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Poverty orderings and intra-household inequality: The lost axiom

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Abstract

We investigate under which conditions it is possible to infer the evolution of poverty at the individual level from the knowledge of poverty among households. Poverty measurement is approached by the poverty orderings introduced by Foster and Shorrocks (1988). The analysis is based on a reduced form of household bargaining (Peluso and Trannoy 2007) and provides results in terms of preservation of poverty orderings. We point out the main analogies and differences between inequality and poverty assessment, expressing them in terms of empirically testable conditions. In particular, knowing the change in poverty at the household level is not sufficient to deduce a similar change in poverty at the individual level. We need to know the change in the household income distributions far beyond their poverty line. The focus axiom does not hold in this context.

Key words: Poverty orderings, intra-household allocation, concavity, *focus axiom*.
JEL classification: D31, D63, I32.

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1 Introduction

The concern for intra-household distribution has been advocated as an essential ingredient for a correct measurement of inequality and poverty (Haddad and Kanbur 1990, 1994 Sen 1999 Ravallion 1996). In this paper we question the current practice of assessing poverty at the household level. A major difficulty in performing poverty analysis at the individual level arises from the assessment of intra-household inequality. Joint consumption, externalities and lack of information about the precise assignment of goods in the household generate a "veil of ignorance" over intra-household distribution of consumption and welfare. To overcome this obstacle, we assume the existence of a general pattern of intra-household inequality. More precisely, we suppose that each household is composed of two types of individuals, differentiated by some characteristics such as sex or age. The actual distribution of resources within each household is unfair between a dominant and a dominated individual. This discrimination prevails despite the fact that the allocation of welfare within households should be egalitarian due to equal needs among individuals. We postulate that this discrimination is homogeneously diffused within the population, for instance due to a common cultural bias. Our aim is to identify the minimal information about this general "discrimination bias" to predict the evolution of poverty among individuals, knowing only the pattern of poverty among households. We deal with robust poverty assessments, focusing on poverty orderings introduced by Foster and Shorrocks' (1988) and generalized by Spencer and Fisher (1993) and Jenkins and Lambert (1997).[1]

To infer poverty at the individual level from poverty measurement between households we assume a simplified household model: intra-household allocation is described through a *sharing function*, which maps household income to the income received by the dominated type. The properties of the sharing function reflect how intra-household inequality changes with household income. We show that poverty analysis among households is informative about

[1] See Zheng (2000) for a survey.

poverty among individuals if and only if the household sharing rule is concave: the poorest households have also to be the more egalitarian. This result is in line with that in Peluso and Trannoy (2007) on the preservation of Lorenz-type welfare and inequality orderings. This parallelism reflects the well-known link between poverty orderings and stochastic dominance criteria.

However, when looking at the information needed to implement the result, a complication arises from the fact that poverty measurement is based on censored data (incomes beyond the poverty line are neglected). In a model with only private goods and equally needy individuals, the poverty line for individuals is half the poverty line of the couple. When the sharing function is egalitarian, there are as much poor individuals than poor households (in relative terms). If the sharing function expresses intra-household inequality, this equivalence is lost to the detriment of individuals. As a result, we need to get information about households which are beyond their poverty line to document the evolution of poverty at the individual level. In other terms, the knowledge of the change in poverty at the household level is not sufficient to decide about the change in poverty at the individual level. We also need to know a little about the evolution of inequality in income distribution among households beyond their poverty line up to some threshold, which is all the more important that intra household allocation is unequal. Extra information becomes necessary to empirically detect individual poverty trends using only households' data, and this represents a major difference with respect to inequality measurement. The focus axiom singled out by Sen (1976) for poverty measurement does not hold anymore in this context.

The rest of the paper is organized as follows. Section 2 introduces poverty orderings and other useful measurement tools. In Section 3 the household model is illustrated and the main results are stated and discussed. Section 4 concludes the paper and hints for future developments.

