Income poverty measurement in India: Defining group-specific poverty lines or taking preferences into account?*

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Abstract

We study absolute income poverty measurement when households differ in preferences and face different prices. The difficulty arising from price heterogeneity is typically solved using equivalent income, but the choice of the reference price vector remains arbitrary. We provide a way to solve this arbitrariness problem by making the poverty measure consistent with preferences: a household qualifies as poor if and only if she prefers the poverty line bundle to her current consumption bundle. We then prove that defining group/region specific poverty lines is another way of recovering consistency with preferences, provided one uses the headcount ratio. Comparing the resulting three approaches using Indian data, we show that the different approaches lead to different poverty conclusions. We find that not taking preferences into account leads to severely underestimating urban poverty.

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1 Introduction and background

Measuring poverty is a key component of the evaluation of policies aiming at improving the well-being of the worse off in society. How to measure poverty, however, has been under debate over many decades. The theory of poverty measurement was pioneered by Sen (1976).[1] A common challenge the theory of income poverty measurement is faced with is that of measuring poverty when prices and preferences vary. Measuring income poverty in a country with varying prices across regions requires a comparison of incomes giving rise to different budgets, that is different opportunities to buy goods. In general, this implies to choose a poverty line bundle or a criterion to define the poverty line, and to define region-specific poverty line incomes as the incomes that are needed to afford this bundle or criterion given the prices in the region. This creates two well-known problems.

The first problem is that people who like a good quite a lot and live in a region in which this good is relatively cheap may be better-off than people having exactly the same preferences, a larger income, but living in a region in which this good is relatively expensive. To put it differently, we don't have a monotonic relationship between incomes and well-being: a household can at the same time be poorer in income but better-off than another household who has the same preferences but lives in another region and faces different prices (see, for instance, Roberts (1980)).[2]

[1] For a recent and comprehensive overview of the debates about poverty lines, see Ravallion (2016) Part2-Chapter 4.

[2] The problem is even worse if the objective is to measure global poverty or to make comparisons across countries. Indeed, differential evolutions of the value of currency units

A solution to this problem is grounded on Samuelson and Swamy (1974)'s proposal to measure price-deflated income changes in a way that is consistent with utility changes. This is done as follows. One and only one reference price vector is defined. Then, for each household, an equivalent income is computed, having the property that each consumer is indifferent between facing actual prices with her actual income or facing the reference prices with that equivalent income. The immediate consequence of this correction is that expenditure functions have to be estimated, making the exercise of measuring poverty much more difficult (and demanding on the data). Another consequence is that a new problem arises: how to choose the reference price vector? In the absence of a clear theory of how to do it, this choice remains arbitrary (for a complete review, see Fleurbaey (2009)).

The second problem is that income poverty so defined is inconsistent with poverty defined in terms of satisfaction of the preferences in the following sense: a household may qualify as poor and at the same time strictly prefer her actual bundle to the poverty line bundle. This inconsistency could imply that alleviating poverty becomes a fight of which poor people themselves disapprove.

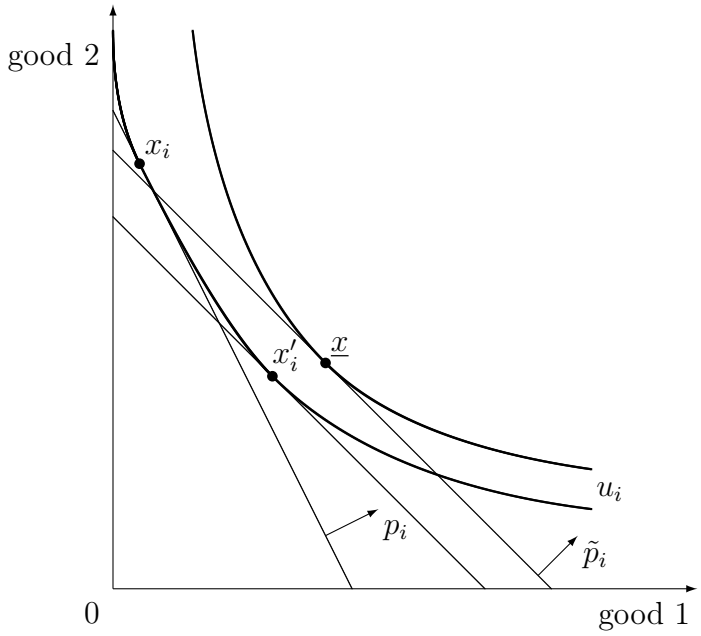
In this paper, we propose a solution to this second problem that also solves the arbitrariness difficulty associated with the equivalent income solution to the first problem. This solution is based on the idea that a household is identified as poor if and only if s/he strictly prefers the poverty line bundle to his/her actual bundle. Therefore, the household-specific poverty line income is the monetary value of the poverty line bundle at prices such that the poverty line bundle is precisely the demand of the household. This household-specific price vector is also the one that should be used to evaluate the equivalent income of the household below the poverty line. This solution amounts to construct interpersonal well-being comparability by assuming that well-being is the same across households at the poverty line bundle.[3] From this well-being comparability at one point we deduce comparability everywhere by relying on the supporting price vector at that point and using it to compute household incomes everywhere.

typically affects the relative prices of tradble goods versus non-tradable ones, which raises the difficult question of the measurement of purchasing power parities (PPP). For a detailed presentation of this question and a proposed solution, see World Bank (2016).

[3]The observation that poverty lines provide a way to anchor well-being comparisons traces back to at least Blackorby and Donaldson (1987).

Our proposal is illustrated in Figure 1. Household i, whose utility function u_i is represented by two indifference curves, has an income y_i, faces price vector p_i and consumes bundle x_i (with $y_i = p_i x_i$). The poverty line is computed by reference to the poverty line bundle $\underline{x}$, which this household strictly prefers to her actual consumption x_i. The individualized price vector that will be used to evaluate this household is $\tilde{p}_i$, which, as the figure shows, is proportional to the household's marginal rate of substitution at $\underline{x}$. Bundle x_i' gives the same utility level to this household as her actual bundle x_i and, moreover, has the property that it is her demand at prices $\tilde{p}_i$. The contribution to poverty of this household is then a function of $\frac{\tilde{p}_i x_i'}{\tilde{p}_i \underline{x}}$.

Figure 1 Our proposal: evaluate equivalent income with individualized reference prices proportional to the marginal rate of substitution at the poverty line bundle.



Then, we relax the assumption of a common poverty line bundle and explore whether defining group-specific poverty line bundles could also solve the two problems. Our main result is that the answer is yes, provided poverty line bundles are appropriately chosen, provided they are not only group but also region-specific, and, finally, provided the poverty index that is used to ag-

gregate incomes is the headcount ratio. We draw the conclusion that there are three possible approaches to measure income poverty - price insensitive poverty measure with individualised reference prices, price insensitive poverty measure with a common reference price, and price sensitive poverty measure. We compare these approaches on Indian data using four socio-demographic groups (young-urban, young-rural, old-urban, old-rural) and a poverty bundle consisting of cereals, vegetables, clothing, and fuel. We find that taking preferences into account the way we suggest to do it leads to different poverty conclusions than the other two approaches. In particular, not taking preferences into account leads to severely underestimating urban poverty, indicating that their preferences over the poverty bundle matters.

