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Aditi Dimri and François Maniquet

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

Aditi Dimri† François Maniquet‡

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Abstract

We study absolute income poverty measurement when agents 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: an agent 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 find that the different approaches leads to different poverty conclusions. We show that not taking preferences into account leads to severely underestimating urban poverty.

JEL Classification: I32, O15.
Keywords: poverty measurement, prices, heterogeneous preferences.

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†University of Warwick. Corresponding author: Department of Economics, University of Warwick, Coventry, CV4 7AL, United Kingdom; Email: aditidimri@gmail.com.

‡CORE, Université Catholique de Louvain.

1 Introduction

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). In the classical framework, an economy is a set of agents who are each characterized by their income level. An agent is said to be poor if her income falls below some exogenous income threshold, the income poverty line. An income poverty index is a real-valued function defined over the vector of individual incomes, which is insensitive to changes in incomes above the income poverty line. Several desirable properties have been studied and families of poverty indices, such as the class of Foster, Greer, and Thorbecke poverty indices (Foster et al., 1984), have been shown to satisfy them (see, for instance, Foster and Shorrocks (1991), and Ebert and Moyes (1991)). The popular headcount ratio and the poverty gap are examples of such poverty indices (for a survey, see Zheng (1997)).

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 (explicitly or implicitly) choose a poverty line bundle, the same for all individuals, and to define region-specific poverty line incomes as the incomes that are needed to afford this bundle given the prices in the region. We show below that the current way of determining regional poverty line incomes in India corresponds to this methodology. That creates two 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: an individual can be at the same time poorer in income but better-off than another individual who has the same preferences but lives in another region and faces different prices (see, for instance, Roberts (1980)).[1]

[1]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 came soon after Sen's contribution. Incomes have to be adjusted to become price insensitive. This adjustment, initiated by Samuelson and Swamy (1974), is done as follows. One and only one reference price vector is defined. Then, for each individual, 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: an individual 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. 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 aggregate incomes is the headcount ratio. We draw the conclusion that there are three possible approaches to measure income poverty, and we test these on four socio-demographic groups (urban/rural and young/old household head) using Indian data. Our poverty bundle consists of cereals, vegetables, clothing, and fuel. Using the headcount index and TIP curves, we find that taking preferences into account leads to different poverty conclusions than the other two approaches. In particular, not taking preferences into account leads to severely underestimating urban poverty,

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typically affects the relative prices of tradable 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 Report (2016).

indicating that their preferences over the poverty bundle matters. Additionally, the ordering of the TIP curves of the socio-demographic groups change partially using our approach.

A key aspect of our study in this paper is that we find it desirable to measure poverty in such a way that an increase in preference satisfaction should never go together with an increase in poverty. However, taking preferences into account when measuring poverty may look questionable. First, there may be a philosophical stance that individual choices are irrelevant to the definition of well-being. A part of the poverty measurement literature is consistent with this stance (mostly the counting approach developed mainly by Alkire and Foster (2011a,b); Alkire et al. (2015)), which nonetheless, contradicts the classical position of normative economics, embedded in the Pareto principle. Without denying the merits of the counting approach, especially when available data does not allow us to estimate preferences or when time and space price variations make it hard to compare incomes, we choose to embrace the classical position here, without new argument for it. What is underlying our position is that tastes and needs jointly determine what is good to a person. Tastes and needs are revealed by choices. There is good reason, therefore, to believe that if an individual chooses one basket of goods over another one, the well-being of this person is higher with the former basket. Let us add that small individual mistakes or departure from rationality are absorbed in the error term of the econometric estimations. Moreover, these estimations combine the reactions to prices of people above and below the poverty line, to give an average behavior. As will become clear below, what is key for our application will be the estimation of preferences around the poverty line.

The demand of some types of goods, though, is not commanded by the search for a higher welfare. This is the obvious case of temptation (or sin) goods, such as tobacco and alcohol. Ideally, we should, therefore, find the way to estimate what would be the preference satisfaction of each individual, should s/he have a zero demand of these goods. In this paper, we do not enter the difficult methodological questions that such an estimation raises. We would like to note, though, that the groups that we find systematically underrepresented in the poor population when we take preferences into account do not have the largest consumption of temptation goods. Our conclusions, then, would only be reinforced if we were to take temptation goods into account.

Some may argue that choices could be a reason why people fall into or stay in poverty, rendering them not normatively compelling. We disagree with this argument, though, because we interpret recent contributions about choices of the poor as questioning their seeming lack of rationality. The general impression from Banerjee and Duflo (2012, 2007), for instance, is that choices and behavior that look like mistakes at first glance turn out to be rational when the constraints facing agents are clearly identified. Carvalho et al. (2016) recently showed that even the seemingly present bias of poor people may actually be a rational response to liquidity constraints. This kind of evidence supports the assumption that poor people themselves know the constraints they are facing much better than the analyst (or the policy maker) and their choices deserve to be respected. By far the main constraint that they face is the imperfection of capital markets. Given that liquidity constraints do not affect the way people spend their money among the four goods we will be interested in in our application, our results are not affected by these constraints.

Taking preferences into account as we do in this paper turns out to have an interesting normative consequence. The satisfaction level that one needs to reach to escape poverty no longer depends on the region where s/he lives. This amounts to claim that individuals should be compensated for external characteristics (that is the prices) of the region in which they live (for an extensive introduction to the ethics of compensation, see Fleurbaey (2008)). Applying this kind of regional compensation principle to poverty measurement, however, raises the following question: why do people live in regions in which prices are detrimental to their satisfaction, in the sense that other regional price vectors would allow them, given their income, to reach higher satisfaction levels. To put it differently, if individuals are free to move and if they choose to live in a sub-optimal region, should we not hold them responsible for their location instead of compensating them for the prices they face? The reason why we believe that taking individuals responsible for their location is not normatively appealing is that regional price differences are certainly not the main reason why individuals choose where to live. Their ability to earn income, for instance, certainly depends on the region where they live either because they own a plot of land or because of regional specific human capital or imperfections in the labor market. As a result, we believe that compensating for the price vectors individuals face is the relevant normative principle and taking preferences the way we do is a way to satisfy it.

The remainder of the paper is organized as follows. In Section 2, we present the way the region-specific poverty line incomes are currently determined in India. In Section 3, we present the model and the classical approach of price sensitive poverty measurement. We formalize the first problem mentioned above by proving that the classical approach fails to *respect preferences*. In Section 3, we present the equivalent income approach, and we show that it fails to solve the second problem, that is, any poverty measure in this family fails to satisfy a property of *consistency with preference poverty*. We then present our correction of the equivalent income approach that satisfies this property, and, at the same time, solves the arbitrariness problem of the choice of the reference price vector. In Section 5, 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 6, we describe the data. In Section 7, we show how we estimate preferences. In Section 8, we compare the three approaches of income poverty measurement. In Section 9, we give some concluding comments.

