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WORKING PAPER

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Mobility as Distributional Difference*

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Abstract

We propose a new class of mobility measures which we call "measures of distributional difference." Members of this new class measure mobility as integrated weighted distributional difference. We demonstrate that many leading measures of mobility proposed in the literature are members of this class. Our approach therefore permits a considerable unification of a diverse literature. Moreover, our tools enable us to make explicit the implicit weighting properties of leading members of this class whose original forms do not lend themselves to such an analysis. This leads us to question the attractiveness of some popular mobility indices.

Keywords: income mobility measures, distributional difference.

JEL classification: D31, D63

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1 Introduction

Mobility indices are tools routinely used for assessing the changes of income distributions. However, the practitioner is confronted by a large literature that is diverse and offers many measures. For recent surveys see Atkinson, Bourguignon, and Morrisson (1992) and Maasoumi (1998). Although the literature abounds with measures of mobility, we propose a new class of measures which we call "measures of distributional difference." It turns out, however, that many well-established and popular measures are, in fact, members of this class. Leading examples are the Shorrocks-type measures introduced by Shorrocks (1978a) and generalized by Maasoumi and Zandvakili (1986), mobility measures based on transition matrices, as well as the ethical mobility indices proposed by Chakravarty, Dutta, and Weymark (1985). One of our principal contributions is therefore the considerable unification of a diverse literature.

Measures of distributional difference start from the idea that mobility captures a feature of the joint distribution of a variable at successive points in time that is not present in its marginal distributions.[1] The deviations between the relevant aspects of the marginal distributions and the joint distribution are weighted by some function and added up. The weights can be interpreted intuitively because they determine where deviations from the reference distribution are more important, and they also determine the effect of Atkinson and Bourguignon (1982) transformations on mobility.

A major merit of this approach to measuring mobility is that it makes explicit and transparent (i) which particular aspect of the joint distribution matters for a mobility index and (ii) the aggregation rule embodied in mobility measures. We use our insights analytically and examine the properties of some well-known mobility measures which belong to our class. These indices, when written in their original form, typically lack transparency, especially as regards the aggregation rule. Whether their implicit aggregation rules exhibit desirable weighting properties is therefore an open question. We demonstrate that some popular measures exhibit weighting properties which are unlikely to find unanimous support. We are therefore in a position to focus explicitly on important aspects of these mobility measures.

Working with measures of distributional difference, in their explicit form as integrated weighted distributional difference, offers also many practical advantages. We show that such measures can be straightforwardly decomposed by population subgroups or "trigger events" in examinations of the sources of income mobility. Moreover, the aggregation rule can be represented graphically. This suggests a "local" analysis of mobility with the end of explaining the "global" value of the mobility index: by depicting the weighted local distributional differences, the quantitative contributions of different income groups to the global mobility index become immediate. Mobility comparisons of different time periods, regions or countries can be

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[1] The class of measures of distributional difference does not include measures based directly on the distance between incomes in two periods. Such distance-measures constitute the other major class of mobility measures. These measures can be written typically in the generic form $M = \int\int \Psi\left(d\left(x,y\right)\right) dF_{1,2}\left(x,y\right)$, where $F_{1,2}$ denotes the joint distribution of income, and $d\left(.\right)$ is a distance function. Such measures have been proposed recently by Cowell (1985), Fields and Ok (1996), and also by Hart (see Shorrocks (1993) for a discussion) and King (1983).

made more insightful since the depiction of the weighted local distributional difference can highlight the source of global differences. Schluter and Trede (2001) develop the statistical tools necessary for the empirical implementation of a local analysis for measures of distributional difference, and also provide an empirical illustration.

The paper is organized as follows. In Section 2 we introduce the generic form of measures of distributional difference, and interpret their components. We demonstrate in Section 3 that many well-established and popular mobility measures turn out to be members of our new class and we generalize the notion of distributional difference to encompass measures of mobility based on equality of opportunity. We analyze the aggregation rules of all these measures, and thus their weighting properties. Section 4 provides a numerical illustration of the weighting properties of ethical and Shorrocks-type mobility measures. Section 5 concludes. Proofs are collected in the Appendix.

2 Measures of Distributional Difference: The Generic Form

In this section we discuss the generic form of measures of distributional difference, and focus on the principles underlying each specific member: the particular mobility concept to be implemented, and its weighting properties.

2.1 The Generic Form

Let Y_t denote the random variable "personal income received in period t" which is drawn from the marginal income distribution F_t and has realization y_t. We restrict our attention to the two-period case in order to simplify the exposition. The methods can be extended to longer accounting periods. The joint distribution of incomes in both periods is denoted by $F_{1,2}$, the conditional second-period distribution by $F_{2|1}$.