1.1 Basic Concepts

We consider a population composed of n homogeneous households indexed by $i = 1, ..., n$, with $n \geq 2$. The set of the feasible distributions of some quantitative variables (not necessarily income), ordered in an increasing way, is denoted by

$$\mathbb{D} = \left\{ \mathbf{y} \in \mathbb{R}^n_+ \mid y_1 \leq y_2 ... \leq y_n \right\}.$$

We will say that $\mathbf{y}$ dominates $\mathbf{y}'$ according to the rank-order and we write $\mathbf{y} \geqslant \mathbf{y}'$ if $y_i \geq y'_i$ for $i = 1, ..., n$. In the following definition we recall the well-know Generalized Lorenz criterion and a further quasi-ordering, named *submajorization* in mathematics (see Marshall and Olkin 1979) and introduced in inequality measurement by Michelangeli *et al.* (2008). This criterion expresses the idea that the distribution $\mathbf{y}$ dominates $\mathbf{y}'$ if any partial sum of the highest elements is lower in $\mathbf{y}$ than in $\mathbf{y}'$.

Definition 1 *For all* $\mathbf{y}, \mathbf{y}' \in \mathbb{D}$

$\mathbf{y}$ *dominates* $\mathbf{y}'$ *according to the Generalized Lorenz criterion, denoted by* $\mathbf{y} \succcurlyeq_{GL} \mathbf{y}'$, *if*

$$\frac{1}{n} \sum_{i=1}^{k} y_i \geq \frac{1}{n} \sum_{i=1}^{k} y'_i \text{ for } k = 1, .., n.$$

$\mathbf{y}$ *dominates* $\mathbf{y}'$ *according to submajorization, denoted by* $\mathbf{y} \succcurlyeq_M \mathbf{y}'$, *if:*

$$\sum_{i=n-k}^{n} y_i \leq \sum_{i=n-k}^{n} y'_i \text{ for } k = 0, .., n-1.$$

The two criteria are strictly related, in fact:

Remark 1

$$\mathbf{y} \succcurlyeq_M \mathbf{y}' \iff -\mathbf{y} \succcurlyeq_{GL} -\mathbf{y}'.$$

A useful property of submajorization is stated in the following

Proposition 1 *(Marshall and Olkin, 1979) For all* $\mathbf{y}, \mathbf{y}' \in \mathbb{D}$,

$\mathbf{y} \succcurlyeq_M \mathbf{y}' \iff \sum f(y_i) \leq \sum f(y'_i)$ *for all* $f : \mathbb{R}_+ \to \mathbb{R}$ *non-decreasing and convex.*

The following result identifies the class of transformations of the variable y that guarantee the preservation of the submajorization criterion on all the domain $\mathbb{D}$.

Proposition 2 *(Michelangeli et al. 2009) Let $h : \mathbb{R}_+ \to \mathbb{R}$ be a continuous function. The two following conditions are equivalent:*

i) $h : \mathbb{R}_+ \to \mathbb{R}$ is non-decreasing and convex;

ii) $\mathbf{y} \succcurlyeq_M \mathbf{y}' \implies (h(y_1), ..., h(y_n)) \succcurlyeq_M (h(y_1'), ..., h(y_n'))$, for all $\mathbf{y}, \mathbf{y}' \in \mathbb{D}$.

Michelangeli et al. (2009) provide an application of submajorization to the analysis of the evolution of wealth inequality. Here we use submajorization to characterize standard poverty orderings.

1.2 Poverty orderings

Let $\mathbf{y}$ represent an income vector belonging to $\mathbb{D}$ and let z be a poverty line fixed in absolute terms. We designate by $g_i = z - y_i$ the *absolute poverty gap* of the household i. The resulting vector of poverty gaps is $\mathbf{g}(z, \mathbf{y}) = (g_{1,} ... g_n)$. It will be convenient to introduce the censored vector $\bar{\mathbf{g}}(z, \mathbf{y}) = (\bar{g}_{1,} ... \bar{g}_n)$, where $\bar{g}_i = \max(\ g_i,\ 0)$.