2 Fixing the poverty line: The Indian context

In this section, we detail the official Indian poverty measurement methodology. India has a rich history of academic and policy work on poverty measurement that is both nationally and globally relevant (for a good discussion see Deaton and Kozel (2005)). Since the first official recommendation in 1962 on fixing the poverty line, there have been several improvements, though the poverty line dependence on a calorie intake has been a constant feature (see Bandyopadhyay et al. (2010) for more details). Additionally, the large regional price variation across India is a well documented fact and the poverty measurement methodology tries to address this.[2] The current methodology is the one proposed by the Rangarajan (2014) expert group (Rangarajan et al., 2014), which fixes the poverty line as an all-India poverty line bundle valued in monetary terms covering both food and non-food dimensions.

The methodology entails the following steps - first, it establishes the all-India average requirements of calories, proteins and fats based on official nutritional

[2]Deaton and Dupriez (2011) document this variation. The same is reflected in the data we use as shown in Figure 7.

norms. Then a food basket that simultaneously meets all these normative requirements is defined as the food component of the poverty line bundle. This is implemented by finding the quantile of the income distribution that meets these nutrient norms and using their average monthly per capita consumption expenditure on food as the food component of the poverty line. Note that in principle the methodology is fixing on a consumption bundle that meets certain norms. For the non-food dimensions, they propose to use the median values of clothing expenses, rent and education expenses as the normative requirement. For all the remaining non-food dimensions the expenses of the quantile that meets the nutrient norms are added to the poverty line. This gives two poverty line bundles, urban and rural, and the monetary value of this basket gives the national rural and national urban poverty lines. Finally state-specific (i.e., region-specific) poverty line incomes are derived as the income that is needed to afford this bundle given the prices in the region.

As discussed in the Introduction, such an approach leads to two problems, which we address in this paper. Additionally we explore the possibility of region-specific poverty bundles instead of the common national bundle. This is one of the issues being discussed with regard to the current methodology as consumption preferences vary across India along different dimensions. Atkin (2013), for instance, finds huge regional differences in food consumption in India. The current methodology has been criticized for ignoring this large variation in dietary and consumption preferences across India by using an all-India bundle. Ray and Sinha (2014) suggest that - *It would have been more realistic to follow this procedure for each state and region (urban, rural) and fix the poverty line state-wise rather than derive the state poverty lines from the cost of buying the all-India basket of items*. In turn, this is acknowledged by the members of the committee in their clarification response (Rangarajan and Dev, 2014) by stating that the need for separate poverty lines based on variation in consumption of different states has been an issue long known to the various expert committees but remains unsolved. In this paper, we construct the poverty line and prices in a similar way to the official Indian methodology.

3 The model and the classical approach

Following the discussion above, we begin by defining a measure of income poverty, in a way that will allow us to discuss different ingredients we are interested in, that is price heterogeneity and variable poverty line bundles.

There is a non-empty and finite set $N \subset \mathbb{N}$ of agents. There are ℓ private goods. Each agent's consumption set is $X = \mathbb{R}^{\ell}_{+}$. For agent $i \in N$, we let $x_i \in X$ denote agent i's consumption bundle, $p_i \in \Delta^{\ell-1}$ denote the price vector facing i (and $\Delta^{\ell-1}$ denotes the $\ell - 1$ dimensional simplex), 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[3] (that is, for two bundles $x_i, x'_i \in \mathbb{R}^{\ell}_{+}$, if $x_i \leq x'_i$, then $u_i(x'_i) \geq u_i(x_i)$, and if $x_i \ll x'_i$, then $u_i(x'_i) > u_i(x_i)$), and convex.

The (economic) situation of agent $i \in N$ is a triple $s_i = (x_i, p_i, u_i) \in X \times \Delta^{\ell-1} \times \mathcal{U}$. 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 agent 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 individual situations of agent $i \in N$. An *economy* is a list of individual situations, one per agent, $s = (s_i|_{i \in N}) \in \mathcal{S} = \prod_{i \in N} \mathcal{S}_i$.

Measuring poverty requires to define three functions. An *income construction function* $Y : \mathcal{S} \to \mathbb{R}^N_+$ transforms individual situations into comparable incomes. An *income poverty line function* $\underline{y} : \mathcal{S} \to \mathbb{R}^N_+$ transforms individual situations into an income threshold below which the agent is poor and above which the agent 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 agent's income increases from below to above the threshold, and income poverty does not increase if the income of a poor agent increases. Formally, for all

[3] The three vector inequalities are denoted $\leq$, $<$ and $\ll$.

$y = (y_i|_{i\in N}), y' = (y'_i|_{i\in N}) \in \mathbb{R}^N_+$, for all $j \in N$, if $y_i = y'_i$ for all $i \neq j$, then

$$1 \leq y_j < y'_j \;\Rightarrow\; \Pi(y) = \Pi(y') \tag{2}$$
$$y_j < 1 < y'_j \;\Rightarrow\; \Pi(y) > \Pi(y') \tag{3}$$
$$y_j < y'_j < 1 \;\Rightarrow\; \Pi(y) \geq \Pi(y'). \tag{4}$$

The best-known income poverty indices are the headcount ratio and the poverty gap ratio. The headcount ratio simply computes the fraction of the population N who has an income below the line. The poverty gap ratio measures the total amount of income that would be necessary to move all poor agents out of poverty, as a fraction of the total amount of money that is sufficient to have all agents in the population above the line. They both belong to the Foster-Greer-Thorsbeek (FGT) family of indices, defined by

$$\Pi(y) = \frac{1}{N} \sum_{\begin{pmatrix} i \in N \\ y_i < 1 \end{pmatrix}} (1 - y_i)^\alpha$$

in which parameter α represents the degree of income inequality aversion among the poor. The headcount ratio, resp. poverty gap ratio, corresponds to the FGT index with α equal to 0, resp. 1. We do not a priori restrict the choice of the poverty index, even not to the class of FGT indices. However, as we will show in Section 5, the axioms we will impose on the poverty measure will lead us to prefer the headcount ratio.

Definition 1 *A* consumption-price-utility poverty measure*, in short, 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 $s = ((x_i, p_i, u_i)|_{i\in N}) \in \mathcal{S}$,*

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

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 agents' 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 agents' 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 agents' preferences. That is, it may be the case that poverty increases after a change in one poor individual's situation that makes her strictly better off. The following axiom requires that this paradox be avoided.

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* $u_i(x_i') \geq u_i(x_i)$ *for all* $i \in N$ *and* $u_j(x_j') > u_j(x_j)$ *for some* $j \in N$ *such that* $Y(x_j', p_j', u_j) < \underline{y}(x_j', p_j', u_j)$, *then* $P(s) \geq P(s')$.

