexes in the literature may be inadequate in variable population contexts. Finally, the paper considers how to arrive at a better poverty index and accounts for some of the intuitions motivating the traditional alternatives.

3 Critique of some common poverty indexes

3.1 The SST index

Consider, first, the Sen-Shorrocks-Thon index (SST):

$$SST = H I^{P} (1+G) \tag{1}$$

Here, H is the headcount index, the proportion of people below the poverty line.

$$H = n^{p} / n \tag{2}$$

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[15] Furthermore, even if poverty is sensitive to proportions in some cases, that is not enough to establish the likelihood principle, which suggests that poverty is always sensitive to the proportion of the population that is poor. So, even if proportions are sometimes relevant to how much poverty there is in a population, it will still be worth examining the no mere addition axiom. For, the mere addition of a rich person to a population may not generally decrease poverty in that population. In fact, even if one is not completely convinced by these debunking explanations of why one might find the likelihood principle compelling, it is worth considering the no mere addition axiom further. For, it may be possible to create an index that captures some of the force of no mere addition axiom and the likelihood principle. Modifying Subramanian's suggestion on how to satisfy both the likelihood principle and the strong focus axiom in some cases, one might apply the following decision procedure: If two distributions have the same population size, then rank the population using the weighted aggregate gap index. If they have the same score on the weighted aggregate gap index, then rank the populations based on the proportion of the population that is poor. At best, however, this mitigates the tension between the likelihood principle and no mere addition axiom (Subramanian 2006). Nevertheless, the remainder of this paper proceeds on the assumption that the no mere addition axiom is correct.

n is the number of people in the population and n^p the number of people who have an amount of good y_i less than the amount necessary to reach the poverty line z.

I^P is the poverty gap index *for the poor only*:

$$I^P = 1/n^P \sum_{i=1}^{n^p} x_i^P \quad (3)$$

Again, n^P is the number of poor individuals in the population. x_i^P is the individual *i*'s poverty gap $(z - y_i)/z$ and all $_i$s, in this case, are below the poverty line (indicated by the superscript ^{P}).

G is the Gini of the poverty gap ratios *for the whole population*:

$$G = \frac{\sum_{I=1}^{n}\sum_{j=1}^{n} | x_i - x_j |}{2n^2 I} \quad (4)$$

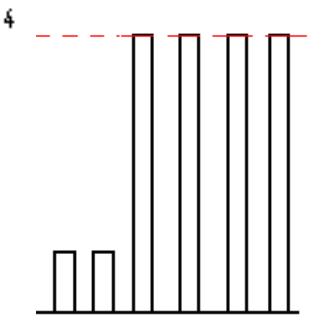
Here all individuals' gaps are taken into account including the gaps of the rich. Though, if y_i > z, then x_i = 0. *I* is the poverty gap index *for the whole population.*

$$I = 1/n \sum_{i=1}^{n} x_i \quad (5)$$

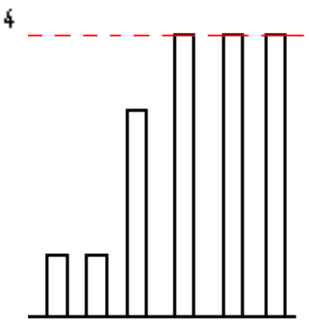
Again, x_i is the individual *i*'s poverty gap where some *i*'s are above the poverty line. If y_i > z , then x_i = 0, otherwise x_i = (z- y_i)/z.

The SST suggests that poverty declines with the mere addition of a rich person to a population that contains some poverty: Since I^P doesn't change and the denominator of *H* is increased by 1 with the addition of a rich person, but *G* outputs a value between 0 and 1, the SST can suggest that poverty is the same or decreases with the addition of a rich person, but it cannot say poverty increases. Unless *G* was 0 before the addition and becomes 1 after, poverty will decrease on the SST. But if there are some poor people who have some income, *G* will never be 1 after the addition of a rich person, so the SST suggests that poverty decreases with the addition of a rich person.

It will help to consider some illustrative examples. Consider the following populations where people need four units of good to avoid poverty:



P1 P2 P3 P4 P5 P6
Population A



P1 P2 P3 P4 P5 P6
Population B

In both of these populations P1 and P2 have one unit each, P4-P6 have four units each. In population A, P3 has four units. In population B, P3 has three units. Note, however, that no matter how many units P4-P6 have, their gaps will be equal to 0 since if y_i > z, then x_i = 0. So the SST would return equivalent results even if the rich were much richer in A or B.