We make two main contributions to the literature. The first contribution is guiding the choice of the reference price. The equivalent income approach has been popular in the 1970s and 80s, however critiques raised over time lead to a slowdown (see Fleurbaey (2009) and Ravallion (2016) for an overview). One of the key criticisms was that the choice of the reference price is arbitrary and equivalent income functions depend on this (Roberts; 1980; King; 1983; Slesnick; 1991). A known way to ensure that the social welfare function is independent of these reference parameters, is to impose severe restrictions like homothetic preferences. There have also been other reference price suggestions in the literature, though they rely on a common reference price for all households and are often not based on a theoretical foundation, a commonly used reference price being the sample mean price. Ravallion and van de Walle (1991) gives an alternative way to choose the reference price suggesting that it can be chosen such that the equivalent income function is concave in money incomes and determines the conditions for the AIDS demand system. However, they acknowledge that one still has to check if the social welfare ordering is sensitive to the choice of the sample mean price and the suggested reference price. They do not find a big difference in their application.

The choice of the reference price in other equivalent income applications is also not trivial, for example, King (1983) and Almås and Kjelsrud (2017).

The second contribution is to show that group and region specific poverty lines is another way to take preferences into account under certain conditions. We show that price-sensitive poverty measures will fail to satisfy our axioms unless poverty line bundles are regional and preference specific and

the headcount ratio is used. The Indian poverty measurement debates highlight the need for separate poverty lines based on variation in consumption across different states (Lakdawala et al.; 1993; Radhakrishna and Ray; 2005; Ray and Sinha; 2014; Rangarajan et al.; 2014). We contribute to this discussion by suggesting a potential way of doing this. The idea of several poverty lines has been studied before with Greer and Thorbecke (1986) suggesting a new method to take into account heterogenous regional prices and dietary preferences. Their cost-of-calories approach defines Engel curves for each subgroup (defined over regions or other characteristics) such that the prices faced and preferences are the same within a subgroup but different across. This method is restricted to food poverty and gives rise to multiple regional poverty lines. Another paper that studies group-specific poverty lines though from a different point of view is Mogstad et al. (2007). They acknowledge inter-regional price heterogeneity, but their objective is to measure relative poverty and the main reason why they define specific poverty lines is because they consider that needs depend on the level of consumption of the community to which households belong. We stick to the measurement of absolute poverty.

The remainder of the paper is organized as follows. In Section 2.1 and 2.2, we present the model and the classical approach of price sensitive poverty measurement. In Section 2.3, we present the classical price insensitive approach and our individualised reference price approach. In Section 2.4, we prove that defining group and region-specific poverty line bundles is another way of respecting preferences and satisfying consistency with preference poverty. In Section 3, we present an illustration by applying the theory to Indian data. In Section 4, we give some concluding comments. The Supplementary Materials contains details of the empirical illustration and the proofs.

2 Poverty measures

2.1 The model

Measuring poverty requires first to identify the poor. In the frame of income poverty measurement, this requires to compare one's income with an income threshold. Such a threshold is computed with reference to the money value

of a poverty line bundle given regional prices. As we would like to make this poverty line bundle vary, we need to formalize it and make the poverty threshold depend on these bundles. Then, the heterogeneity in the prices households face will be dealt with by looking at equivalent incomes, that is the incomes that leave households indifferent between their current situations and facing different prices. This requires that preferences, or the utility functions representing them, be also part of the picture. As a result, we arrive at the following framework.

There are ℓ goods. Each household's consumption set is $X = \mathbb{R}^{\ell}_{+}$. There is a set N of households. For household $i \in N$, we let $x_i \in X$ denote household i's consumption bundle, $p_i \in \mathbb{R}^{\ell}_{+}$ denote the price vector facing i, and $u_i \in \mathcal{U}$ denote a utility function representing i's preferences. We let $\mathcal{U}$ denote the set of utility functions representing preferences that are differentiable on the interior of X, monotonic (in the sense that an increase in the vector of goods increases utility, and a strict increase in all the goods increases utility strictly) and convex. Monotonicity and convexity are classical restrictions. We add differentiability because we need that marginal rates of substitution be uniquely defined at all relevant bundles.

The (economic) situation of household $i \in N$ is a triple $s_i = (x_i, p_i, u_i) \in X \times \mathbb{R}^{\ell}_{+} \times \mathcal{U}$. We further restrict our attention to bundles that are equilibrium bundles given the prices, that is, situation $s_i = (x_i, p_i, u_i)$ is a valid situation if and only if x_i is the demand bundle of v i given the prices she faces, that is,

$$x_i = \arg \max_{p_i x \leq p_i x_i} u_i(x). \tag{1}$$

Let $\mathcal{S}_i$ denote the set of possible household situations of household $i \in N$. An *economy* is a list of household situations, one per household, $s = (s_i|_{i \in N}) \in \mathcal{S} = \prod_{i \in N} \mathcal{S}_i$.

Measuring poverty requires us to define three functions: an income construction function, an income poverty line function, and an income poverty index. Let us begin with an informal description of each of them. The first step in measuring income poverty consists in estimating the incomes of the households. It can be done by simply evaluating the money value of their consumption, but, as the literature has widely discussed, there are better ways of doing it. The many ways of constructing incomes is captured by the income construction function. The second step is the identification step.

Given their income, do households qualify as poor or not? This is determined by comparing an household's income to a poverty line *income*. How the latter is constructed is summarized in an income poverty line function. The third and final step consists in aggregating poor households' contributions to aggregate poverty. This is what the income poverty index achieves. Of course, an income poverty index is required to satisfy formal properties such as the ones introduced by Sen (1976). We will only list very few of them given that what we prove in this paper about income poverty indices is valid for all those that satisfy this limited set of properties.

Formally, an *income construction function* $Y : \mathcal{S} \to \mathbb{R}_+^N$ transforms household situations into comparable incomes. An *income poverty line function* $\underline{y} : \mathcal{S} \to \mathbb{R}_+^N$ transforms household situations into an income threshold below which the household is poor and above which the household is non-poor. Finally, an *income poverty index* is a function $\Pi : \mathbb{R}_+^N \to \mathbb{R}$ that satisfies the following properties: there exists an income threshold, which we normalize to 1, such that income changes above that threshold do not affect poverty, poverty strictly decreases if an household's income increases from below to above the threshold, and income poverty does not increase if the income of a poor household increases. Formally, for all $y = (y_i|_{i\in N}), y' = (y'_i|_{i\in N}) \in \mathbb{R}_+^N$, for all $j \in N$, if $y_i = y'_i$ for all $i \neq j$, then

$$1 \leq y_j < y'_j \quad \Rightarrow \quad \Pi(y) = \Pi(y') \tag{2}$$

$$y_j < 1 < y'_j \quad \Rightarrow \quad \Pi(y) > \Pi(y') \tag{3}$$

$$y_j < y'_j < 1 \quad \Rightarrow \quad \Pi(y) \geq \Pi(y'). \tag{4}$$

The best-known income poverty indices are the headcount ratio and the poverty gap ratio. However, as we will show in Section 3.4, the axioms we will impose on the poverty measure will be satisfied by one of the approaches we discuss (namely the price-sensitive approach) only if the index is the headcount ratio.[4] Observe that the arguments of the Π function are numbers: each household is represented by one number. This is the role of the Y and $\underline{y}$ functions to reduce the situation $s_i = (x_i, p_i, u_i)$ of an household into a number (the ratio between her income and the poverty income threshold).