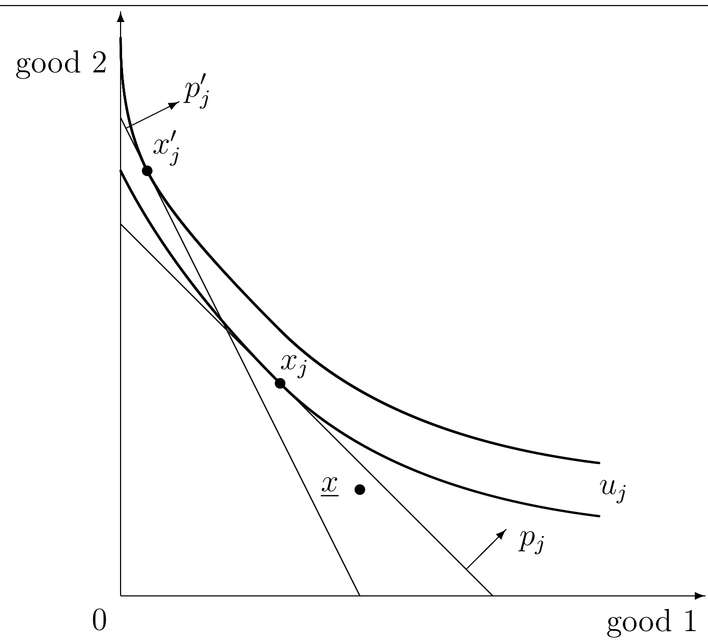
Lemma 1 *A* price-sensitive poverty measure P^S *does not* respect preferences.

This can be illustrated in Figure 1. Let us assume that $(x_i, p_i) = (x_i', p_i')$ for all agents $i \neq j$, and agent 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 agent 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 requires.

4 Price-insensitive poverty measures

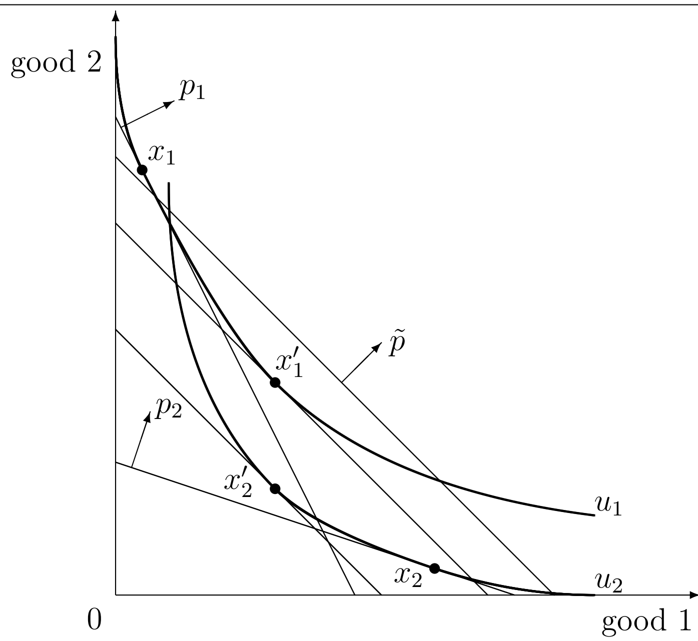
We now turn to price-insensitive poverty measures. The general idea consists in transforming each individual situation into an equivalent income, which

Figure 1 A price-sensitive poverty measure does not respect preferences: $u_j(x'_j) > u_j(x_j)$, whereas $P(x_j, p_j, u_j) < P(x'_j, p'_j, u_j)$.



does not depend on the actual prices but respects preferences. The typical way of constructing equivalent incomes is by fixing some exogenous price vector, $\tilde{p} \in \mathcal{P}$, and compute the income that, at price $\tilde{p}$, is sufficient to leave the agent indifferent to her actual consumption. This is illustrated in Figure 2.

Figure 2 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.



Formally, it corresponds to using the income construction function $Y^{I\tilde{p}}$ defined by

$$Y^{I\tilde{p}}(x_i, p_i, u_i) = e_i(\tilde{p}, u_i(x_i)), \tag{5}$$

where e_i stands for the expenditure function, and an income poverty line function

$$\underline{y}^{I\tilde{p}}(x_i, p_i, u_i) = \tilde{p}\underline{x}. \tag{6}$$

That gives us the following poverty measures, indexed by a reference price vector $\tilde{p}$.

Definition 3 *Let* $\tilde{p} \in \mathcal{P}$. *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* $s = ((x_i, p_i, u_i)|_{i \in N}) \in \mathcal{S}$,

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

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 agent'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 agents. What is key for a poverty measure to respect preferences is that the 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 agents.

Definition 4 *Let* $\tilde{p}_i \in \mathcal{P}$ *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. An agent is income poor if the income poverty line $\underline{y}$ is larger than her equivalent income, computed by using a reference price vector. An agent is preference poor if she prefers the poverty line bundle $\underline{x}$ to her actual consumption. The axiom is defined as follows.

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

$$u_j(x_j) > u_j(x'_j) \geq u_j(\underline{x}) \quad \Rightarrow \quad P(s) = P(s') \tag{7}$$
$$u_j(x_j) > u_j(\underline{x}) > u_j(x'_j) \quad \Rightarrow \quad P(s) < P(s') \tag{8}$$
$$u_j(\underline{x}) \geq u_j(x_j) > u_j(x'_j) \quad \Rightarrow \quad P(s) \leq P(s'). \tag{9}$$

Many poverty measures satisfy this requirement, even if they are not price insensitive. 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 agents' 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 agent i's best bundle when agent i maximizes u_i facing prices $\tilde{p}_i$ with income $\tilde{p}_i\underline{x}$.

It gives us the following result.

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* $x_i \in X$*,*

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

Proof. 1) Let us prove that P satisfies *Consistency with Preferences Poverty* if it is defined as in the statement of the theorem. By differentiability of the u_i's on the interior of X, $\tilde{p}_i$ exists and is unique. Because $e_i(\tilde{p}_i, u(\cdot))$ is a numerical representation of the preferences,

$$e_i(\tilde{p}_i, u_i(x_i)) \leq e_i(\tilde{p}_i, u_i(x'_i)) \Leftrightarrow u_i(x_i) \leq u_i(x'_i).$$

Moreover, Eq. 10 guarantees that

$$e_i(\tilde{p}_i, u_i(x_i)) \leq \tilde{p}_i\underline{x} \Leftrightarrow u_i(x_i) \leq u_i(\underline{x}).$$

Then, (7), (8) and (9) follow from (2), (3) and (4).