The generic form of a mobility measure of distributional difference is given by

$$M = \int w(x; H) d(H(x) - G(x)), \tag{1}$$

where $H(x)$ is a distribution of a random variable that only depends on the marginal distributions F_1 and F_2. We refer to H as the reference or benchmark distribution. $G(x)$ is a function of the joint distribution of incomes and contains information on the joint distribution that is not present in the marginal distributions. $w(x; H)$ is a weighting function, capturing the mathematical structure of the mobility measure M, which may also depend on the reference distribution $H(x)$. Distributional difference is precisely contained in the term $d(H(x) - G(x))$, and this is weighted by the function $w(x; H)$.

The specific choice of H and G will be governed by the aspect of mobility that we seek to implement. Mobility of incomes can be measured over an individual's lifetime or over generations. In the former case, the natural concern is the extent to which mobility equalizes lifetime income: x is then time averaged income. In the latter case people care for mobility because it leads to more equality of opportunity: x is childrens' income.[2] It is the benchmark case that determines H, while G will be determined by the actual mobility process. $d(H(x) - G(x))$ thus represents the deviation between the reference distribution of x (determined by the benchmark case) and its actual distribution.

2.1.1 Example:The Shape of the Weighting Function

In order to illustrate the intuitively desirable properties of the weighting function, we consider an illustrative example in which mobility is considered as equalizing lifetime incomes. In this context x denotes the average income over the two periods, G its distribution, and g its density. By considering two special transformations of g, we argue that the weights should be increasing and convex in x. Indeed, we show in sections 3.1 and 3.2 below that decreasing and convex weights are a crucial ingredient of those approaches to mobility that have a sound normative foundation.

Consider a transformation of the distribution function $G(x)$ that:

1. increases the difference between $G(x)$ and $H(x)$ at only two points, $x' < x''$ in the following mean-preserving, life-time income equalizing manner. The density of the transform, denoted by $\widetilde{g}$ equals g for all $x \neq x', x''$. At these two points, we set $\widetilde{g}(x') = g(x') + \varepsilon$, and $\widetilde{g}(x'') = g(x'') - \varepsilon$ with $\varepsilon > 0$. The effect of this transformation on mobility, as measured by (1), is $\Delta M = \int w(x; H)\, d\left(\widetilde{G} - G\right) = [w(x', H) - w(x'', H)]\,\varepsilon$. A natural assumption is that the effect on mobility at the lower end of the income distribution should dominate: $w(x', H) > w(x'', H)$. Hence the weights should be a decreasing function of x.

2. does not change the marginal distributions and hence does not change $H(x)$. This kind of transformation requires a change in the joint distribution function of (Y_1, Y_2) at four points - see, for instance, Atkinson and Bourguignon (1982). An example of such a transformation is depicted in Figure 1. $(-)\,\varepsilon$ is the increase (decrease) of the joint density. The effect of this transformation is to increase the density function $g(x)$ at low and high income levels, say $x_1 = y_1' + y_2'$ and $x_4 = y_1'' + y_2''$, while the density is decreased at intermediate levels of income, say $x_2 = y_1' + y_2''$ and $x_3 = y_1'' + y_2'$. The effect of this transformation on mobility is $\Delta M = [(w(x_2, H) - w(x_1, H)) + (w(x_3, H) - w(x_4, H))]\varepsilon$. Intuitively, the transformation should decrease mobility since it makes first and second period incomes more like each other. This requires that the coefficient of ε be smaller

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[2] There is a third aspect of mobility that is often mentioned as desirable: the movement aspect of mobility. We do not see that movement is valuable in itself. In the framework that we develop below, the social welfare effect (or the equality of opportunity aspect) of mobility will be judged against a benchmark case. This benchmark can either be the perfectly mobile situation or the completely immobile situation. According to this conceptualisation, movement (deviations from complete immobility) or the lack of movement (deviations from perfect mobility) matters, but only indirectly.

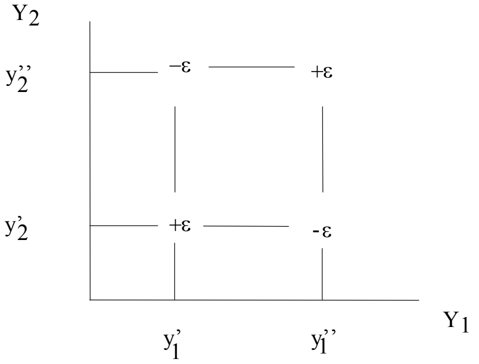

Figure 1: The Atkinson-Bourguignon transformation.

than 0. This holds for all possible values of y'_1, y''_1, y'_2, y''_2 and ε only if the weights are convex.