The simplest and more diffused poverty measure is the *headcount ratio,* that is the q number of households with $y_i \leq z$ on the total population:

$$H(\mathbf{y},z) = \frac{q}{n}.$$

Another important poverty measure is the *per capita income gap* (see Sen 1976)

$$Q(\mathbf{y},z) = \frac{1}{n} \sum_i \bar{g}_i.$$

Since H and Q depend on the poverty line chosen as reference, the result of the comparison of two income distributions based on such measures may be reversed by considering different z's. In order to secure the independence of poverty comparisons from the specific value chosen for z, Foster and Shorrocks (1988) defined the *poverty orderings* $\succcurlyeq_H$ and $\succcurlyeq_Q$ as follows:

Definition 2 *For all* $\mathbf{y}, \mathbf{y}' \in \mathbb{D}$,

$\mathbf{y} \succcurlyeq_H \mathbf{y}' \Longleftrightarrow H(\mathbf{y},z) \leq H(\mathbf{y}',z)$, *for all* $z > 0$

$\mathbf{y} \succcurlyeq_Q \mathbf{y}' \Longleftrightarrow Q(\mathbf{y},z) \leq Q(\mathbf{y}',z)$, *for all* $z > 0$.

Foster and Shorrocks (1988) also proved that $\succcurlyeq_H$ is equivalent to the first order stochastic dominance and that $\succcurlyeq_Q$ is equivalent to the second order stochastic dominance (and therefore to GL dominance). The following proof of the Foster and Shorrocks result about the GL criterion illustrates the relevance of the submajorization ranking for poverty analysis.

Proposition 3 *For all* $\mathbf{y}, \mathbf{y}' \in \mathbb{D}$,

$$\mathbf{y} \succcurlyeq_{GL} \mathbf{y}' \Longleftrightarrow \mathbf{y} \succcurlyeq_Q \mathbf{y}'.$$

Proof. $\Longrightarrow$ We know from Remark 1 above that $\mathbf{y} \succcurlyeq_{GL} \mathbf{y}' \Longleftrightarrow -\mathbf{y} \succcurlyeq_M -\mathbf{y}'$. Then, $\mathbf{y} \succcurlyeq_{GL} \mathbf{y}' \Longrightarrow z\mathbf{e} - \mathbf{y} \succcurlyeq_M z\mathbf{e} - \mathbf{y}'$ $\forall z \geq 0$, that is $\mathbf{g}(z, \mathbf{y}) \succcurlyeq_M \mathbf{g}(z, \mathbf{y}')$, $\forall z \geq 0$. Since max(x, 0) is non-decreasing and convex, by Proposition 1 we deduce $\bar{\mathbf{g}}(z, \mathbf{y}) \succcurlyeq_M \bar{\mathbf{g}}(z, \mathbf{y}')$, $\forall z \geq 0$, that gives the result.

$\Longleftarrow$ By setting $z \geq y_n$, from $z\mathbf{e} - \mathbf{y} \succcurlyeq_M z\mathbf{e} - \mathbf{y}'$ and Remark 1 we immediately get the result. ∎

Notice that $\succcurlyeq_Q$ is a very very demanding criterion, since it requires to check $\succcurlyeq_M$ also for very high poverty lines. Checking the quasi-order $\succcurlyeq_M$ on the vector $\bar{\mathbf{g}}(z, \mathbf{y})$ - for *a given* z - we get an intermediate criterion between $\succcurlyeq_Q$ and the simple comparison of per capita income gap, for a *fixed* poverty line. We define "z- poverty count" and "z- poverty gap majorization" (and we respectively denote by $\succcurlyeq_{H_z}$ and $\succcurlyeq_{Q_z}$) the headcount poverty ordering and submajorization applied on poverty gaps, for a fixed poverty line z.

Definition 3 *For all* $\mathbf{y}, \mathbf{y}' \in \mathbb{D}$,

$\mathbf{y} \succcurlyeq_{Q_z} \mathbf{y}' \Longleftrightarrow \bar{\mathbf{g}}(z, \mathbf{y}) \succcurlyeq_M \bar{\mathbf{g}}(z, \mathbf{y})$.

It is easy to see that to test $\succcurlyeq_{H_z}$ *is* equivalent to check the rank ordering between two truncated income distributions. Similarly, by inspecting the proof of Proposition 3, it emerges that $\succcurlyeq_{Q_z}$is equivalent to check the GL dominance for the income distributions censored at z. More precisely, if we replace $\mathbf{y}$ by $\bar{\mathbf{y}}^z$, where $\bar{y}_i = \min(z, y_i)$, we may state the following remark.