We now gather all the ingredients introduced up to now and we define a poverty measure. The arguments of a poverty measure are the consumptions

[4]The axiomatic properties of the FGT indices have been studied, among others, by Foster and Shorrocks (1991) and Ebert and Moyes (1991). For a survey, see Zheng (1997))

of the households, the price vectors they face, and their household utility functions. These arguments are treated using the three functions that we defined. We obtain the following definition.

Definition 1 *A* poverty measure *is a function* $P : \mathcal{S} \to \mathbb{R}_+$ *such that there exists an income construction function* $Y : \mathcal{S} \to \mathbb{R}_+^N$*, an income poverty line function* $\underline{y} : \mathcal{S} \to \mathbb{R}_+^N$ *and an income poverty index* $\Pi : \mathbb{R}_+^N \to \mathbb{R}$ *such that for all* $s = ((x_i, p_i, u_i)|_{i \in N}) \in \mathcal{S}$*,*

$$P(s) = \Pi \left(\frac{Y(x_i, p_i, u_i)}{\underline{y}(x_i, p_i, u_i)} |_{i \in N} \right).$$

2.2 Price sensitive poverty measures

The first poverty measures we introduce are the ones that do not correct for the heterogeneity in prices, and that define income thresholds with respect to a common poverty bundle $\underline{x}$. That is, they apply the income poverty index to the ratio between households' actual incomes, or total expenditures, that is $Y(s_i) = p_i x_i$, and the money value of the poverty line bundle evaluated at households' actual prices, that is $\underline{y}(s_i) = p_i \underline{x}$.

Definition 2 *A* price-sensitive poverty measure *is a poverty measure* $P^S : \mathcal{S} \to \mathbb{R}_+$ *such that for all* $s = ((x_i, p_i, u_i)|_{i \in N}) \in \mathcal{S}$*,*

$$P^S(s) = \Pi \left(\frac{p_i x_i}{p_i \underline{x}} |_{i \in N} \right).$$

The fundamental difficulty with price-sensitive poverty measures is that they fail to measure poverty in a way that is consistent with households' preferences. That is, it may be the case that poverty increases after a change in one poor householdl's situation that makes her strictly better off. The following axiom requires that this paradox be avoided, that is, it requires that an increase in one household's utility cannot bring about an increase in poverty. Our first lemma recalls the well-known fact that *price-sensitive poverty measure* are unable to avoid the paradox.

Axiom 1 *A poverty measure* respects preferences *if and only if for all* $s = ((x_i, p_i, u_i)|_{i \in N}), s' = ((x'_i, p'_i, u_i)|_{i \in N}) \in \mathcal{S}$*, if* $(x_i, p_i, u_i) = (x'_i, p'_i, u_i) \, \forall i \neq j$*,*

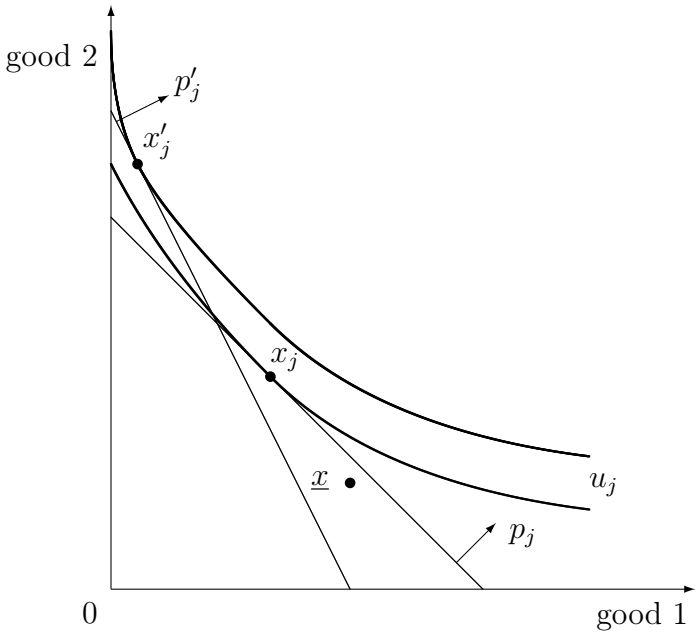
for some $j \in N$ *such that* $Y(x'_j, p'_j, u_j) < \underline{y}(x'_j, p'_j, u_j)$*, then*

$$u_j(x'_j) > u_j(x_j) \quad \Rightarrow \quad P(s) \geq P(s'). \tag{5}$$

Lemma 1 *A* price-sensitive poverty measure P^S *does not* respect preferences.

This is illustrated in Figure 2. Let us assume that $(x_i, p_i) = (x'_i, p'_i)$ for all households $i \neq j$, and household j faces price vector p_j in one situation, consuming x_j, and p'_j in another situation, consuming x'_j. The two indifference curves through those consumption bundles are drawn, and we can see that $u_j(x'_j) > u_j(x_j)$. We would expect poverty to be larger at x_j, but it is not the case. Indeed, prices are such that $p_j x_j > p_j \underline{x}$, so that household j does even not qualify as poor at x_j, whereas she qualifies as poor at x'_j, because $p'_j x'_j < p'_j \underline{x}$. By property (2) of the income poverty index, $P(s) < P(s')$, in violation of what the axiom of *respect of preferences* requires.

Figure 2 A price-sensitive poverty measure does not respect preferences: $u_j(x'_j) > u_j(x_j)$, whereas $P\left((x_i, p_i, u_i)_{i \neq j}, (x_j, p_j, u_j)\right) < P\left((x_i, p_i, u_i)_{i \neq j}, (x'_j, p'_j, u_j)\right)$.