2.2 Decomposability

We have enumerated in the Introduction the principal theoretical and practical merits of the generic form (1) of measures of distributional difference. Another property of practical importance of these measures is their straightforward decomposability by population subgroups or events. Partition the population into $k = 1, ...K$ groups. For instance, in comparative work, population subgroups could be defined by demographic characteristics. An alternative decomposition is by "trigger events". In an examination of the sources of mobility, events could be defined in terms of candidate events which the investigator hypothesizes trigger substantial income changes, e.g. labor market events such as a job loss, or demographic events such as family formation. Given the linearity of (1), it is immediate that measures of distributional difference decompose as follows:

$$M = \sum_{k=1}^{K} \int w(x; H) d(H(x) - G_{|k}(x)) f_k \tag{2}$$

where $G_{|k}$ is the distribution G conditional on membership of group k, and f_k denotes the population share of this group. If the partition is over events, then $G_{|k}$ is the distribution G conditional on event k, and $f_k = \Pr\{\text{event k}\}$.[3]

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[3] This decomposition differs markedly from decomposition rules proposed in the literature, which depend on the additive decomposability of the mobility index into "within-group" and "between-group" components. Such decompositions are typically only achieved for mobility measures defined in terms of decomposable inequality indices. See, for instance, Buchinsky and Hunt (1999).

3 Leading Examples of Measures of Distributional Difference

In this section we demonstrate that many popular and well-established mobility measures turn out to be measures of distributional difference. We derive the measure-specific definitions of the distributions H and G, and of the weighting function. Writing these measures in the form (1) makes explicit their underlying aggregation rule. We discuss the properties of their weighting functions. It turns out that the weighting properties of "ethical mobility indices" are intuitively appealing, whereas those of the "statistical mobility indices" are non-trivial and may not command universal support.

We introduce some recurrent notation. The moment functional is denoted by $\mu_\alpha(F_t) = \int y^\alpha dF_t(y)$. For a functional $I(F)$ we need to introduce the following measure of its sensitivity to incomes at point x:

Definition 1 *The influence function of the functional I is defined by*

$$IF(x; I, F) = \frac{d}{d\varepsilon} I(F + \varepsilon(1_x - F))|_{\varepsilon=0},$$

where $1_x(z) = \begin{cases} 1 \text{ if } z \geq x \\ 0 \text{ otherwise} \end{cases}$ *denotes a point mass distribution at x.*

In geometric terms, the influence function is the directional derivative (Gateaux differential) of I in the space of distribution functions at F in the direction of distribution $1_x(.)$ (see also Serfling (1980)).

3.1 Ethical Mobility Indices

Chakravarty, Dutta, and Weymark (1985), henceforth CDW for short, propose a (discrete) mobility index based on the effect of mobility on social welfare, as measured by a social welfare function defined over the income vectors of both periods. As usual in the literature on ethical indices, a key quantity is the equally distributed income (cf. Atkinson, 1970). CDW's benchmark is a completely immobile income vector. Their mobility index is an increasing function of the ratio of the equally distributed observed income vectors to the equally distributed income with the benchmark income structure.

3.1.1 Generalized Ethical Mobility Indices

We generalize CDW's ideas in two ways: we adapt them to a continuous framework, and we extend the class of admissable benchmark distributions. Let social welfare be measured by an additively separable social welfare function defined over the average incomes of individuals: $S(F) = \int v(y)\, dF$, where F denotes an income distribution, $v'(\cdot) > 0$ and $v''(\cdot) \leq 0$. The equally distributed equivalent income is

$$y^e(F) = v^{-1}\left(\int v(y)\, dF\right).$$

Following CDW, mobility is measured by comparing the actual and a benchmark distribution H of average lifetime income $0.5\left(Y_1+Y_2\right)$.

Proposition 2 *The generalized ethical mobility indices are defined by*

$$M_{CDW}=\frac{y^e\left(G\right)}{y^e\left(H\right)}-1, \tag{3}$$

with G denoting the actual distribution of average lifetime income, and H the reference distribution.