2) Let us now prove that if P, a price-insensitive poverty measure indexed by individualized $\tilde{p}_i$, satisfies *Consistency with Preferences Poverty* then $\tilde{p}_i$ satisfies Eq. 10. Assume not. Then, for some $i \in N$, some $u_i \in \mathcal{U}$,

$e_i(\tilde{p}_i, u_i(\underline{x})) < \tilde{p}_i\underline{x}$. Therefore, there exists x_i^* such that $e_i(\tilde{p}_i, u_i(x_i^*)) < \tilde{p}_i\underline{x}$ whereas $u_i(x_i^*) > u_i(\underline{x})$. Let $x_i^{**} \in X$ satisfy $u_i(x_i^{**}) > u_i(x_i^*)$ and $e_i(\tilde{p}_i, u_i(x_i^{**})) > \tilde{p}_i\underline{x}$. Let $s, s' \in \mathcal{S}$ be such that $s_j = s'_j$ for all $j \in N \setminus i$, $s_i = (x_i^*, p_i^*, u_i)$ and $s_i = (x_i^{**}, p_i^{**}, u_i)$, where p_i^* and p_i^{**} are chosen so that condition 1 of the model is satisfied. Because

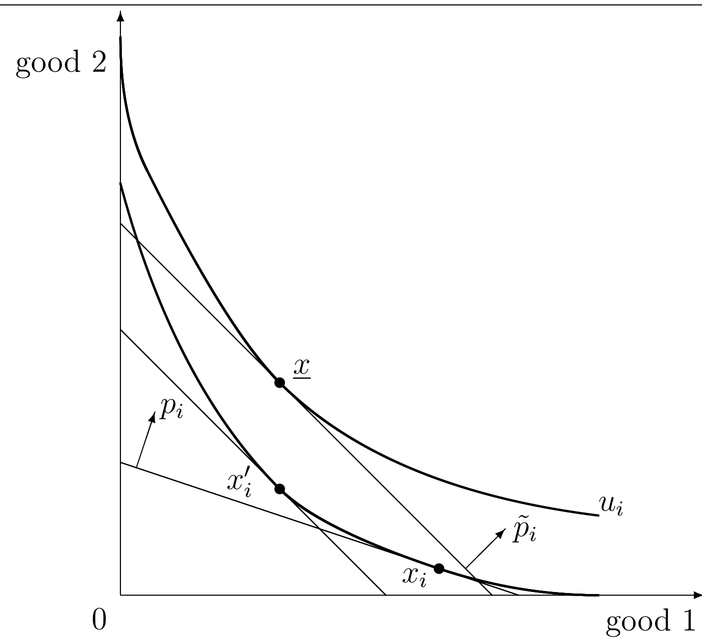
$$e_i(\tilde{p}_i, u_i(x_i^*)) < \tilde{p}_i\underline{x} < e_i(\tilde{p}_i, u_i(x_i^{**})),$$

by (3), $P(s) > P(s')$, whereas, the preference ranking

$$u_i(\underline{x}) < u_i(x_i^*) < u_i(x_i^{**})$$

implies that $P(s) = P(s')$, by (7), a contradiction. ■

Figure 3 Illustration of Theorem 1: agent i's equivalent income at x_i is equal to $\tilde{p}_i x'_i$.



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 in first choosing an income poverty measure, let us call it Π, a poverty line bundle $\underline{x}$, and then, for each agent $i \in N$, compute a price vector $\tilde{p}_i$ that is proportional to the marginal rates of substitution at $\underline{x}$, and compute the poverty measure P^{II} defined as:

$$P^{II}\left(x_i, p_i, u_i|_{i\in N}\right) = \Pi\left(e_i(\tilde{p}_i, u_i(x_i))|_{i\in N}\right). \tag{11}$$

5 Group-specific poverty lines?

Since the recent methodological change in the way of measuring poverty in India, a debated question concerns the definition of the poverty line bundle. It is argued that it should vary across groups, in oder to capture different needs or consumption habits. It 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.

Group-specific poverty lines are discussed by Mogstad et al. (2007) from a different point of view. 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 individuals belong. Taking account of the standard of living of that community calls for specific poverty lines. We stick to the measurement of absolute poverty. Therefore, we study specific poverty lines while keeping the proviso that the income threshold should refer to some equivalent standard of living across all individuals.

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 individuals belonging to the same group have the same preferences, and all individuals living in the same region face the same price vector. Therefore, we will refer to the situation of individual $i \in N$ 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 $\underline{x}_{gr} \in X$. Compared to the proposal that are currently debated, we add the possibility of making the poverty line bundle depend on actual prices as well. As we will see below, this will play a crucial role. 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? The theorem below states that the answer is yes, provided these poverty lines bundles are defined in a very precise way. Moreover, in the case of price sensitive poverty measures, poverty measures are required to use the headcount ratio poverty index in order to satisfy the axioms. 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 individual satisfaction.

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 and prove the main result of the paper.

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* $i \in N$*,*

$$\underline{x}_{g(i)} = \arg \max_{\tilde{p}x \leq \tilde{p}\underline{x}_{g(i)}} u_i(x). \tag{12}$$

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*

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

$$u_g(\underline{x}_{gr}) = u_g(\underline{x}_{gr'}) \tag{13}$$

- *for all* $i \in N$*,*

$$\underline{x}_{g(i)r(i)} = \arg \max_{p_{r(i)}x \leq p_{r(i)}\underline{x}_{g(i)r(i)}} u_{g(i)}(x) \tag{14}$$

  and

- Π *is the headcount ratio.*

Before we prove the theorem, 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. 12 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. 13, but, again, no restriction is imposed across groups.

Proof. The proof of statement a) is straightforward. It is illustrated in Fig. 4. If for all $g \in G$, the group specific poverty lines $\underline{x}_g$ are chosen so that Eq. 12 is satisfied, as illustrated in the figure in the case of two groups, then for any $x_g \in X$, we have $e(\tilde{p}, u_g(x)) \leq \tilde{p}\underline{x}_g$ if and only if $u_g(x) \leq u_g(\underline{x}_g)$ and the axiom follows.

Let us prove statement b) in two steps. First, the necessity of Eq. 13 and 14 is clear and similar to the necessity of Eq. 12. It is illustrated in Fig. 5 in the case of two groups and two regions. The difficult part consists in proving that Π needs to be the Headcount ratio. This is illustrated in Fig. 6. The figure

Figure 4 A price insensitive poverty measure with a common reference price vector $\tilde{p}$ and group specific poverty lines satisfies *Consistency with Preferences Poverty* for appropriately chosen poverty line bundles.