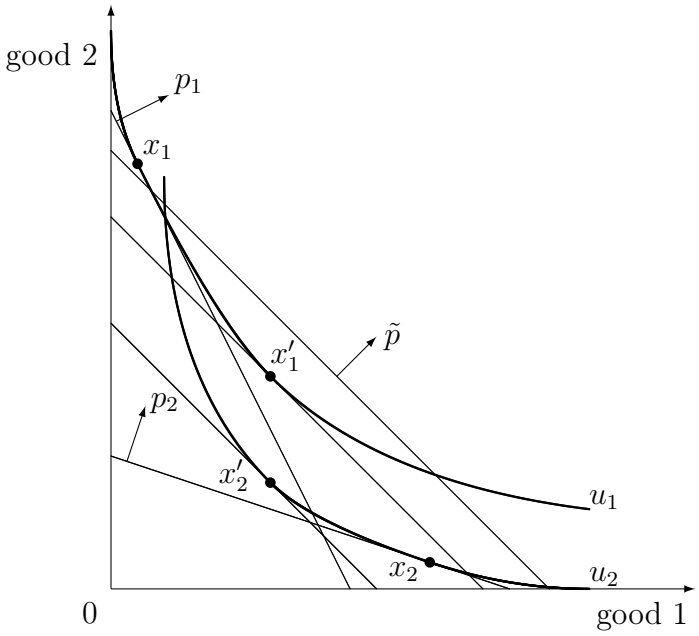


In our terminology, the current Indian methodology, which we briefly present in Section 3.1 below and which we discuss in detail in Section 5 of the Supplementary material, leads to a price-sensitive poverty measure, with which preferences are violated in 15% of pairwise poverty comparisons (see below for the estimation of preferences). The methodology takes different consumption patterns and regional prices into account in the definition of the income poverty line, but given what we try to achieve in this paper, the key problem in the Indian case is that the actual prices households face are the ones that are used to compute and compare their incomes.

2.3 Price insensitive poverty measures

We now turn to price-insensitive poverty measures. The general idea consists in transforming each household situation into an equivalent income, which does not depend on the actual prices but respects preferences. The typical way of constructing equivalent incomes is by fixing some exogenous price vector, $\tilde{p} \in \mathbb{R}^{\ell}_{+}$, and compute the income that, at price $\tilde{p}$, is sufficient to leave the household indifferent to her actual consumption. This is illustrated in Figure 3 in the case of two households with different preferences.

Figure 3 A price-insensitive poverty measure: a common reference price vector $\tilde{p}$ is used to compute equivalent incomes at x'_1 and x'_2 rather than at x_1 and x_2.



The corresponding formal definition of the income construction function uses the concept of an expenditure function (called a cost function by some authors). Given some price vector $p \in \mathbb{R}^{\ell}_{+}$ and some utility level u, the expenditure function tells us the minimal amount of expenses $e_i(p, u)$ that household i needs to spend at prices p to reach utility u. The second type of poverty measure we are interested in requires to define the income construction function $Y^{I\tilde{p}}$ by computing, for each household, the minimal expenditure needed to reach her actual utility level at some common price vector $\tilde{p}$, that is

$$Y^{I\tilde{p}}(x_i, p_i, u_i) = e_i(\tilde{p}, u_i(x_i)), \tag{6}$$

and to define an income poverty line function by applying the same reference price vector to the poverty line bundle so as to compute the income poverty line, that is,

$$\underline{y}^{I\tilde{p}}(x_i, p_i, u_i) = \tilde{p}\underline{x}. \tag{7}$$

That gives us the following poverty measures.

Definition 3 *Let $\tilde{p} \in \mathbb{R}^{\ell}_{+}$. A* price-insensitive poverty measure indexed by $\tilde{p}$ *is a poverty measure $P^{I\tilde{p}} : \mathcal{S} \to \mathbb{R}_{+}$ such that for all $s = ((x_i, p_i, u_i)|_{i\in N}) \in \mathcal{S}$,*

$$P^{I\tilde{p}}(s) = \Pi\left(\frac{e_i(\tilde{p}, u_i(x_i))}{\tilde{p}\underline{x}}|_{i\in N}\right).$$

Let us note that it is customary to call $e_i(\tilde{p}, u_i(x_i))$ household i's money-metric utility or i's equivalent income.

A price-insensitive poverty measure indexed by $\tilde{p}$ clearly respects preferences. It is transparent from the fact that expenditure functions are themselves numerical representations of preferences. Then, properties (2), (3) and (4) guarantee that an increase in an household's utility cannot increase poverty.

The question that now arises is the one of the choice of $\tilde{p}$. As proven by Blackorby and Donaldson (1988), different price vectors lead to different poverty measures. The resulting poverty measures face a problem of arbitrariness, which does not seem to have received satisfactory solutions.

We propose to solve the arbitrariness problem by dropping the idea that the reference price should be the same for all households. What is key for a poverty measure to respect preferences is that the reference price vector is independent of the actual prices. It is not necessary, though, to compute equivalent incomes by using the same reference price vector for all households. If we index the reference price vector to make it household specific, we obtain the following definition.

Definition 4 *Let $\tilde{p}_i \in \mathbb{R}^{\ell}_{+}$ for each $i \in N$. A* price-insensitive poverty measure indexed by individualized $\tilde{p}_i$ *is a poverty measure $P^{I\tilde{p}_i} : \mathcal{S} \to \mathbb{R}_{+}$ such that for all $s = ((x_i, p_i, u_i)|_{i\in N}) \in \mathcal{S}$,*

$$P^{I\tilde{p}_i}(s) = \Pi\left(\frac{e_i(\tilde{p}_i, u_i(x_i))}{\tilde{p}_i\underline{x}}|_{i\in N}\right).$$

Price-insensitive poverty measures indexed by individualized $\tilde{p}_i$ clearly respect preferences. Now, the family of such measures is larger than the family of price-insensitive poverty measures indexed by a unique price vector $\tilde{p}$. This larger family, however, allows us to single out a poverty measure, by imposing the following axiom. It requires consistency between income poverty and preference poverty. A household is income poor if the income poverty line

$\underline{y}$ is larger than her equivalent income, computed by using a reference price vector. A household is preference poor if she prefers the poverty line bundle $\underline{x}$ to her actual consumption. The axiom contains two requirements. The first requirement is reminiscent of Sen's focus axiom. If the equivalent income of a household who prefers her consumption bundle over the poverty line bundle increases, then poverty should remain unaffected. This means that households who would lose in terms of utility exchanging their bundle with the poverty line bundle should not qualify as poor. The second requirement is a monotonicity requirement. If an household's situation changes in such a way that the initial situation is strictly worse than the poverty line bundle according to this households' preferences and the final situation is strictly better than the poverty line bundle, then poverty must have decreased. Formally,

Axiom 2 Consistency with Preference Poverty
For all $s = ((x_i, p_i, u_i)|_{i\in N}), s' = ((x'_i, p'_i, u_i)|_{i\in N}) \in \mathcal{S}$, *if* $(x_i, p_i, u_i) = (x'_i, p'_i, u_i)\, \forall i \neq j$, *for some* $j \in N$, *then*

$$u_j(x_j) > u_j(x'_j) \geq u_j(\underline{x}) \quad \Rightarrow \quad P(s) = P(s') \tag{8}$$
$$u_j(x_j) > u_j(\underline{x}) > u_j(x'_j) \quad \Rightarrow \quad P(s) < P(s'). \tag{9}$$

Many poverty measures satisfy this requirement, even if they are not price insensitive (see, for instance, the poverty measures of Decancq et al. (2019)). There is one and only one way for a price-insensitive poverty measures indexed by individualized $\tilde{p}_i$ to satisfy it. It consists in defining the individualized reference prices $\tilde{p}_i$ as proportional to households' marginal rates of substitution at $\underline{x}$. To put it differently, $\tilde{p}_i$ should be the price vector having the property that $\underline{x}$ is household i's best bundle when household i maximizes u_i facing prices $\tilde{p}_i$ with income $\tilde{p}_i\underline{x}$.