The benchmark distribution H can represent either the perfectly mobile or immobile distribution. The immobile benchmark can be defined in several ways, and we present the cases of a "constant rank" and "constant share" hypothesis. More precisely:

1. Benchmark: perfect mobility. There is widespread agreement in the literature that perfect mobility is a situation in which second period incomes are independent of first period incomes, i.e. $F_{2|1}=F_2$. The benchmark distribution is therefore the convolution of the marginal distributions

$$H\left(x\right)=\int_0^{2x} f_1\left(y_1\right)F_2\left(2x-y_1\right)dy_1. \tag{4}$$

2. Benchmark: perfect immobility as "constant shares." CDW define the immobile second period distribution as that distribution in which everybody receives the same income share as in the first period, i.e. $y_2=\left(\mu_2/\mu_1\right)y_1$. Average lifetime income is therefore $z\left(y_1\right)=0.5\left[\left(\mu_1+\mu_2\right)/\mu_1\right]y_1$, and the benchmark distribution follows as

$$H\left(x\right)=F_1\left(\frac{2\mu_1}{\mu_1+\mu_2}x\right). \tag{5}$$

3. Benchmark: perfect immobility as "constant ranks." Another way to define the immobile benchmark starts from the idea that the immobile distribution of second period income is obtained if everybody's rank in the second period remains the same as in the first period. Formally: $y_2=a\left(y_1\right)$, where $a\left(y_1\right)$ is an increasing function defined implicitly by $F_1\left(y_1\right)=F_2\left(a\left(y_1\right)\right)$. Average second period income of an individual with first period income level y_1 is $z\left(y_1\right)=0.5\left(y_1+a\left(y_1\right)\right)$, leading to the benchmark distribution

$$H\left(x\right)=F_1\left(z^{-1}\left(x\right)\right). \tag{6}$$

We discuss some properties of M_{CDW} in the following remark:

Remark 1 *(i) Suppose that the benchmark distribution H is a completely immobile distribution. If there is no mobility, then $y^e\left(G\right)=y^e\left(H\right)$, and $M_{CDW}=0$. If there is mobility, then $y^e\left(G\right)>y^e\left(H\right)$, and $M>0$. M_{CDW} can also be interpreted* *as the reduction in inequality due to the presence of mobility. This follows from using the class of Atkinson inequality indices* $I_A(F) = 1 - y^e(F)/\mu_1(F)$*, so that* $M_{CDW} = [I_A(H) - I_A(G)]/[1 - I_A(H)]$.

(ii) Suppose that the benchmark distribution H *is characterized by perfect mobility. If there is perfect mobility, then* $y^e(G) = y^e(H)$*, and* $M_{CDW} = 0$*. In the presence of imperfect mobility,* $y^e(G)$ *will usually be smaller than* $y^e(H)$*, and* $M < 0$*.*[4] *The absolute value of* M_{CDW} *can then be interpreted as the increase in lifetime inequality due to the presence of incomplete mobility.*

3.1.2 Class Membership and Welfare Properties of M_{CDW}

Theorem 3 *The ethical indices* M_{CDW} *are approximately measures of distributional difference, with* G *denoting the distribution of actual average income, and* H *being one of the reference distributions given by (4)-(6). The weighting function for this measure of distributional difference is given by*

$$w_{CDW}(x, H) = \frac{\int v(y)\,dH - v(x)}{v'\left(\int v(y)\,dH\right) y^e(H)}. \tag{7}$$

The following corollary describes the properties of the weighting function:

Corollary 4 *The weighting function for the measure of distributional difference* M_{CDW} *defined in (7) is (a) a decreasing and convex function of* x*,*

$$\frac{\partial w_{CDW}(x, H)}{\partial x} < 0 \text{ and } \frac{\partial^2 w_{CDW}(x, H)}{(\partial x)^2} \geq 0,$$

and satisfies
(b)

$$w_{CDW}(x, H) \geq [\leq]\, 0 \Longleftrightarrow x \leq [\geq]\, y^e(H),$$

(c)

$$\int w_{CDW}(x, H)\,dH = 0$$

The crucial properties are given by (a). (b) and (c) depend on the cardinalization of the mobility index in (3). The welfare properties of the weighting function captured by (a) and thus of the aggregation rule are directly inherited from the explicit properties of the social welfare function embodied in the social weight function $v(.)$. The properties do not depend on the chosen benchmark. They are completely in line with the intuitively desirable properties of the weights discussed in section 2.1.

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[4] If incomes in period 2 are negatively correlated with incomes in period 1, then the actual process will be more equalizing than the perfectly mobile process, $y^e(G) > y^e(H)$ and $M_{CDW} > 0$.