These are the gaps:

	Goods	Poverty Gap
P1	1	.75
P2	1	.75
P3	4	0
P4	4	0
P5	4	0
P6	4	0

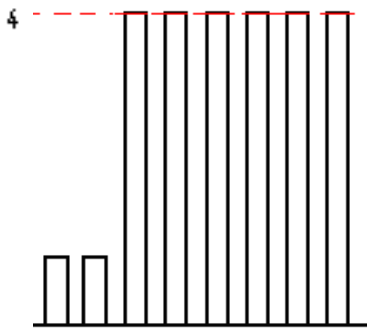
Population A

	Goods	Poverty Gap
P1	1	.75
P2	1	.75
P3	3	.25
P4	4	0
P5	4	0
P6	4	0

Population B

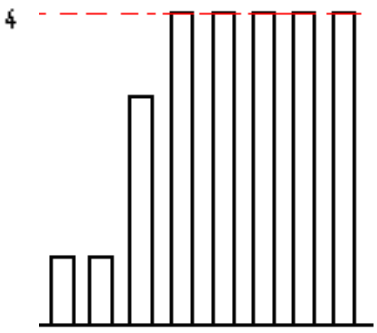
Intuitively, moving from population A to population B increases poverty. For, P3 can no longer secure what he/she needs in population B. The SST index gets the right result in this case.[16] The SST in population A is 0.4166 = 0.3333*0.75*(1+0.6667). The SST in B is 0.4652 = 0.5*0.5833*(1+0.5952). Since 0.4652 > 0.4166, poverty increases in B.[17]

Consider, however, what happens if two additional people who can meet their needs are added to each population. Let us call the new (resulting) populations C and D, respectively.



P1 P2 P3 P4 P5 P6 P7 P8

Population C



P1 P2 P3 P4 P5 P6 P7 P8

Population D

16 On the index, changes in poverty are a function of the per cent change in the headcount, the per cent change in the poverty gap index for the poor, and the per cent change in (1+ the Gini coefficient of the poverty gaps).

17 In A, H = 0.3333 = 2/6. In B, H = 0.5 = 3/6. In A, I^P = 0.75 = (0.75+0.75)/2. In B, I^P = 0.5833 (0.75+0.75+0.25)/3. In A, I = 0.25 = 1.5/6. In B, I = 0.2917 = 1.75/6. The Gini in population A is 0.6667 = 12/(2*36*0.25) The Gini in population B is 0.5952 = 12.5/(2*36*0.2917). The sum of (the absolute value of) the differences between each pair of individuals' poverty gaps in population A is 12 = 2*(0.75*8). The sum of (the absolute value of) the differences between each pair of individuals' poverty gaps in population B is 12.5 = 2*(0.75*6 + 0.5*2 + 0.25*3). In each population there are six individuals so the square of the number of individuals in the population is 36.

In both of these populations, P1 and P2 have one unit each, P4-P8 have four units each. In population A, P3 has four units. In population B, P3 has three units. Note that no matter how many units P4-P8 have, their gaps will be equal to 0 since if $y_i > z$, then $x_i = 0$. So the SST would return equivalent results even if the rich were much richer in C or D.

The SST in population C is 0.3281. The SST in population D is 0.3710.[18] Furthermore, recall that the SST in population A was 0.4166 and the SST in population B was 0.4652. So, poverty decreases on the SST moving from A to C or B to D though the only difference is that many more people who are above the poverty line are added to the population in C and D. Even worse, moving from A to D decreases poverty on the SST. It suggests that the increase in poverty due to the fact that P3 falls below the poverty line is swamped by a decrease in poverty due solely to the fact that many more people who are above the poverty line are added to the population.

Furthermore, if one does not find the above examples unintuitive, it is easy to construct other counter examples to the SST.[19] It is possible to generate counter examples by adding much richer people to the population, with a smaller number of people who can barely avoid poverty, or with a greater number of those who become poorer. (I leave the exercise to the reader.)

3.2 Sen's index

Sen's index also suggests that poverty declines when more people who are not poor are added to a population.