This gives us the following result. The detailed proof can be found in Appendix 2 of the Supplementary Materials.

Theorem 1 *A* price-insensitive poverty measure indexed by individualized $\tilde{p}_i$ *satisfies* Consistency with Preferences Poverty *if and only if all* $i \in N$, $\tilde{p}_i$ *satisfies: for all* $x_i \in X$,

$$u_i(\underline{x}) \geq u_i(x_i) \Leftrightarrow \tilde{p}_i\underline{x} \geq \tilde{p}_i x_i. \tag{10}$$

□

In conclusion, the best way to have a poverty measure that respects preferences and that avoids the arbitrariness of the choice of a reference price vector consists of first choosing an income poverty index, let us call it Π, a poverty line bundle $\underline{x}$, and then, for each household $i \in N$, compute a price vector $\tilde{p}_i$ that is proportional to the marginal rates of substitution at $\underline{x}$, and compute the corresponding price-insensitive poverty measure indexed by individualized prices.

2.4 Group-specific poverty lines

As discussed in Section 1, the need for separate poverty lines based on variation in consumption across different regions has long been debated by Indian poverty measurement Expert Groups. It is argued that the poverty line should vary across groups, in order to capture different needs or consumption habits. This sounds like a competing way of facing price variations and acknowledging heterogeneity of preferences. In this section, we would like to compare it with our way to take price and preference heterogeneity into account through price-insensitive poverty measures using individualized reference price vectors. The question we raise is the following: do price-sensitive and/or price insensitive poverty measures with a common reference price satisfy the axioms of *Respect of Preferences* and *Consistency with Preferences Poverty* when the poverty lines are allowed to be group and/or region specific?

In order to address this issue, we need to give more structure to our economic situations. We now assume that there is a set G of socio-demographic groups (characterized by gender, age, etc.) and a set R of regions. The assumptions are that all households belonging to the same group have the same preferences, and all households living in the same region face the same price vector. Therefore, we will refer to the situation of household $i \in N$ belonging to group $g(i) \in G$ and living in region $r(i) \in R$ as $s_i = (x_i, p_i, u_i) = (x_i, p_{r(i)}, u_{g(i)}) \in S_i$. We study the consequence of assuming that for all group $g \in G$ and region $r \in R$, there exists a specific poverty bundle $\underline{x}_{gr} \in X$.

We first need to redefine our poverty measures to allow the poverty line to be group and/or region specific.

Definition 5 *A group specific poverty line price-insensitive poverty measure indexed by $\tilde{p}$ is a poverty measure $P^{gI\tilde{p}} : \mathcal{S} \to \mathbb{R}_+$ such that for all $s = ((x_i, p_i, u_i)|_{i\in N}) \in \mathcal{S}$,*

$$P^{gI\tilde{p}}(s) = \Pi\left(\frac{e_i(\tilde{p}, u_i(x_i))}{\tilde{p}\underline{x}_{g(i)}}|_{i\in N}\right).$$

Note that this definition does not impose any restriction on the way the $\underline{x}_g$ are chosen, $g \in G$.

Definition 6 *A group/region specific poverty line price-sensitive poverty measure is a poverty measure $P^{grS} : \mathcal{S} \to \mathbb{R}_+$ such that for all $s = ((x_i, p_i, u_i)|_{i\in N})$ $\in \mathcal{S}$,*

$$P^{grS}(s) = \Pi\left(\frac{p_i x_i}{p_i \underline{x}_{g(i)r(i)}}|_{i\in N}\right).$$

Again, this definition does not impose any restriction on the way the $\underline{x}_{gr}$ are chosen, $g \in G$.

We now state the main result of the paper (proof in Appendix 2 of the Supplementary Materials) that gives us the answer to the question we raised: do price-sensitive and/or price insensitive poverty measures with a common reference price satisfy the axioms of *Respect of Preferences* and *Consistency with Preferences Poverty* when the poverty lines are allowed to be group and/or region specific?

The answer is yes, provided some conditions are satisfied. In the case of a price-insensitive measure with a common reference price vector $\tilde{p}$, the poverty line bundles have to differ across groups. For each group, the poverty line bundle, $\underline{x}_{g(i)}$, needs to be the exact demand of households of this group at the reference price vector (condition a) in the theorem).

In the case of a price-sensitive measure, the poverty line bundles have to differ both across regions and across groups. Within a group, the poverty lines in the different regions simply have to give the same utility level to the households of the group (condition b)1. in the theorem). Moreover, the poverty line bundle associated to a precise group in a precise region, $\underline{x}_{g(i)r(i)}$, needs to be the exact demand of households of this group given the price vector of this region (condition b)2. in the theorem). Moreover,

poverty measures are required to use the headcount ratio poverty index in order to satisfy the axioms (condition b)3. in the theorem). Indeed, by not making the measure sensitive to increases in preference satisfaction below the poverty line, the headcount ratio is the only way for a price sensitive measure to guarantee that poverty conclusions will not go against household satisfaction.

Theorem 2 *a) A* group specific poverty line price-insensitive poverty measure indexed by $\tilde{p}$ $P^{gI\tilde{p}}$ *satisfies* Consistency with Preferences Poverty *if and only if for all* $i \in N$*,*

$$\underline{x}_{g(i)} = \arg \max_{\tilde{p}x \leq \tilde{p}\underline{x}_{g(i)}} u_i(x). \tag{11}$$

b) A group/region specific poverty line price-sensitive poverty measure P^{grS} Respects Preferences *and satisfies* Consistency with Preferences Poverty *if and only if*

1. *for all* $g \in G$ *and* $r, r' \in R$*,*

$$u_g(\underline{x}_{gr}) = u_g(\underline{x}_{gr'}) \tag{12}$$

2. *for all* $i \in N$*,*

$$\underline{x}_{g(i)r(i)} = \arg \max_{p_{r(i)}x \leq p_{r(i)}\underline{x}_{g(i)r(i)}} u_{g(i)}(x) \tag{13}$$

   and

3. Π *is the headcount ratio.*

□

Theorem 2 may be interpreted as a negative result about price-sensitive poverty measures, because the headcount ratio has the drawback of being insensitive to changes in income of poor households staying below the poverty line. This theorem, therefore, shows the limit of price-sensitive measures of income poverty. The first part of the theorem, on the contrary, shows that price-insensitive measures do not have this drawback.

In Appendix 3 of the Supplementary Materials, we comment on the close relationship between Theorem 2 and results in the literature about welfare ratios, concave social welfare functions, and the true cost-of-living indices.