3.2 Mobility as Equality of Opportunity

Van de gaer, Schokkaert, and Martinez (2001) take an approach similar to CDW in an intergenerational context. They focus on the extent to which children's incomes are determined by their parents' incomes. We present their equality of opportunity measure and demonstrate that the results derived in the previous section can be extended in a natural way.

We proceed to sketch the construction of their equality of opportunity index. In a world of perfect equality of opportunity, the distribution of children's incomes is independent of the income level of their parents, and therefore given by F_2. If opportunities differ, the conditional distributions $F_{2|1}$ differ. The opportunities of someone whose parents had income level y_1 can be measured by $y^e\left(F_{2|1}\right)$. If society is inequality averse with respect to the distribution of opportunities, the additively separable social welfare function can be written as $S\left(F_{2|1}, F_1\right) = \int W\left(y^e\left(F_{2|1}\right)\right) dF_1$, $W' > 0$ and $W'' \leq 0$. The associated equally distributed equivalent income is

$$y^E\left(F_{2|1}, F_1\right) = W^{-1}\left(\int W\left(y^e\left(F_{2|1}\right)\right) dF_1\right).$$

An equal opportunity mobility index can then be defined by comparing $y^E\left(F_{2|1}, F_1\right)$ with a benchmark of perfect mobility:

Proposition 5 *Mobility as equality of opportunity can be measured by*

$$M_O = \frac{y^E\left(F_{2|1}, F_1\right)}{y^E\left(F_2, F_1\right)} - 1. \tag{8}$$

If there is perfect equality of opportunity, $F_{2|1} = F_2$ and $M = 0$. If opportunities are unequally distributed, $y^E\left(F_{2|1}, F_1\right) < y^E\left(F_2, F_1\right)$ and $M < 0$.

3.2.1 Class Membership and Welfare Properties of M_O

Measures of distributional difference are based on the assumption that what matters for mobility measurement is a one-dimensional deviation between the benchmark distribution H and the distribution G. However, some measures of mobility, such as the equality of opportunity index M_O, measure the deviation between the actual joint distribution and the distribution under independence. It is natural to extent the class of measures of distributional difference, in order to accommodate such special cases. Extended measures of distributional difference can be defined as

$$M^E = \int\int w\left(x, y, H\right) d_x d_y \left(H\left(x, y\right) - G\left(x, y\right)\right) \tag{9}$$

Typically, the reference distribution is $H\left(x, y\right) = F_2\left(x\right) F_1\left(y\right)$ while $G\left(x, y\right) = F_{1,2}\left(y, x\right)$.

Measures of equality of opportunity M_O can be written in the form given by (9):

Theorem 6 *The equal opportunity index M_O is approximately a member of the extended class of measures of distributional difference, defined by (9).The benchmark distribution is $H(x,y) = F_2(x) F_1(y)$ and $G(x,y) = F_{1,2}(y,x)$ is the actual joint distribution. The weighting function for this extended measure of distributional difference is given by*

$$w_O(x, F_2) = \frac{W'(y^e(F_2)) \cdot [v(y^e(F_2)) - v(x)]}{y^E(F_2, F_1) \cdot W'(W(y^E(F_2, F_1))) \cdot v'(v(y^e(F_2)))}. \tag{10}$$

Remark 2 *Note the absence of y in the definition of the weighting function (10). This is due to the fact that $y^E(F_2, F_1) = y^e(F_2)$, which implies that the weights do not depend on the value of parental income nor on the distribution of parental income. This property reflects the individualistic (as opposed to dynastic) point of departure of equality of opportunity*[5].

The following corollary describes the properties of the weighting function:

Corollary 7 *The weighting function for the extended measure of distributional difference M_O defined in (10) is (a) a decreasing and convex function of x,*

$$\frac{\partial w_O(x, F_2)}{\partial x} < 0 \text{ and } \frac{\partial^2 w_O(x, F_2)}{(\partial x)^2} \geq 0,$$

and satisfies
(b)

$$w_O(x, F_2) \geq [\leq] \, 0 \Longleftrightarrow x \geq [\leq] \, y^e(F_2).$$

(c)

$$\int w_O(x, F_2) \, dF_2 = 0.$$

As in the case of the ethical mobility measures, the welfare properties of the weighting function and thus of the aggregation rule of the equal opportunity index are directly inherited from the explicit properties of the social welfare function embodied in the social weight function $v(.)$.