This is Sen's index (*S*):

$$S = HI^P(1+G^P) \tag{6}$$

The only difference between Sen's index and the SST is that, rather than G, Sen's index includes G^P, the Gini of the poverty gap ratios *for the poor only:*

$$G^P = \frac{\sum_{i=1}^{n^P}\sum_{j=1}^{n^P} | x_i^P - x_j^P |}{2(n^P)^2 I^P} \tag{7}$$

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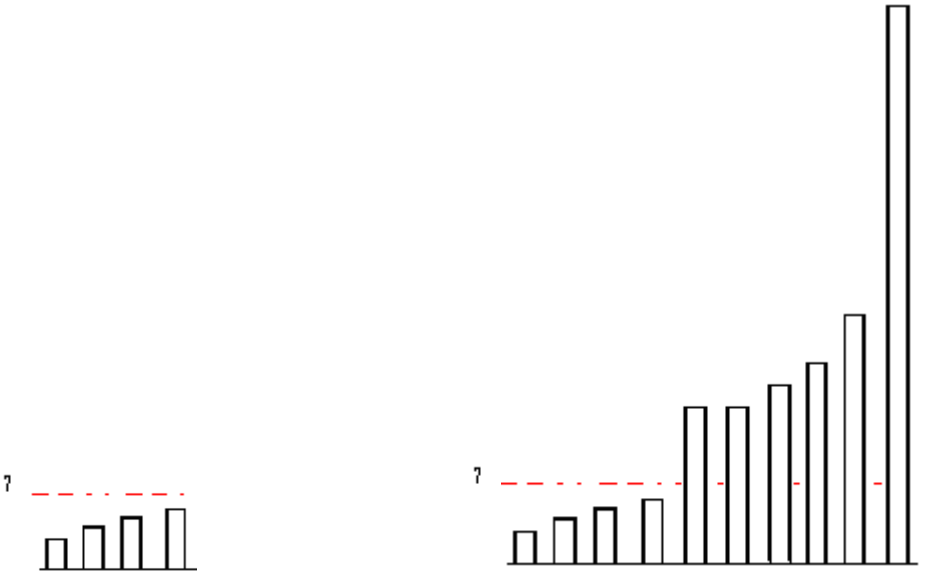
18 In C, H = 0.25 = 2/8. In D, H = 0.375 = 3/8. In C, I^P = 0.75 = 1.5/2. In D, I^P = 0.5833 = 1.75/3. In C, I = 0.1875 = 1.5/8. In D, I = 0.2188 = 1.75/8. So the Gini in population C is 0.75 = 18/(2*64*0.1875). The Gini in population in D is 0.6963 = 19.5/(2*64*0.2188). The sum of (the absolute value of) the differences between each pair of individuals' poverty gaps in population C is 18 = ((0.75*6)*2)*2. The sum of (the absolute value of) the differences between each pair of individuals' poverty gaps in population D is 19.5 = (((0.75*5)*2)+(0.5*2)+(0.25*5))*2. In each population there are 8 individuals so the square of the number of individuals in the population is 64.

19 Consider what happens, for instance, if there are six people with one unit of good and two people with three units in population A but one of the people with three units looses a unit in population B.

Note that G^P only takes the sum of the absolute value of the differences between the gaps between all pairs of poor individuals in a population. It then divides the result by the square of the number of poor individuals in the population n^P (rather than n) and the poverty gap index for the poor only I^P (rather than I).[20]

It is easy to see why S fails to satisfy the 'no mere addition axiom'. Because I^P is just $1/n^P$ times the sum of the gaps amongst the poor, it is unchanged by the addition of a rich person. Because G^P just relies on the sum of the gaps amongst the poor, I^P, and the number of poor, it is also unchanged by the addition of a rich person. So the only change in S is due to H. Because adding a rich person to the population increases the total number of people in the population but does not change the number of poor people, H declines. So, S declines.

Consider an example modified from Xu and Osberg (1999) on which the amount of poverty S suggests there is in a population change just because more people who are not poor are added to the population. Suppose, again, there are two populations E and F (again it does not matter how much the rich have since if $y_i > z$ then $x_i = 0$):



P1 P2 P3 P4 — Population E

P1 P2 P3 P4 P5 P6 P7 P8 P9 P10 — Population F

[20] Because he wants his measure to be ordinal, Sen suggests ranking individuals according to their incomes and uses the relative rank to calculate the poverty gap index and Gini. Forster, Greer and Thorbecke (1997) argue that because Sen uses individuals' ordinal rank as a way of approximating the gap, an increase in poverty in a subgroup of the population will not necessarily increase poverty in the population even holding everything else equal. So, Forster, Greer and Thorbecke (1997) go on to provide an alternative that can satisfy the transfer axiom. The only difference they suggest is weighting not on the basis of ordinal rank, but on the basis of how far below the line a person falls. The examples below assume cardinal comparisons are possible in utilizing the index, though similar results will hold with only ordinal comparisons.