We need to insist again on the degree of freedom that is left in the definition of the group and group/region specific poverty line bundles. If we apply $P^{gI\tilde{p}}$, then the axiom is satisfied for all $\underline{x}_g$ satisfying Eq. 11 so that no restriction is imposed on the relationship between the different $\underline{x}_g$, $g \in G$. If we apply P^{grS}, on the other hand, the choice of the poverty line bundles is constrained within each group $g \in G$ according to Eq. 12, but, again, no restriction is imposed across groups.

In conclusion, we report in Table 1 the extent to which the different possible approaches satisfy the two axioms of *Respect for Preferences* and *Consistency with Preferences Poverty* as a function of whether the poverty line bundles are allowed to depend on the groups or the regions.

Table 1 Ability of the poverty measures to satisfy the axioms, as a function of the nature of the poverty line bundle

	Resp. of Pref.	Cons. with Well-Being
$P^{I\tilde{p}_i}$, with $\underline{x}$	yes	yes
$P^{I\tilde{p}}$, with $\underline{x}$	yes	no
$P^{I\tilde{p}}$, with $\underline{x}_g$	yes	yes
P^S, with $\underline{x}$	no	no
P^S, with $\underline{x}_{rg}$	yes if Π is the HC	yes if Π is the HC

Before we switch to the application, we need to fix the group and group/region specific poverty line bundles. Our strategy will be to choose them in a way that minimizes the difference among the resulting poverty measures. Any remaining difference will underline the consequences of choosing one approach or another.

Let us assume that a global poverty line bundle $\underline{x}$ is given. This is the current situation. First, if the $\underline{x}_g$ are chosen such that

$$u_g(\underline{x}_g) = u_g(\underline{x}), \forall\, g \in G,$$

and if the $\underline{x}_{gr}$ are chosen such that

$$u_g(\underline{x}_{gr}) = u_g(\underline{x}), \forall\, g \in G, \forall\, r \in R,$$

then it is routine to check that $P^{gI\tilde{p}} = P^{grS} = P^{I\tilde{p}_i}$, provided Π is the headcount ratio.[5] This comes from the fact that the combination of *Consistency with Preferences Poverty* and the headcount ratio clearly leads to a unique way of measuring poverty when the poverty line bundles are chosen to be indifferent to a common $\underline{x}$: the poverty measure should be equal to the fraction of people who prefer $\underline{x}$ over their actual bundle. At the risk of stressing something obvious, we may mention that the role played by incomes and income measurement is minimal in this approach. Observing the bundles households consume and their preferences become the only necessary ingredients to compute poverty. Of course, preferences are not observable and need to be estimated. In the following section we will use demand systems to estimate preferences, and that will be the only role prices and incomes will play.

There are two other approaches to the measurement of income poverty. The second approach consists in applying a *price-insensitive poverty measure* with a common poverty line. The resulting measure *Respects Preferences* but does not satisfy *Consistency with Preferences Poverty*. Moreover, it faces the arbitrariness of the choice of the reference price vector. The third approach consists of applying the *price-sensitive poverty measure*, which does not satisfy any of the axioms. In the application we develop in the next section, we compare these three approaches. In order to make them as close to each other as possible, we adopt the headcount ratio. Our strategy then consists in comparing the sub-populations that are identified as poor according to the three approaches.

Theorems 1 and 2 have been proven under the assumption that there was one poverty line bundle, the same for all households. We show in Appendix 4 of the Supplementary Materials how to generalize our results to the case of multiple poverty line bundles. This is relevant given the way income poverty lines are determined in India implies that several poverty lines be defined (more details in Appendix 5 of the Supplementary Materials).

[5] If Π is not the headcount ratio, then $P^{gI\tilde{p}} \neq P^{grS} \neq P^{I\tilde{p}_i} \neq P^{gI\tilde{p}}$, in spite of the fact that both $P^{I\tilde{p}_i}$ and $P^{gI\tilde{p}}$ *Respect Preferences*.

3 Illustration: income poverty in India

3.1 Data

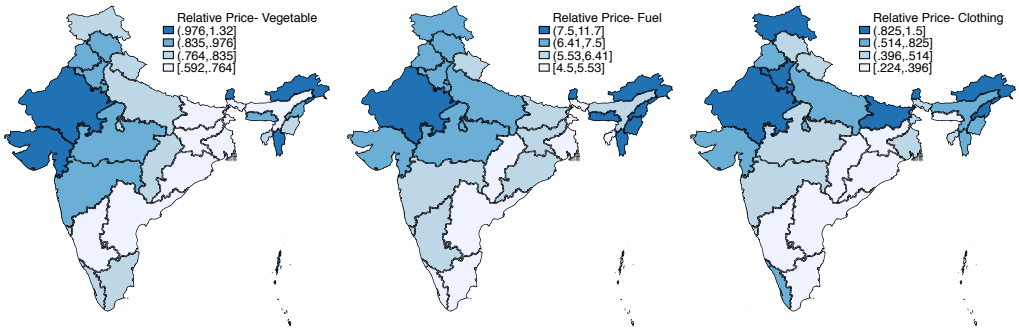
We compare the three approaches (prise sensitive, price insensitive with common reference price, price insensitive with individualized reference price) by applying them to Indian data from the 61^{th}(2004-05) round of the Consumer Expenditure Survey (CES). The dataset contains household level consumption (quantity and expenditure) data on a variety of goods. Given that we observe consumption only at the household level, we treat the household as a unitary unit and compare households of similar composition and size by restricting our sample to households with three to five members.

As we are concerned with measuring income poverty, we focus on a basket of marketable goods containing both food and non-food dimensions. Our basket contains - cereals, vegetables, fuel, and clothing. In our subsample, the total expenditure on these four goods is 45% of the total expenditure on all goods (often used as a proxy for total income). Corresponding to Section 2, we create x_i, y_i, w_i vectors that denote the consumption, total expenditure, budget share vector respectively for household i. More details on the dataset and variables is provided in Appendix 6 of the Supplementary Materials.

For the identification of preferences, price variation is key. We exploit the price variation across the 70 regions of India, where a region is the rural or urban sector of each of the 35 states. As before all households living in the same region face the same price vector and for household i living in region $r(i)$ the price vector is denoted by $p_{r(i)}$. To construct these price vectors we follow the methodology proposed by Deaton and Dupriez (2011) of calculating item level unit values and correcting them for potential quality selection. Figure 4 shows substantial price variation across the different states of India for the three goods in our basket relative to the price of cereal.

The second key element for our methodology is preferences. Given that we assume that all households in the same group have the same preference, we choose the groups such that the assumption is likely to be valid while offering sufficient between group heterogeneity in preferences. We use sector (rural/urban) and age of household head (young/old) to create four preference groups, where young (old) is defined as those below (above) the age of

Figure 4 Relative prices (with respect to cereal) across India



50. Our sample is well distributed across the four groups, as shown in Table 2, allowing the estimation of preferences by group.