3.3 The Class of Stability Indices

This class of popular mobility measures, proposed by Shorrocks (1978a) and generalized by Maasoumi and Zandvakili (1986), is routinely used in empirical work. These measures are based on the comparison between inequality of time-averaged income and a weighted sum of single period income inequalities, and measure thus the reduction of income inequality occurring when the accounting period is extended beyond

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[5] The dynastic point of view is present in the work by Atkinson (1981), Markandya (1982) and Dardanoni (1993). In this approach, the social marginal utility ofchildrens' income depends directly on the level of parental income. In the approach in this subsection, parental income only matters to the extent that it leads to different opportunities, as measured by $y^e\left(F_{2|1}\right)$. This indirect link gets lost due to the linerization.

a single period. The more inequality is reduced by looking at long-term rather than short-term incomes, the higher is income mobility.

Let G denote the distribution of average income $0.5\,(Y_1 + Y_2)$. The stability index M_I based on an inequality measure I is defined by

$$M_I = 1 - \frac{I(G)}{\lambda I(F_1) + (1-\lambda)\,I(F_2)}, \tag{11}$$

where λ is the weight attached to period 1. The typical choice is $\lambda = \mu_1(F_t)/[\mu_1(F_1) + \mu_1(F_2)]$, the share of total aggregate income of the first period. Other weighting schemes have been discussed by Maasoumi (1986) who also considers a more general distribution function G.

However, the implementation of the mobility concept in equation (11) gives rise to one major problem. The mobility index is a non-linear functional of the joint distribution function. This non-linearity results in a non-transparent aggregation rule: it is not obvious, for instance, whether income changes of some income groups are accorded a greater weight than those of others. Whether the implicit weighting scheme has intuitively attractive properties is therefore an open question. We address this question below.

3.3.1 Class Membership of M_I

Theorem 8 *Stability indices M_I are approximately measures of distributional difference, with G denoting the distribution of average income, and the reference distribution $H = \lambda F_1 + (1-\lambda)F_2$ being the mixture of the marginal distributions. The weighting function for this measure of distributional difference is given by*

$$w_I(x;H) = IF(x;I,H)/I(H). \tag{12}$$

where IF denotes the influence function of inequality measure I (see Definition 1).

The weighting function is proportional to the influence function of the inequality index, and thus reflects the dependence of the mobility index on the inequality index. It measures the sensitivity of the inequality index to point x, and thus weights the contribution of distributional difference at income level x to overall mobility.

In order to discuss the welfare properties of M_I we consider two leading cases for the inequality index I appearing in (11): the Generalized Entropy Index and the Gini coefficient.[6] Stability indices focus on time averaged incomes. Hence, when the weighting function is not convex, they have the counter-intuitive property that the transformation $T\left(y_1', y_1'', y_2', y_2''; \varepsilon\right)$ increases mobility.

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[6] For an extensive discussion of the properties of these inequality indices see Cowell (2000).

3.3.2 Welfare Properties of Stability Indices based on the Generalized Entropy Index

Lemma 9 *(Cowell and Victoria-Feser 1996) The Generalized Entropy measure* GE_α[7] *(or Theil's index) is defined by*

$$GE_\alpha(F_t) = \left(\alpha^2 - \alpha\right)^{-1}\left[\mu_\alpha(F_t)\mu_1(F_t)^{-\alpha} - 1\right] \qquad \alpha \notin \{0,1\}.$$

Its influence function is

$$IF(x; GE_\alpha, F_t) = A_1(F_t) + B_1(F_t)x^\alpha + C_1(F_t)x \qquad \alpha \notin \{0,1\}, \tag{13}$$

with

$$\begin{aligned} A_1(F_t) &= (\alpha - 1)\, GE_\alpha(F_t) + 1/\alpha, \\ B_1(F_t) &= \mu_1(F_t)^{-\alpha}[\alpha^2 - \alpha]^{-1}, \\ C_1(F_t) &= -\mu_1(F_t)^{-1}[\alpha GE_\alpha(F_t) + (\alpha - 1)^{-1}]. \end{aligned}$$

We proceed to characterize the weighting function (12), and thereby the implied welfare judgement, for M_{GE_α}:

Corollary 10 *The weighting function for* M_{GE_α}

$$w_{GE_\alpha} = \frac{IF(x; GE_\alpha, H)}{GE_\alpha(H)}$$

depends on α. *It is decreasing in* x *until income level* $\left[-C_1/\left(\alpha B_1\right)\right]^{1/(\alpha-1)}$ *and then monotonically increasing. It is only convex if* $\alpha \in [0,1]$.

The welfare judgement implied by the aggregation rule for M_{GE_α} is therefore to attribute weights which are larger the lower the income below the turning point, but also increasing weights to incomes above it. In addition, when $\alpha \notin [0,1]$, the weighting function is not convex.