The only difference between population E and F is that there are 6 extra people who are above the poverty line in population F. Here is the amount of goods each person has and their poverty gap in the two populations:

	Goods	Poverty Gap
P1	3	.5714
P2	4	.4286
P3	5	.2857
P4	6	.1429

Population E

	Goods	Poverty Gap
P1	3	.5714
P2	4	.4286
P3	5	.2857
P4	6	.1429
P5	14	0
P6	14	0
P7	16	0
P8	18	0
P9	27	0
P10	55	0

Population F

In population E, the Sen index is 0.4464 = 1*0.3571*(1+0.2500). In population F, the Sen index is 0.1786 = 0.4*0.3571*(1+0.2500).[21] So, on Sen's index, poverty decreases in F just because more people who are not poor are added to the population.[22] So S fails to satisfy the no mere addition axiom.

3.3 The FGT index

One might initially think the problem with the SST and Sen's indexes stems from the fact that they include a measure of inequality in their evaluation of poverty. Indexes need not include a measure of inequality, however, to violate the no mere addition axiom.[23] Other popular indexes, such as the FGT, also violate the no mere addition axiom. At least some well-known members of the FGT class (e.g., *H*) do not include a measure of inequality. Consider the FGT index.

$$FGT = 1/n(\sum_{i=1}^{n} x_i^a) \tag{8}$$

When a = 0 this is H, when a = 1 it is I, and when a > 1 it is a weighted poverty gap index for the whole population. Recall that x_i = 0 when y_i > z. So $\sum_{i=1}^{n} x_i^a$ is unchanged by the mere addition of a rich person to a population. Because the addition of a rich

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[21] In population E, H is 1 = 4/4. In population F, H is 0.4. = 4/10. In both populations, I^P is 0.3571 = (0.5714+0.4286+0.2857+0.1429)/4. In both populations, the Gini is 0.2500 = ((0.5714-0.4286)+(0.5714-0.2857)+(0.5714-0.1429)+(0.4286-0.2857)+(0.4286-0.1429)+(0.2857-0.1429))*2)/(2*16*0.3571).

[22] Note that the SST returns the same measure for population E but that it is 0.2429 in F (0.4*3571*(1+0.7000)). Its results are only slightly less bad in this population.

[23] So, the Gini in A is higher than B but poverty is lower because I^P is greater (I^P is so much greater that it even compensates for the fact that H is lower in A as well).

person increases *n*, however, poverty declines on the FGT when the only change is that a rich person is added to the population. Consider a few examples.[24] When $a = 2$, the FGT suggests that poverty is less in C than A and B. It also suggests that poverty is less in D than B. It even suggests that poverty is less in D than in A.[25] The FGT violates the no mere addition axiom and indexes need not include a measure of inequality to violate the axiom.

The above reflections are significant. They suggest that common poverty indexes get wrong intuitively compelling judgements about how poverty is changing in different states of the world. For, people are born, die, and migrate in almost every real world population where economists try to measure poverty.

One might object that it does not matter what an index calls poverty. These indexes may be measuring how it is best to fulfil need more generally. Perhaps this is what some intend to indicate by calling some (other) measures 'ethical' indexes of poverty (Bossert 1990).

It is implausible to interpret the standard poverty indexes in this way. At least Sen's index is clearly intended as a descriptive measure of poverty. He explicitly denies that he is trying to provide a measure of how it is best to fulfil need (Sen 1976). Furthermore, these indexes would suffer from closely related problems if taken as measures of how it is best to fulfil need. They would suggest using resources to bring more rich people into a population rather than to help those who are below the poverty line even when this does not, in itself, fulfil need. The indexes would suggest that bringing rich people into a population is desirable even when their wealth neither trickles down to the poor nor is redistributed.[26]

The paper's general lesson may be that indexes that seem plausible in fixed population contexts may fail in variable population contexts.[27]

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24 Consider how the FGT with $a = 2$, for instance, suggests that poverty changes in populations A-D above. (I leave examples of how the FGT with other values of a violates the no mere addition axiom to the reader). In population A, the index suggests that poverty is 0.1875 = (0.752+0.752)/6. In population B, the index suggests that poverty is 0.1979 = (0.752+0.752+0.252)/6. In population C, the index suggests that poverty is 0.1406 = (0.752+0.752)/8. In population D, the index suggests that poverty is 0.1484 = (0.752+0.752+0.252)/8.