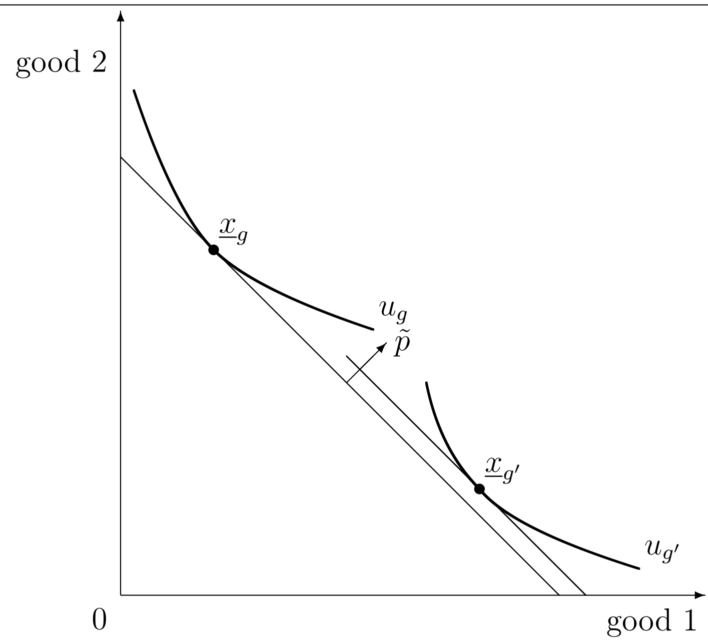
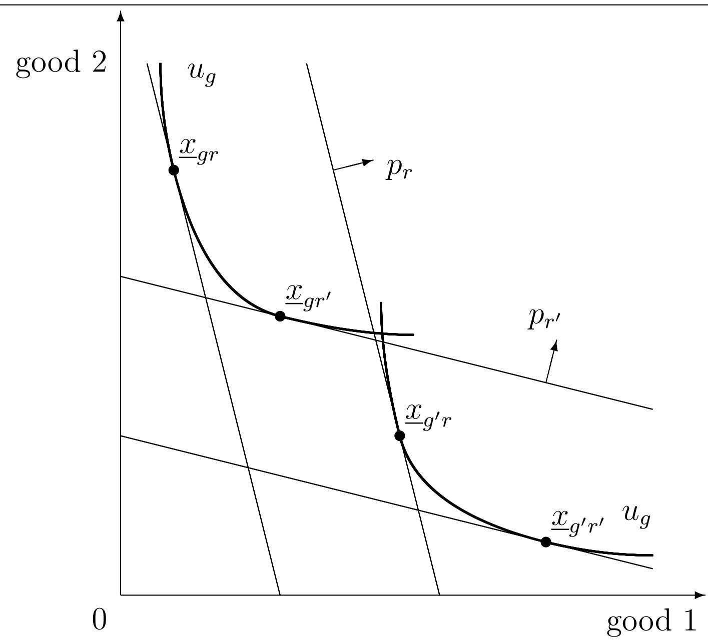
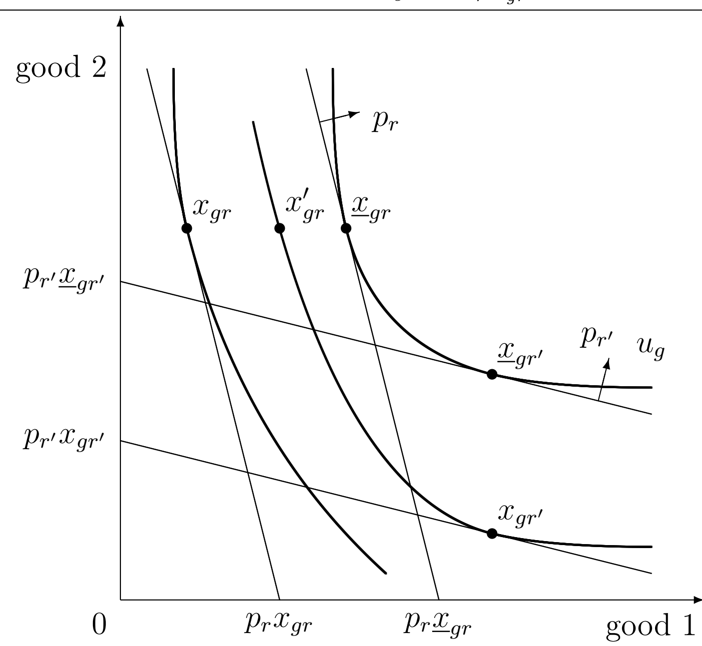


Figure 5 The construction of group/region specific poverty lines necessary for a price-sensitive poverty measure to *Respect Preferences* and satisfy *Consistency with Preferences Poverty*.



illustrates two individual economic situations, (x_{gr}, p_r, u_g) and $(x_{gr'}, p_{r'}, u_g)$, where u_g represents preferences that are not homothetic. We need to think of these preferences as non-homothetic in any non-empty open subset of X. By construction, $\frac{p_r \underline{x}_{gr}}{p_r x_{gr}} = \frac{p_{r'} \underline{x}_{gr'}}{p_{r'} x_{gr'}}$, so that, by definition, any P^{grS} will conclude that poverty is the same at the two situations. However, $u_g(x_{gr}) \neq u_g(x_{gr'})$. Consider situation (x'_{gr}, p_r, u_g). We have $u_g(x'_{gr}) = u_g(x_{gr'})$. As a consequence, if P^{grS} is to *Respect Preferences*, poverty needs to be the same at (x'_{gr}, p_r, u_g) and $(x_{gr'}, p_{r'}, u_g)$, so that, by transitivity, poverty needs to be the same at (x_{gr}, p_r, u_g) and (x'_{gr}, p_r, u_g). We can derive the same requirements by making x_{gr} and x'_{gr} vary from $(0, \ldots, 0)$ to $\underline{x}_{gr}$. That amounts to requiring that poverty be independent of the utility of the agents below the poverty line, which is exactly what the Headcount ratio and only the Headcount ratio guarantees. ■

Figure 6 The preferences represented by u_g are not homothetic. As a result, we have $u_g(x_{gr}) \neq u_g(x_{gr'})$ whereas $\frac{p_r \underline{x}_{gr}}{p_r x_{gr}} = \frac{p_{r'} \underline{x}_{gr'}}{p_{r'} x_{gr'}}$.



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.

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.[4] 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. This is the approach we favor. 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 individuals 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 sections 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

[4] 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*.

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 sections, 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.

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. w/ Well-Being
$P^{I\tilde{p}_i}$, with $\underline{x}$	+	+
$P^{I\tilde{p}}$, with $\underline{x}$	+	-
$P^{I\tilde{p}}$, with $\underline{x}_g$	+	+
P^S, with $\underline{x}$	-	-
P^S, with $\underline{x}_{rg}$	+ if Π is the HC	+ if Π is the HC

6 Description of the data

We compare the three approaches by applying them to Indian data from the 61^{th}(2004-05) round of the Consumer Expenditure Survey (CES) conducted by the National Sample Survey Organization(NSSO) of India. This is the same survey used by the Indian government to obtain the official poverty estimates. The dataset contains household level consumption (quantity and expenditure) data on a vast variety of goods. In addition to these, the dataset contains demographic information like age, gender, religion. The total sample size is 100,855 households. Given that we observe consumption only at the household level, we will be treating the household as a unitary unit and referring to it as an individual. We compare households of similar household composition and size by restricting our sample to households with three to five members.

As we are concerned with measuring income poverty and following the official Indian methodology, we focus on a basket of marketable goods containing both food and non-food dimensions.[5] Our basket contains - cereals, vegetables, fuel, and clothing.[6] 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). To ensure a clean and meaningful dataset we drop households with total expenditure on the four goods in the 1-percentile and 99-percentile, households with no cooking arrangement at home, and those with the household head eating-out for more than 60 meals a month.