3.3.3 Welfare Properties of Stability Indices based on the Gini Coefficient

Lemma 11 *(Monti 1991) The Gini coefficient is defined by*

$$Gini\left(F_t\right) = 1 - 2\mu^{-1}R\left(F_t\right),$$

where $R\left(F_t\right) = \int_0^1 GL\left(p; F_t\right)dp$ *is the integrated Generalized Lorenz curve* $GL\left(p; F_t\right) = \int_0^{F_t^{-1}(p)} u dF_t\left(u\right)$. *Its influence function is*

$$IF\left(x; Gini, F_t\right) = A_2\left(F_t\right) + B_2\left(F_t\right)x + C_2\left(x; F_t\right) \tag{14}$$

---

[7] Its sensitivity properties are determined by the parameter α. The smaller is α, the larger is the sensitivity of the inequality index to the lower tail of the income distribution. This index, however, is not monotonic in α.

where

$$\begin{aligned} A_2(F_t) &= 2\mu_1(F_t)^{-1} R(F_t) \\ B_2(F_t) &= 2\mu_1(F_t)^{-2} R(F_t) \\ C_2(x;F_t) &= -2\mu_1(F_t)^{-1}\left[x\left[1-F_t(x)\right] - GL\left(F_t(x);F_t\right)\right]. \end{aligned}$$

We proceed to characterize the weighting function (12), and thereby the implied welfare judgement, for M_{Gini}:

Corollary 12 *The weighting function for* M_{Gini} *given by*

$$w_{Gini} = \frac{IF(x;Gini,H)}{Gini(H)}$$

is first a decreasing function in x*, and becomes an increasing function for higher incomes. Whether it has a single turning point depends on the elasticity of the income density at* x*, i.e. whether* $\eta(x) > -3/2$ *in the parts of the income space where the density is falling. Whether the weights are convex or not depends on non-trivial properties of the distribution function* $F_t(x)$*.*

The weighting functions for M_{GE_α} and M_{Gini} share the property of being at first decreasing but eventually increasing for higher incomes. From a welfare viewpoint, the initial fall of the weights is usually deemed desirable (the higher the weight the lower the income), but the eventual increase might not find unanimous support. The usual form of the stability indices (8) does not reveal this important property. In section 4 we provide some numerical illustrations, showing that when incomes are jointly lognormally distributed, the weighting function is not convex.

3.4 The Prais-Shorrocks Index

This class of indices is based on a prior discretization of the income space into a partition of income classes $i = 1,..,K$, which in turn define a transition matrix $P = \left[p_{j|i}\right]$. $p_{j|i}$ denotes the probability that income class j is occupied in the second period given what income class i was occupied in the first. The Prais-Shorrocks index, discussed extensively in Shorrocks (1978b), is defined by

$$M_P = \frac{1-\sum_{i=1}^{K} p_{ii}}{K-1}. \qquad (15)$$

It therefore measures mobility in terms of movers, i.e. people who change income classes, and thus focuses on period-to-period movement.

3.4.1 A Generalized Prais-Shorrocks Index

Since ours is a continuous framework, we first generalize the index given by (15) by abandoning the discretizations of the income space. Consider the generic staying probability

$$p_{i|i} = \frac{\Pr\left\{Y_1 \in [\underline{x}_i, \overline{x}_i), Y_2 \in [\underline{y}_i, \overline{y}_i)\right\}}{\Pr\left\{Y_1 \in [\underline{x}_i, \overline{x}_i)\right\}}.$$

Define the second period partition in terms of first period incomes, $\underline{y}_i = t_1 \left(\underline{x}_i \right)$ and $\overline{y}_i = t_2 \left(\overline{x}_i \right)$, which places a band around the main diagonal in the income space. The exact parametrization depends on value judgements, e.g., it may have a constant width or fan out as incomes increase. Let $\overline{x}_i \rightarrow \underline{x}_i$. This suggests the continuous generalization of the staying probability

$$p\left(x\right) = \frac{1}{f_1\left(x\right)} \int_{t_1(x)}^{t_2(x)} f_{1,2}\left(x, y\right) dy.$$

The index (15) is normalized by the number of income classes. In the continuous generalization their number is infinite, which suggests the application of a weighting function $w_{cP}\left(.\right)$, and hence $M_{cP} = \int w_{cP}\left(x\right)\left(1 - p\left(x\right)\right) dx$. Since $M_P \in [0, 1]$, we impose the requirement that $\int w_{cP}\left(x\right) dx = 1$. The index (15) weights moving equally irrespective of the income class. This would translate immediately into requiring that, if the support of the income distributions is $[0, \overline{x}]$, $w_{cP}\left(x\right) = \overline{x}^{-1}$ for all x. However, it is more appealing from a welfare-theoretic viewpoint to abandon this last restriction, since income gains amongst first-period poors could be attributed greater social weight than income gains amongst the rich.