Remark 2 *For all* $\mathbf{y}, \mathbf{y}' \in \mathbb{D}$,

$$\bar{\mathbf{y}}^z \geqslant \bar{\mathbf{y}}^{z\prime} \Longleftrightarrow \mathbf{y} \succcurlyeq_{H_z} \mathbf{y}'$$

$$\bar{\mathbf{y}}^z \succcurlyeq_{GL} \bar{\mathbf{y}}^{z\prime} \Longleftrightarrow \mathbf{y} \succcurlyeq_{Q_z} \mathbf{y}'.$$

If the individual poverty gaps are valued by a social decision-maker by using a non-decreasing and convex 'hardship' function $h(\bar{g}_i)$, and the total 'social disappointment' is $\sum_{i=1}^n h(\bar{g}_i)$, using Proposition 1, we get a result of Spencer and Fisher (1993), also studied by Jenkins and Lambert (1997).[2]

Proposition 4 *For all* $\mathbf{y}, \mathbf{y}' \in \mathbb{D}$, *and for a fixed* $z > 0$,

$$\mathbf{y} \succcurlyeq_{Q_z} \mathbf{y}' \iff \sum_{i=1}^n h(\bar{g}_i) \leq \sum_{i=1}^n h(\bar{g}'_i) \text{ for all } h \text{ non-decreasing and convex.}$$

In the next section, we study the preservation of poverty orderings from households' to individual income distributions. For these purposes, a preliminary description of household behavior is necessary.

2 From household to individual poverty

We follow here the setup of Peluso and Trannoy (2007) considering a population of couples, where each household is faced to a simple cake-sharing problem. Each couple is composed of two equally needy individuals, but the intra-household allocation is unfair: A *dominated* individual receives at most an income share equal to the share received by the *dominant* one.

[2] See Bishop et al. (1993) for an empirical analysis based on censored GL dominance.

Let us denote by $f_p^i(y_i)$ the amount received by the dominated individual in household i. The amount r_i received by the dominant is $r_i = f_r^i(y_i) \equiv y_i - f_p^i(y_i)$. Joint consumption, externalities, altruism are neglected in this reduced model, as well as domestic production and other components of household behavior.

Given a vector $\mathbf{y}$ of household incomes, $\mathbf{p}(\mathbf{y}) = (p_1, .., p_j, .., p_n)$ designates the income vector for dominated individuals, $\mathbf{r}(\mathbf{y}) = (r_1, ..., r_j, ..., r_n)$ the income vector for dominant individuals, and we also denote $\mathbf{x}(\mathbf{y}) = (\mathbf{p}(\mathbf{y}), \mathbf{r}(\mathbf{y}))$.

The sharing functions f_p^i is assumed to be the same among households. In other terms, a common bias induces a homogeneous intra-household discrimination within the population considered. Let us designate by $\mathcal{F}$ the set of continuous sharing functions f_p, with $f_p(0) = 0$ and $f_p(x) \leq \frac{1}{2}x$ for all positive x.

The importance of the set $\mathcal{I} \subset \mathcal{F}$ of increasing sharing functions and $\mathcal{C} \subset \mathcal{F}$ of increasing and concave sharing functions is clarified in the following

Theorem 1 *(Peluso and Trannoy 2007)*

a) $f_p \in \mathcal{I} \iff [\mathbf{y} \geqslant \mathbf{y}' \implies \mathbf{x}(\mathbf{y}) \geqslant \mathbf{x}(\mathbf{y}'),\ \textit{for all}\ \mathbf{y}, \mathbf{y}' \in \mathbb{D}]$

b) $f_p \in \mathcal{C} \iff [\mathbf{y} \succcurlyeq_{GL} \mathbf{y}' \implies \mathbf{x}(\mathbf{y}) \succcurlyeq_{GL} \mathbf{x}(\mathbf{y}'),\ \textit{for all}\ \mathbf{y}, \mathbf{y}' \in \mathbb{D}]$.

Increasing sharing functions guarantee the preservation of the ranking order $\geqslant$ from households to individuals. Concavity of the sharing function is identified as the key-condition on intra-household inequality which is necessary and sufficient to preserve the GL dominance relation from the household level to the individual one. Denoting by z^c and z^s the poverty line fixed at couple and individual level, the immediate relation $z^s = \frac{z^c}{2}$ comes from the fact that the two individuals have the same needs. Some immediate consequences concerning Shorrocks and Foster's poverty orderings are summarized in the following proposition, where we are requiring dominance for all possible poverty lines.