Table 2 Sample Size

Full	Young-Rural	Young-Urban	Old-Rural	Old-Urban
64,497	28,948	17,130	11,329	7,090

We fix the poverty line bundle, $\underline{x}$, following a procedure similar to that proposed by Rangarajan (2014) for the official Indian poverty measurement. The aim is to allow for comparison of different approaches to poverty measurement. For the food dimensions, cereal and vegetables, we take the average household monthly expenditure in the fifth quantile (the quantile at which the nutritional norm is met in the Indian methodology) of the income distribution and calculate the quantity consumed at average prices. The non-food dimensions, fuel and clothing, are set at the median values.

Table 3 Poverty bundle

	Cereal	Vegetable	Clothing	Fuel
Quantity of good	41	18	4.5	174

where the quantity of cereal, vegetable, clothing, fuel are expressed in the unit of kilogram, kilogram, piece, piece, respectively.

3.2 Estimation of the preferences

Given the detailed self-reported consumption data and regional price variation available to us, estimating preference using demand systems is the most attractive method. We use the Almost Ideal Demand System (AIDS) introduced by Deaton and Muellbauer (1980) which gives for household i belonging to group g the budget share of good ℓ as :

$$w_{ig}^{\ell} = \alpha_{ig}^{\ell} + \sum_{k \in I} \gamma_{ig}^{\ell k} log(p_{r(i)}^{k}) + \beta_{ig}^{\ell} log\left[\frac{y_{ig}}{a(p)}\right], \ell \in I$$

where α, β, γ are the parameters to be estimated, y is the total expenditure on all the goods in the system, p^k the price of good k, and $a(p)$ is the price index given by

$$log(a(p)) = \alpha_0 + \sum_{k \in I} \alpha^k log(p_{r(i)}^{k}) + \frac{1}{2} \sum_{\ell \in I} \sum_{k \in I} \gamma_{ig}^{\ell k} log(p_{r(i)}^{\ell}) log(p_{r(i)}^{k})$$

The AIDS is an attractive demand system for us as it accounts for cross price elasticities and the parameters can be restricted such that it satisfies the properties - homogeneity of degree zero in p and y, Slutsky symmetry, and adding up. One property that is does not guarantee is that of negative-semi-definiteness of the Slutsky matrix. However, this property is crucial for our methodology as we evaluate the marginal rate of substitution at specific bundles. We use the method proposed by Moschini (1998) and Ryan and Wales (1998) to impose negative-semi-definiteness at a specific point. Further details on the estimation is provided in Appendix 6 of the Supplementary Materials.

We estimate this system separately for each of the four groups to obtain heterogeneous preference parameters. To tackle the issue of autocorrelation between the demand equations, we use the nonlinear seemingly unrelated regression (NLSUR) (see, for example, Poi (2008)). In Table 2 in Appendix 6 we present the estimates of the parameters α, β, and, τ for each group. We find that most parameters are precisely estimated and they are often significantly different between the groups.

3.3 Results

In this section, we apply the three different poverty measurement approaches discussed in this paper to our data and compare who they identify as poor. Before we enter into the details, we should come back to the main objective of our inquiry in order to avoid a possible misunderstanding of the results. We do not plan to draw direct conclusions on who is poor in India. We plan to draw conclusions on how different the answer to this question may be when one uses one method or another. Any weaknesses of the data we use affect all three measures in the same way. Therefore, our conclusions about how the identification of the poor differs across measures is likely to be immune to these weaknesses. What is at stake here, is that different groups of households have different preferences, which we capture in our estimates, and the differences in poverty we will identify only come from the approach of taking preferences into account.

We begin with the first approach, which we implement by computing individualized reference price vectors and the associated equivalent incomes. The reference price vector is the price faced by the household such that her demand is exactly the poverty bundle, $\underline{x}$, given her preferences. For household i belonging to group $g(i)$, the reference price vector $\tilde{p}_{g(i)}$ is the vector solving

$$x_i(\tilde{p}_{g(i)}, \underline{x}\tilde{p}_{g(i)}) = \underline{x}$$

where $x_i(\cdot,\cdot)$ is to the demand function of i. Table 4 presents these vectors for the four groups. It can be noted that they vary across groups.

Table 4 Reference Price

	Young-Rural	Young-Urban	Old-Rural	Old-Urban
Cereal	2.78	1.72	2.78	1.67
Vegetable	0.79	0.59	0.78	0.74
Clothing	0.91	0.72	0.94	0.95
Fuel	1	1	1	1

Finally, we evaluate the equivalent income such that the household is indifferent between her actual situation and facing the reference price. We evaluate

this for each household using the following equation of the indirect utility function,

$$v_i(p_{r(i)}, y_i) = v_i(\tilde{p}_{g(i)}, e_i(\tilde{p}_{g(i)}, u_{g(i)}(x_i)))$$

where $v_i(\cdot, \cdot)$ stand for i's indirect utility function (derived from the estimation of the demand system).

Similarly, for the second approach, we evaluate the equivalent income at the common reference price, $\tilde{p}$, denoted by $e_i(\tilde{p}, u_{g(i)}(x_i))$. We pick the mean national price vector as the exogenous common reference price.

Now, we have all the ingredients to compare the different poverty measurement approaches discussed in Table 1. The poverty measure definitions 2, 4, 5, 6 are used with the poverty index as the headcount index, P_0, to allow for comparison. Let $I(.)$ denote an indicator function and N the total sample size. The poverty measures we will evaluate are given by,

$$P_0^{I\tilde{p}_i}(s) = \frac{1}{N} \sum_{i=1}^{N} I(e_i(\tilde{p}_{g(i)}, u_{g(i)}(x_i)) < \tilde{p}_{g(i)}\underline{x})$$

$$P_0^{I\tilde{p}}(s) = \frac{1}{N} \sum_{i=1}^{N} I(e_i(\tilde{p}, u_{g(i)}(x_i)) < \tilde{p}\underline{x})$$

$$P_0^{S}(s) = \frac{1}{N} \sum_{i=1}^{N} I(p_{r(i)}x_i < p_{r(i)}\underline{x})$$

As proven in Theorem 2, the headcount ratio is important because it allows us to stick to a price-sensitive poverty measure and still satisfy the axioms. If we favor price-insensitive measures, though, there is no reason to limit ourselves to the headcount ratio. This is why we also evaluate cumulative poverty gap curves of the four groups (Jenkins and Lambert; 1997) which are created by plotting the cumulated proportion of population on the x-axis and the cumulated per capita poverty gap on the y-axis from the biggest one downwards. These curves provides more information on the poverty rate than the headcount ratio as they capture the incidence, intensity, and inequality

of poverty. We present the results by the three measures for each group in Table 5 and Figure 5.

Using our preferred approach of individualized reference prices, 56% of the sample is identified as poor, with heterogeneity between the groups, i.e., 68% are identified as poor in the Young-Urban group while 41% in the Old-Rural. However, the main take away of our results is that using the different approaches leads to different poverty conclusions. The headcount ratio shows large differences between the individualized and common reference price measures, with all groups having higher rates of 7-14% using the common reference price approach. The price sensitive approach yields smaller differences compared to our new measure. Thus we to explore more than the headcount ratios.