25 Atkinson (1987) suggests that there is a general class of additive poverty measures including the FGT and Watts.

26 Note, the modified index suggested below is not intended as a metric of how it is best to fulfil need. Although it would not have this implication, it would share with some of the other indexes an even worse implication—it would suggest that it is possible to fulfil need by killing off poor people. Though there would be less poverty in the world if poor people were killed, that is not a reason to kill the poor. Using any metric for policy purposes will require at least a modicum of good judgement. See discussion below.

27 It is possible to provide some impossibility results that draw into question axioms intended for both fixed and variable population contexts using the No Mere Addition Axiom and others (Kundu and Smith 1983; Subramanian 2002; Hassoun and Subramanian 2010).

4 Towards a better measure of poverty

It is possible to modify some of the above indexes so that they satisfy the no mere addition axiom. This section illustrates this modification with the FGT. This paper is not the first to suggest this modification. See, for instance, Lambert (2002). It will go further, however, to explain how this modified index can account for some of the intuitions motivating Sen's index (and probably the SST).

The problem with the indexes this paper has considered comes from the fact that they are normalized; dividing by the number of people in the population.[28] To avoid the problem, one can modify the indexes so that they do not divide by the number of people in the population.[29] In this case, *H* would be transformed into a measure of the number of poor people in the population:

$$n \tag{9}$$

I would just become the aggregate gap index:

$$\sum_{i=1}^{n} x_i \tag{10}$$

More generally, the FGT would be replaced by the weighted aggregate gap index.

$$\sum_{i=1}^{n} x_i^a \tag{11}$$

This index will only register an increase in poverty when the population of poor people changes or their gaps increase. It is intuitive, however, that poverty increases if a person who starts out above the poverty line becomes poor or a new poor person is added to a population. It is also intuitive that poverty should decrease if a poor person moves above the poverty line.

The weighted aggregate gap index with $a = 2$, for instance, does not get obviously unintuitive results in populations A-F. It suggests that there is more poverty in B than A. It suggests that the amount of poverty in populations B and D, A and C, and E and F are equal.[30]

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28 Perhaps there is room for an index that divides by the number of people in a population. Such an index might provide a very rough and ready measure of how difficult it will be to alleviate poverty in a population. This is a different matter, however, than determining how much poverty there is in a population (though, these things are often related).

29 Without this modification, other problems also arise. On *H*, for instance, a population that is initially composed entirely of poor individuals can have no more poverty in it. So adding a poor person to the population will not increase poverty (Subramanian 2002).

30 Settling on a measure of poverty does not in itself have any policy implications. If, for instance, policymakers were concerned to treat all countries equally, they might just look at the average depth of poverty in a country in deciding where to direct aid, rather than the total amount of poverty. See discussion below.

If $a>1$ the weighted aggregate gap index can also account for the concern for distribution amongst the poor underlying the SST and Sen's index. These versions of the weighted aggregate gap index will account for at least some of the motivation for the indexes this paper has considered. These versions of the weighted aggregate gap index even satisfy a (restricted) version of the transfer axiom which motivated Sen to provide his own proposal (Sen 1976; Donaldson and Weymark 1986). *Ceteris paribus*, poverty will increase if goods are transferred from a poor person to a less poor one as long as both remain below the threshold. For a given amount of good will, *ceteris perabus*, alleviate less need for a person who is less poor. (If this assumption does not hold, the index may not satisfy the restricted transfer axiom, but there is little reason to think that it should in that case.)

One might object by appeal to Sen's work in defence of the unrestricted transfer axiom. The unrestricted transfer axiom applies even when a given amount of good will not alleviate less need for a person who is less poor. According to Foster (1984) and Zheng (1997), Sen gives two lines of reasoning in favour of the unrestricted transfer axiom. First, he appeals to the fact of declining marginal utility. Second, Sen defends the unrestricted transfer axiom by suggesting that relative deprivation increases with regressive transfers.