As before, x_i and p_i denote the consumption and price vector respectively for agent $i \in N$. In the data we observe the quantities consumed and expenditure made on each *item*, where an item is the most disaggregate level at which we observe data, for example the good of cereal is composed of items like rice, wheat, maize, barley etc. The quantity consumed of a good is the sum of consumption in all the items that compose the good. For each agent $i \in N$ and good $\ell \in I$, we let $x_{i\ell}$ denote agent i's consumption in good ℓ given by

$$x_{i\ell} = \sum_{m \in M^\ell} x_{im}^\ell$$

where $m \in M^\ell$ denotes the items that compose good ℓ and x_{im}^ℓ the quantity consumed of item m by agent i. In addition to consumption, we also observe the expenditure at the item level which we denote by y_{im}^ℓ. The sum of these expenditures gives us the expenditure on each good which in turn is summed to give the total expenditure and is denoted by $y_i \in \mathbb{R}_+$.

Information for cereal, vegetable and fuel is reported for 30-days recall period giving us monthly expenditures. For clothing two recall periods are reported, 30-days and 365-days. We use the 365-days (adjusted to monthly) as longer recall-periods are argued to be more reliable for durable goods. Clothing includes bedding and footwear. We exclude second-hand items. As our basket consists of aggregated, essential goods we observe very low rates, i.e., less than 5%, of zero consumption for each of the four goods. Home-production and items supplied by the public-distribution-system (PDS) are

[5]These being the ones for which we can calculate regional level prices. This rules out goods and services like health, transport, rent.

[6]Fuel constitute a significant share of household expenditure in India and consists of items such as firewood, electricity, kerosene, coal.

relevant for cereal and fuel consumption.[7] We assume that consumption from either of these sources reveals a preference for the good and hence evaluate them at the constructed market price. In cases of only home-production or PDS consumption for an item we construct and use the home-production or PDS price respectively. For agent i we let w_i denote the budget share vector that is defined as the total expenditure on a good divided by the total expenditure on the four goods.

Table 2 Budget Shares

	Cereal	Vegetable	Clothing	Fuel
Mean budget share	0.29	0.13	0.15	0.42

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 individuals living in the same region face the same price vector and for individual i living in region $r(i) \in R$ 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.[8]

Once we have the item level prices, we aggregate all items constituting a good using the Stone index to form the good level price as:

$$p_{r(i)\ell} = \sum_{m \in M^\ell} \overline{w}^\ell_{r(i)m} log(p^\ell_{r(i)m})$$

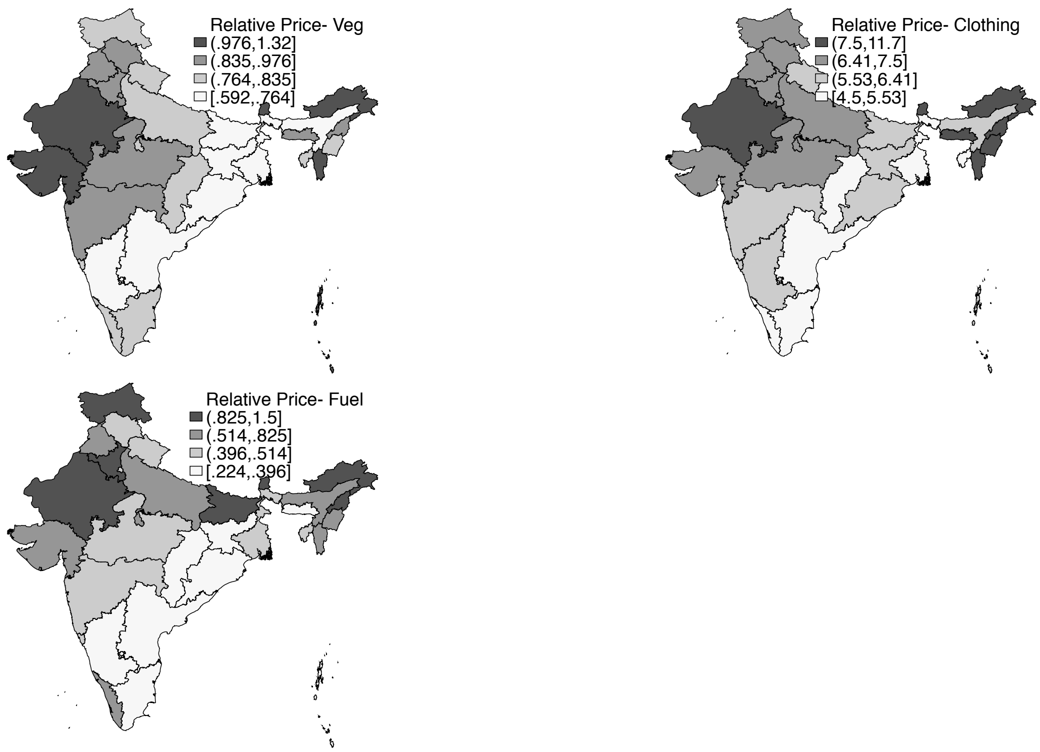
where $\overline{w}^\ell_{r(i)m}$ is the mean budget shares of item m in the individual's region and $p^\ell_{r(i)m}$ the price of item m. The figure below shows the substantial price

[7]The PDS system provides a fixed quantity of rice, wheat, kerosene and sugar at subsidized prices.

[8] The methodology involves constructing the unit value of each item by diving the expenditure by the quantity of the item. However, unit values cannot be treated as prices as they could reflect quality effects when there are different varieties of the same item available on the market at different prices. To correct for this, the methodology uses individual level regression of the unit value on the total income (in this case the total expenditure on all goods in the survey) and a regional dummy. Then one evaluates the predicted value at the mean national total income to give the price of item m denoted by $p^\ell_{r(i)m}$.

variation across the different states of India for the three goods in our basket relative to the price of cereal.

Figure 7 Relative prices (wrt cereal) across India



The second element key to our methodology is preferences. Given that we assume that all individuals in the same group have the same preferences, 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 50. Our sample is well distributed across the four groups, as shown in the table below, allowing the estimation of preferences by group.

Table 3 Sample Size

Full	Young-Rural	Young-Urban	Old-Rural	Old-Urban
59,421	26,558	16,260	9,998	6,605

Finally, we fix the poverty line bundle, $\underline{x}$, following the procedure of Rangarajan (2014). The aim is not to reproduce the poverty line but to allow for comparison of different approaches to poverty measurement, one of them being the one followed by the Indian government right now. Our food dimension consists of cereal and vegetables for which we take the average monthly expenditure in the fifth quantile (20-25%) of the income distribution and calculate the quantity consumed at average prices. The quantity consumed of the non-food goods fuel and clothing at the tenth quantile (45-50%) is used to form the non-food dimension of the poverty bundle. This gives us one all-India national level poverty bundle as,

Table 4 Poverty bundle

	Cereal	Vegetable	Clothing	Fuel
Quantity of good	40	17	6	144

7 Estimation of the preferences

Given the detailed self-reported consumption data and regional price variation available to us, estimating group level preference using demand systems is the most attractive method. It must be noted that such consumption data is readily available for numerous countries making our methodology feasible to implement. We use the Almost Ideal Demand System (AIDS) introduced by Deaton and Muellbauer (1980) which gives for agent 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

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

We estimate this system separately for each of the four groups to obtain heterogeneous preference parameters. The AIDS is an attractive demand system for us as it accounts for cross price elasticities and satisfies properties like 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 add constraints on the AIDS to impose negative-semi-definiteness at a specific point. This method is grounded in the fact that a negative-semi-definite matrix can be expressed as the product of a diagonal matrix and it's transpose. Elements of this matrix are denoted by $\tau^{\ell k}$. As we will evaluate the marginal rate of substitution at the poverty bundle, we choose this point to be such that prices are normalized by their geometric mean and income by the expenditure needed to consume the poverty bundle, $\underline{x}$, facing the geometric mean prices. We set α_0 to be zero as suggested by Deaton and Muellbauer (1980).