Proposition 5 *Let* $f_p \in \mathcal{F}$. *For all* $\mathbf{y}, \mathbf{y}' \in \mathbb{D}$

a) $[H(\mathbf{y},z^c) \leq H(\mathbf{y}',z^c)\ \forall\ z^c > 0 \implies H(\mathbf{x}(\mathbf{y}),z^s) \leq H(\mathbf{x}(\mathbf{y}'),z^s)\ \forall\ z^s > 0]$ *iff* $f_p \in \mathcal{I}$

b) $[Q(\mathbf{y},z^c) \leq Q(\mathbf{y}',z^c)\ \forall\ z^c > 0 \implies Q(\mathbf{x}(\mathbf{y}),z^s) \leq Q(\mathbf{x}(\mathbf{y}'),z^s),\ \forall\ z^s > 0]$ *iff* $f_p \in \mathcal{C}$

Proof. **a)** It is an immediate consequence of Shorrocks and Foster (1988) and of Theorem 1-a. **b)** is obtained combining Theorem 1-b and Proposition 3 above. ■

This result has an empirical relevance since it implies that to safely neglect intra-household in poverty analysis based on the Shorrocks and Foster main poverty orderings, it is not necessary to have a complete knowledge of the sharing rule. The sign of its second derivative is the only crucial information. A concavity test then becomes the appropriate econometric tool to be implemented.

Albeit important, the above result should be completed by analyzing conditions that secure the preservation of the poverty orderings from the household to the individual level, for a given poverty line. In poverty analysis, due to the presence of thresholds and censored distributions, only limited information about the distribution of household incomes is exploited. However, in contrast with a first intuition, instead of simplifying the framework, censoring data generates a supplementary difficulty: any information about dominated individuals living in households with incomes above the poverty line is missed. This loss of information results would be harmless in assessing individual poverty if households are perfectly egalitarian. In other cases, this loss of information results in us being unable to decide about the pattern of poverty among individuals.

To explain this difficulty, let us consider a population of perfectly egalitarian couples. The results conveyed by poverty orderings checked among couples for a poverty line z^c, are immediately translated into equivalent results among individuals for an individual poverty line $z^s = z^c/2$. Does this result still hold if intra-household inequality arises from a less regular sharing rule? Let us first consider the case in which the individual poverty line z^s is set at the level $z^s = f_p(z^c)$, where f_p is a specific sharing function belonging to the class $\mathcal{F}$. Assuming this threshold, it is easy to infer poverty relations at the individual level using data about couples' income distributions.

Lemma 1 *Let $f_p \in \mathcal{F}$, $z^c > 0$ and $z^s = f_p(z^c) \leq \frac{z^c}{2}$.* Then

i) $f_p \in \mathcal{I}$ on the interval $[0, z^c] \iff [\mathbf{y} \succcurlyeq_{H_{z^c}} \mathbf{y}' \Rightarrow \mathbf{x}(\mathbf{y}) \geqslant_{H_{z^s}} \mathbf{x}(\mathbf{y}')$ *for all* $\mathbf{y}, \mathbf{y}' \in \mathbb{D}]$.

ii) $f_p \in \mathcal{C}$ on the interval $[0, z^c] \iff [\mathbf{y} \succcurlyeq_{Q_{z^c}} \mathbf{y}' \Rightarrow \mathbf{x}(\mathbf{y}) \succcurlyeq_{Q_{z^s}} \mathbf{x}(\mathbf{y}')$ *for all* $\mathbf{y}, \mathbf{y}' \in \mathbb{D}]$.