Looking at the cumulative poverty gap curves we find that the individualized reference price measure yields a different poverty ordering of the groups than the other two approaches. Using these two approaches, the curve of Young-Rural is above Old-Urban implying more poverty in the Young-Rural group. On the contrary, the individualized reference price measure identifies the Old-Urban curve above Young-Rural implying more poverty in the Old-Urban group. Second, we find that the Old-Urban group is much more poor compared to Old-Rural by our measure than the other two. Similarly, Young-Urban is poorer than Young-Rural. The height of the curves tell us that the intensity of the poverty gap is greater when using the common reference price measure than our measure for all the four groups.

In conclusion, the way preferences are taken into account proves key in quantifying the poverty of the urban population and the approach we favor leads to a higher estimation of poverty in this population than the other two approaches.

The different conclusions that arise from the three approaches can potentially come from differences in preferences or economic situation. To understand better how much of the differences between the groups come from their different preferences compared to their economic situation, we do the following decomposition exercise.

In Table 8, the columns tell us the price-insensitive individualized poverty rate, keeping the economic situation of that group constant and varying the preference across all the groups. Each row evaluates the poverty rate keep-

Figure 5 Cumulative poverty gap curves

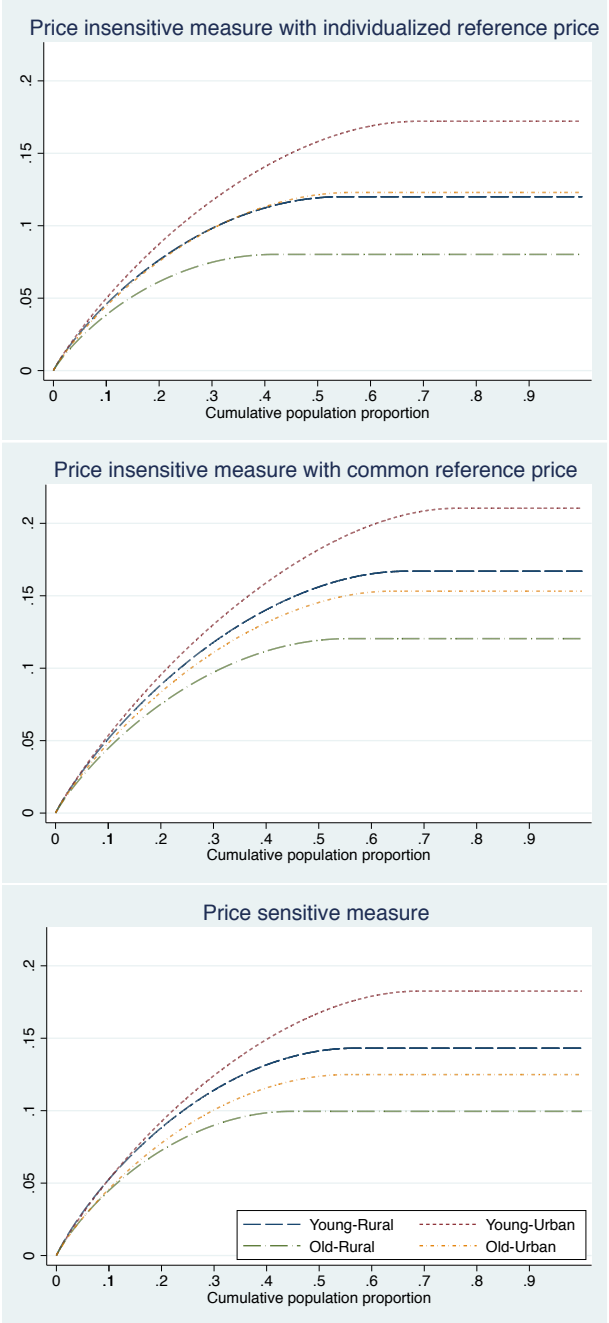


Table 5 Poverty Comparisons

		Full	Young-Rural	Young-Urban	Old-Rural	Old-Urban
$P^{I\tilde{p}_i}$, with $\underline{x}$	No. of poor	36230	15714	11799	4726	3991
	HC ratio	0.561	0.542	0.688	0.417	0.562
	% of poor	1.00	0.433	0.325	0.130	0.110
$P^{I\tilde{p}}$, with $\underline{x}$	No. of poor	43085	19224	13049	6286	4526
	HC ratio	0.668	0.664	0.761	0.554	0.638
	% of poor	1.00	0.446	0.302	0.145	0.105
P^{S}, with $\underline{x}$	No. of poor	37176	16367	11798	5088	3923
	HC ratio	0.576	0.565	0.688	0.449	0.553
	% of poor	1.00	0.440	0.317	0.136	0.105
	Sample Size	64,497	28,948	17,130	11,329	7,090

ing the preference of that group constant and varying the economic situation across all the groups. The second cell of the first row, for instance, tells us that Young-Rural would have a poverty rate of 65.04% if they were living in the current conditions of the Young-Urban. In the columns we see what would happen if each group had exactly the same economic situation, i.e., they would have the same poverty rates according to the price-sensitive approach but not according to our approach, indicating the effect of preferences. Similarly, the rows tell us the effect of the economic situations.

Looking at the first column of the Young-Rural group, we see that in the same economic situation, Young-Urban and Old-Urban preferences would give a higher poverty rate for the Young-Rural group than 0.54. This implies that not taking preferences into account would lead us to overestimate their poverty. Column 3 for the Old-Rural group shows a similar pattern and tells us that the Old-Rural group's poverty is overestimated if preferences are not taken into account. We see from the table that poverty of any urban group is higher than that of any rural group, whatever the economic situation we look at, that is, the first or the third row is dominated by the second or fourth one. That strongly suggests that not taking preferences into account leads to severely underestimating urban poverty.

Table 6 Price and Preference decomposition

vary eco situation / vary preference	Young-Rural	Young-Urban	Old-Rural	Old-Urban
Young-Rural	0.5428	0.6504	0.4217	0.5138
Young-Urban	0.5858	0.6888	0.4653	0.5549
Old-Rural	0.5385	0.6468	0.4172	0.5094
Old-Urban	0.6082	0.6960	0.4892	0.5629

4 Conclusion

We propose in this paper a new way to measure income poverty without relying on arbitrary reference price selection while taking heterogeneous preferences into account. The estimations that are needed to apply our approach, of course, are more demanding than what is required to apply the classical price sensitive measures, but it is the same as a price insensitive measure. Applying our method, we find that not taking preferences into account results in systematically underestimating urban poverty.

Overall suggesting that taking preferences into account the way we do has serious consequences on the identification of the poor, and, therefore, on the design and target of poverty policies. Our analysis, however, has been limited to looking at preferences over four goods and partitioning the population into four groups, potentially capturing only fraction of the existing preference heterogeneity. Much more can be done and much more data should be collected to make it possible to estimate preferences is a much finer way.

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