Few transformations gives us the following system that satisfies all the constrains of the usual AIDS system. The cross price elasticity parameter γ is deduced from the τ parameter.

$$w_{ig}^{\ell} = \alpha_{ig}^{\ell} + \alpha_{ig}^{\ell} log(\frac{p_{r(i)}^{\ell}}{P_{\alpha}}) - \sum_{k \in I} \tau^{\ell k} log(P_{\tau}^{k}) + \beta_{ig}^{\ell} log \frac{y_{ig}}{P}, \ell \in I$$

where the aggregation functions, P_{τ}^{k} and P_{α}, and the price index, P, are given by specific formulas. We follow the recommendation of Deaton and Muellbauer (1980) to use the Stone index as an approximation of the price index.

To tackle the issue of autocorrelation between the demand equations, researchers use the technique of seemingly unrelated regressions (SUR) estimation. Here as we have a non-linear system, we use the nonlinear seemingly unrelated regression (NLSUR) (see, for example, Poi (2008)). NLSUR fits a system of nonlinear seemingly unrelated regressions by using iterated feasible generalized least squares (FGNLS) in the background. This is a maximum likelihood estimator for large enough sample.

In Table 5 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.

8 Results

In this section, we apply the three different poverty measurement approaches discussed in this paper to our data and compare who is identified as poor. In order to do so we first develop the next steps in our methodology.[9] Once we have estimated the preference parameters and fixed the poverty bundle, we can use these to solve for the reference price vector for each group. The reference price is the price faced by the individual of a group such that her demand is exactly the poverty bundle, $\underline{x}$, given her preferences. For agent i belonging to group $g(i) \in G$ and living in region $r(i) \in R$, let the demand function be denoted by $x_i(p_{r(i)}, y_i)$, then we should have

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

where $\tilde{p}_{g(i)}$ is the reference price vector of group $g \in G$.

The Indirect Utility function for AIDS is given by:

$$v(p, y) = \frac{ln(y) - ln(a(p))}{b(p)}$$

where $a(p)$ and $b(p)$ are given by,

$$log(a(p)) = \alpha_0 + \sum_{\ell \in I} \alpha^\ell log(p^\ell) + \frac{1}{2} \sum_{\ell \in I} \sum_{k \in I} \gamma^{k\ell} log(p^k) log(p^\ell)$$

and

$$b(p) = \prod_{\ell \in I} p^{\ell^{\beta_\ell}}$$

For each good ℓ the demand can be derived from the indirect utility function using Roy's identity as:

[9] Note that the first approach can be implemented using the three different methodologies detailed in the sections before. However they all amount to computing the fraction of population preferring the poverty bundle to their actual bundle and should give the exact same poverty outcome. Hence, we detail the implementation only of the first methodology.

Table 5 Demand System Parameters

	Young-Rural (1)	Young-Urban (2)	Old-Rural (3)	Old-Urban (4)
α_1	0.296***	0.270***	0.300***	0.270***
	(0.001)	(0.001)	(0.001)	(0.001)
α_2	0.120***	0.146***	0.120***	0.145***
	(0.000)	(0.001)	(0.001)	(0.001)
α_3	0.153***	0.173***	0.141***	0.162***
	(0.001)	(0.001)	(0.001)	(0.001)
β_1	-0.143***	-0.138***	-0.156***	-0.152***
	(0.001)	(0.002)	(0.002)	(0.003)
β_2	-0.048***	-0.033***	-0.043***	-0.035***
	(0.001)	(0.001)	(0.002)	(0.002)
β_3	0.095***	0.089***	0.073***	0.104***
	(0.002)	(0.002)	(0.003)	(0.003)
τ_{11}	0.180***	0.203***	0.179***	0.210***
	(0.003)	(0.007)	(0.005)	(0.011)
τ_{12}	0.001	0.051***	-0.006	0.054***
	(0.005)	(0.006)	(0.007)	(0.009)
τ_{13}	-0.031***	-0.071***	-0.016***	-0.061***
	(0.004)	(0.004)	(0.006)	(0.007)
τ_{22}	0.288***	0.307***	0.277***	0.326***
	(0.003)	(0.005)	(0.005)	(0.007)
τ_{23}	-0.221***	-0.079***	-0.205***	-0.033**
	(0.006)	(0.010)	(0.011)	(0.016)
τ_{33}	0.371***	0.501***	0.317***	0.474***
	(0.010)	(0.007)	(0.017)	(0.012)
Observations	26558	16260	9998	6605

Notes: Cereal is represented by the index 1, Vegetable by 2, and Clothing by 3. The significance levels are as: * significant at 10%, ** 5% and *** 1%.

$$x^{\ell}(p, y) = \frac{y(\alpha^{\ell} + \sum_{k \in I} \gamma^{\ell k} lnp^{k} + \beta^{m}\left[ln(y) - ln(a(p))\right]}{p^{\ell}}$$

For each of the four groups, we numerically solve a system of four equations (one for each good) to give us the reference price vector, $\tilde{p}_{g(i)}$, for the group. As evident in the table below, the estimated reference price vectors (relative to the reference price of fuel) vary between the four groups.

Table 6 Reference Price

	Young-Rural	Young-Urban	Old-Rural	Old-Urban
Cereal	3.06	2.04	3.53	1.93
Vegetable	0.99	0.74	1.11	0.81
Clothing	1.30	1.11	1.63	1.28
Fuel	1	1	1	1

Finally, we evaluate the equivalent income such that the agent is indifferent between her actual situation and facing the reference price. We evaluate it for each agent using the equality of the indirect utility function,

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

Using the indirect utility function formula for AIDS, we have:

$$log(e_i(\tilde{p}_{g(i)}, u_{g(i)}(x_i))) = log(a(\tilde{p}_{g(i)})) + \frac{b(\tilde{p}_{g(i)})(log(y_i) - log(a(p_{r(i)})))}{b(p_{r(i)})}$$

Similarly, 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 then the poverty measures we will evaluate are given by,

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

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

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

In addition to the headcount index, we also analyze the TIP curve which is 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. The TIP curve provides more information on the poverty rate than the headcount index as it captures the incidence, intensity, and inequality of poverty. When a TIP curve dominates another one, all poverty measures that are inequality averse among the poor conclude that poverty is more severe in the former. We present the results by the three measures for each group in Table 7 and Figure 8. We cannot directly compare our results to the official poverty statistics, given the official poverty is evaluated on a larger basket of goods and hence a different poverty bundle. However, we can compare our approach to the price sensitive measure that evaluates poverty as if the official methodology were applied to our poverty bundle.