Proof. Since f_p is increasing, the incomes of the dominated individuals living in households with $y > z^c$ are excluded from $\mathbf{x}(\mathbf{y})$ and $\mathbf{x}(\mathbf{y}')$ censored at $z^s = f_p(z^c)$. We then deduce the result from Theorem 1 and Remark 2 above. ■

It follows that setting the absolute poverty line at $z^s = \frac{z^c}{2}$ allows us to determine the couple poverty line at which it is necessary to check poverty orderings at the couple level. By inverting the sharing function, this threshold is simply given by $z = f_p^{-1}(\frac{z^c}{2})$ and we can state the following

Proposition 6 Let $f_p \in F$ and $z^c > 0$. Then,

i) $f_p \in I$ on the interval $\left[0, f_p^{-1}(\frac{z^c}{2})\right] \iff [y \succcurlyeq_{H_z} y'$ for $z = f_p^{-1}(\frac{z^c}{2}) \Longrightarrow x(y) \succcurlyeq_{H_{\frac{z^c}{2}}} x(y')$ for all $y, y' \in D$]

ii) $f_p \in C$ on the interval $\left[0, f_p^{-1}(\frac{z^c}{2})\right] \iff [y \succcurlyeq_{Q_z} y'$ for $z = f_p^{-1}(\frac{z^c}{2}) \Longrightarrow x(y) \succcurlyeq_{Q_{\frac{z^c}{2}}} x(y')$ for all $y, y' \in D$].

For the preservation result to hold, a concavity test must be performed far beyond the poverty line chosen at the household level, as illustrated by the figure below.

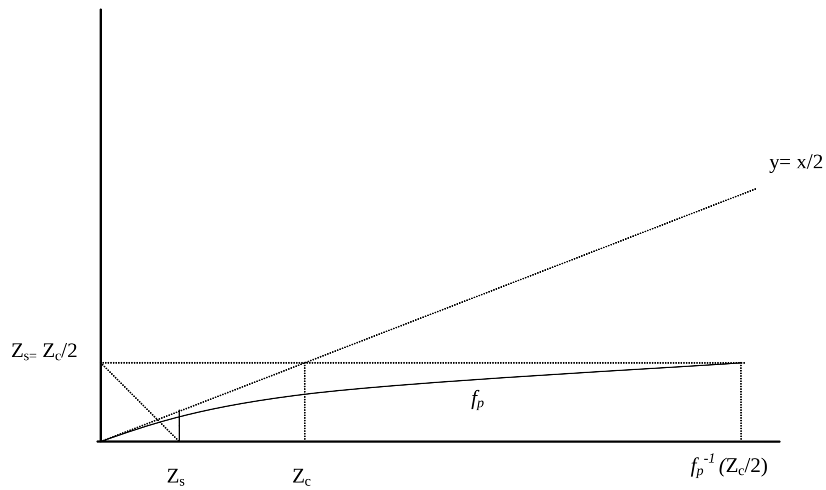

Figure 1 : Illustration of Proposition 6 (ii)

On the empirical side, the proposition conveys a sort of paradox: we have to detect precise information on intra-household inequality not only for poor households, but also for non-poor families! The focus axiom is lost.

3 Conclusive remarks

Assuming a simplified model of household, we have shown conditions under which intra-household inequality can be safely neglected in poverty analysis. A difference with results previously obtained for welfare and inequality criteria of the Lorenz type has been detected. Imagine a practitioner interested in assessing the change in poverty among individuals for a given poverty line z^s for individuals. She lacks a complete description of the intra-household allocation of expenditures, but can easily perform poverty tests over household income distribution, eventually at the poverty line $2z^s$, which identifies poor households. Our results indicate that to infer individual poverty from households data, she should be able to proceed as follows. 1) Test the homogeneity of the sharing function across households; 2) Estimate the sharing function in a range of household income which image (through the *estimated sharing* *function*) contains the chosen individual poverty line z^s; 3) Test the concavity of such a sharing function on the same range; 4) Detect a change in poverty at the household level on the same range. The range condition is specific to poverty analysis in comparison with analogous results carried out in inequality and welfare measurement. It requires a careful investigation since it depends on the estimated sharing function. Any error about the estimation of that function will translate into a mistake about this range. The fourth point prescribes for testing poverty orderings among households up to an income level higher than the poverty line set for households, since *intra-household inequality implies that poor individuals could belong also to non-poor households.* Finally, we remark that albeit the results of this paper are based for illustrative purposes on very stringent assumptions about household behavior, it is possible to extend them, at the price of some technical complication. An example is provided by Couprie et al. (2007) who introduce joint consumption and household heterogeneity in the case of welfare comparisons.

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