Even if it is important to take declining marginal utility (or its analogue if poverty is deprivation in a different space, e.g., capabilities) into account, it is not clear that Sen's index accurately captures the rate at which marginal utility (or whatever) declines. It is not clear, that is, that it gives the right amount of weight to the needs of the less well-off. The weighted aggregate gap index might be better because it can be 'fine tuned' to some degree to give more or less weight to the needs of the less well-off. Further, insofar as one is concerned only with absolute poverty, there is also reason to worry about Sen's second line of defence.[31] So, further defence of the unrestricted transfer axiom is necessary. It may provide a better criterion for an account of social welfare than poverty.

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31 There are some good objections to common relative measures of poverty. On many relative measures, poverty can increase even if absolute deprivation decreases or is completely eliminated. Poverty can increase if, for instance, the rich gain more than the poor. This is implausible. Furthermore, many relative measures implausibly suggest that a population where the worst off person fares as well as Bill Gates can contain some poverty. Even if a relative measure suggests that it is possible to eliminate poverty by reducing inequality (e.g., if people must have more than half of the median income to avoid poverty), it can have this consequence. Bill Gates' income may be less than half of the median income in the above example. It is better to say that poverty is a matter of absolute deprivation. This is not to say that the standards for someone to count as poor must be independent of all social considerations (Sen 1999). It may cost more to secure goods, for instance, in a relatively rich population as demand for those goods may rise (Sen 1999; Smith 1776). Alternately, more expensive goods may be necessary to fulfil basic social roles essential to avoiding such deprivation. As Adam Smith (1776: 351-2) suggested, in 16th century England, a linen shirt might have been necessary to appear without shame in public and, hence, to avoid poverty. Of course, for this paper's inquiry to be important the alternative 'absolute' measures of poverty cannot be formulated so as to satisfy the no mere addition axiom by definition. For one formulation on which this seems to be the case, see Blackorby and Donaldson (1980).

A different objection is that on the proposed way of modifying the above poverty indexes, they suggest poverty will decline if poor people die. So, they might suggest decreasing poverty by killing the poor (Kanbur and Mukherjee 2007; Kanbur 2006).[32]

It would certainly be a bad thing if an index suggested decreasing poverty by killing the poor.[33] Fortunately, the modified indexes are not intended as metrics of how it is best to fulfil need. Though there would be less poverty in the world if poor people were killed, that is not a reason to kill the poor. Using any metric for policy purposes will require at least a modicum of good judgement.

This paper has suggested that if one is just concerned to measure poverty, there is reason to prefer an index that is not normalized like the weighted aggregate gap index with $a>1$ over the SST, Sen, and some other aggregate gap indexes, like the unmodified FGT. It argued, that the weighted aggregate gap index, in particular, has some further advantages. It is sensitive to the distribution of goods amongst the poor in at least one sense—greater need matters more on the index. This index even satisfies a restricted version of the transfer axiom, which motivated Sen to provide his own proposal.

That is not to say that indexes that are not normalized, like the weighted aggregate gap index account for all of the axioms that motivated the creators of the traditional indexes. The justification for these axioms certainly merits consideration because, even with descriptive indexes, 'the choice of the index must ultimately depend on the purpose for which such a measure is sought' (Sen 1981: 190). Nevertheless, some of the axioms may be better captured in an index of social welfare and a good index of social welfare has to take into account more than just poverty. There is a lot of room for further research.

5 Conclusion

This paper suggested that several traditional poverty indexes fail to provide compelling measures of something that can reasonably be called poverty because, it argued, they do not satisfy the no mere addition axiom. Finally, the paper considered a way of modifying indexes to satisfy the no mere addition axiom. It illustrated with the FGT and argued that the resulting weighted aggregate gap index, with appropriately specified parameters, has some additional advantages. It noted, however, that even this index may not do for all policy purposes. So, there is reason to do further research on poverty indexes and axioms in variable population contexts.

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32 The only objection I am aware of to using the weighted aggregate gap indexes, in particular, is that they are impractical as they can range from zero to infinity (Paxton 2003: 3). I am not sure, however, why this makes the indexes impractical in the real world with finite populations. Paxton's suggested alternative scales the weighted aggregate gap indexes by the log of the number of poor people in a population divided by the total number of poor people. It is not clear, however, that this scaling is justified. Why care about the percentage of poor people in a country that are being helped at a decreasing rate? Some justification here is necessary.

33 Furthermore, many poverty indexes give similar results including those this paper has considered, although there is some good work on how to avoid it (Kanbur and Mukherjee 2007).

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