Using our preferred approach of individualized reference prices, 57% of the sample is identified as poor, with heterogeneity between the groups, i.e., 69% are identified as poor in the Young-Urban group while 43% 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 index shows large differences between the individualized and common reference price measures, with all groups having higher rates of 5-10% using the common reference price approach. The price sensitive approach yields smaller differences when compared to our new measure. Thus we look at the TIP curves to explore more than the headcount ratios. According to Theorem 2, looking beyond the headcount ratio is justified on the ground of our price-insensitive measure with individualized reference price but not on the price-sensitive measure with regional and group specific poverty line bundles.

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 TIP curve of Young-Rural is above Old-Urban implying more poverty in the Young-Rural group. On the contrary, our measure identifies the curves of the Young-Rural and Old-Urban groups as almost identical implying no poverty difference between the two groups. Second, we find that the Old-Urban group (orange curve) is much more poor compared to Old-Rural (green curve) by our measure than the other two. Similarly, Young-Urban (red) is poorer than Young-Rural (blue). The height of the TIP 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.

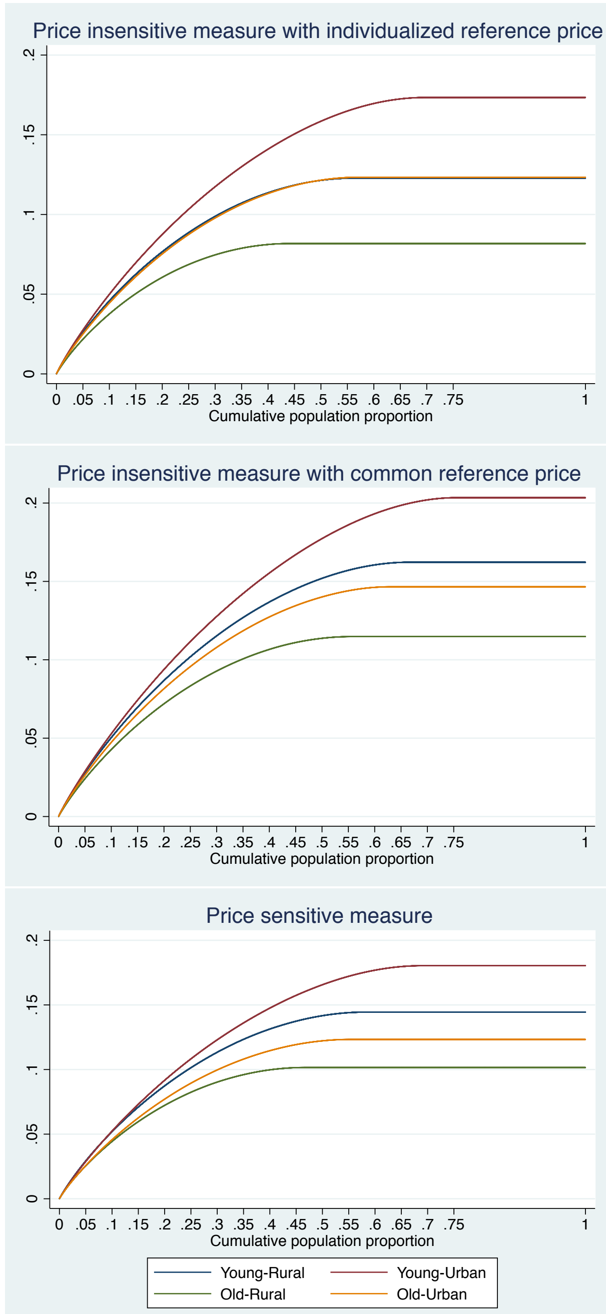
In conclusion, we find that the not taking preferences into account results in systematically underestimating the share of the Urban in the poor population as well as the poverty intensity within these groups. This is an indication towards the two Urban groups suffering in the poverty evaluation by not taking preferences into account or not taking preferences adequately into account, i.e., the price-insensitive with common reference price does take preferences into account but not the way our measure does.

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 decomposition exercise detailed below and depicted in Table 8.

Table 7 Poverty Comparisons

		Full	Young-Rural	Young-Urban	Old-Rural	Old-Urban
$P^{I\tilde{p}_i}$, with $\underline{x}$	No. of poor	34,402	14,907	11,339	4,390	3,766
	HC ratio	0.578	0.561	0.697	0.439	0.570
	% of poor	1.00	0.433	0.329	0.127	0.109
$P^{I\tilde{p}}$, with $\underline{x}$	No. of poor	39,654	17,664	12,256	5,578	4,156
	HC ratio	0.667	0.665	0.753	0.557	0.629
	% of poor	1.00	0.445	0.309	0.140	0.104
P^{S}, with $\underline{x}$	No. of poor	34,988	15,442	11,219	4,669	3,658
	HC ratio	0.588	0.581	0.689	0.466	0.553
	% of poor	1.00	0.441	0.320	0.133	0.104
	Sample Size	59,421	26,558	16,260	9,998	6,605

Figure 8 TIP



Price insensitive measure with individualized reference price
0
.05
.1
.15
.2
0 .05 .1 .15 .2 .25 .3 .35 .4 .45 .5 .55 .6 .65 .7 .75 1
Cumulative population proportion
Price insensitive measure with common reference price
0
.05
.1
.15
.2
0 .05 .1 .15 .2 .25 .3 .35 .4 .45 .5 .55 .6 .65 .7 .75 1
Cumulative population proportion
Price sensitive measure
0
.05
.1
.15
.2
0 .05 .1 .15 .2 .25 .3 .35 .4 .45 .5 .55 .6 .65 .7 .75 1
Cumulative population proportion
Young-Rural
Young-Urban
Old-Rural
Old-Urban

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 keeping 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 65.94% 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 affect of the economic situations.

Looking at the first column of the Young-Rural group, we see that in the same economic situation, Young-Rural and Old-Urban preferences would give a higher poverty rate for the Young-Rural group than 0.56. 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, any of the first or the third row is dominated by any of the second or fourth one. That strongly suggests that not taking preferences into account leads to severely underestimating urban poverty.

Table 8 Price and Preference decomposition

	Young-Rural	Young-Urban	Old-Rural	Old-Urban
Young-Rural	0.5612	0.6594	0.4445	0.5218
Young-Urban	0.6028	0.6974	0.4879	0.5638
Old-Rural	0.5565	0.6592	0.4391	0.5228
Old-Urban	0.6224	0.7036	0.5090	0.5702

9 Conclusion

We propose in this paper an acceptable 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 for any price insensitive measure. Applying our method, we find that the not taking preferences into account results in systematically underestimating urban poverty.

Our application suggests that taking preferences into account the way we do it 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. Much more can be done and much more data should be collected to make it possible to apply the method proposed in this paper.

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