We summarize this discussion in:

Proposition 13 *The generalized Prais-Shorrocks mobility index is given by*

$$M_{cP} = \int w_{cP}\left(x\right)\left(1 - p\left(x\right)\right) dx, \tag{16}$$

where $\int w_{cP}\left(x\right) dx = 1$.

3.4.2 Class Membership and Welfare Properties of M_{cP}

Setting $w\left(x\right) = w_{cP}\left(x\right) / f_1\left(x\right)$ and $G\left(x\right) = \int_{t_1(x)}^{t_2(x)} f_{1,2}\left(x, y\right) dy$, the following theorem is immediate:

Theorem 14 *The generalized Prais-Shorrocks mobility index M_{cP} is a mobility measure of distributional difference.*

Distributional difference is given by the proportion of the population whose income improvements are sufficient to move them outside the income band $\left[t_1\left(x\right), t_2\left(x\right)\right]$ in the second period. As in the case of the discrete index M_P the usual weighting function for M_{cP} is a constant, $w\left(x\right) = \overline{x}^{-1}$ if the support of the income distributions is $[0, \overline{x}]$. Welfare considerations lead to admitting more general weighting rules, typically a decreasing and convex function of x (as in the case of the ethical mobility indices). Even then, however, the index will not be sensitive to transformations that influence the joint distribution function only within the bands around the diagonal or only outside that band.

4 Numerical Illustrations

This section provides some numerical illustrations of the welfare properties of the ethical mobility indices and the class of stability indices. We adopt an intergenerational perspective, and use a simple income model which is calibrated using estimates based on US data reported by Zimmerman (1992). We assume that the income process is in a steady state, and that incomes in two periods are jointly lognormally distributed. The intergenerational income elasticity between successive periods is equal to 0.4, mean income is \$21,959 in each period, the standard deviation equals \$25,248.

We conduct the discussion in terms of the derivatives of the weighting function, whose general properties are summarized in Corollaries 4, 10 and 12 above. As a benchmark, we depict in Figure 2 the case of the ethical mobility measure, whose weighting function is decreasing in income. Figure 3 depicts the case of stability indices M_{GE_α} with $\alpha \in \{1.05, 0.5, 0.05\}$.[8] Figure 4 depicts the case for M_{Gini}. Evidently, the weights are at first decreasing but eventually increase again for higher incomes. This latter property is unlikely to command universal support, and is therefore problematic. It could be argued on pragmatic grounds that the problem could be dismissed if the weighting function starts to increase only at very high values of income. Figures 3 and 4 reveal that this is not the case. For $M_{GE_{0.5}}$, dw/dx changes sign close to mean income (at \$23,551), for M_{Gini} the crossing occurs close to half mean income (at \$9,075). Moreover, the weighting function for M_{Gini} is not convex.

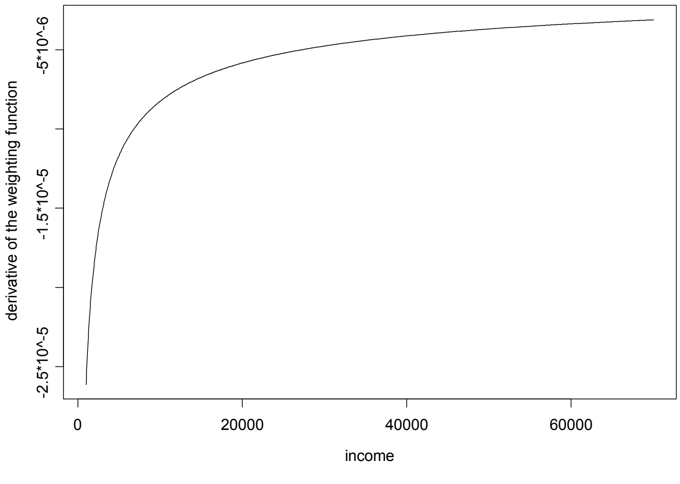

Figure 2: The derivative of the weighting function for M_{CDW}.

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[8] Since GE_α is continuous in α, $GE_{1.05}$ approximates the special case of GE_1, and $GE_{0.05}$ approximates GE_0. These special cases for $\alpha \in \{0, 1\}$ are also known as Theil measures.

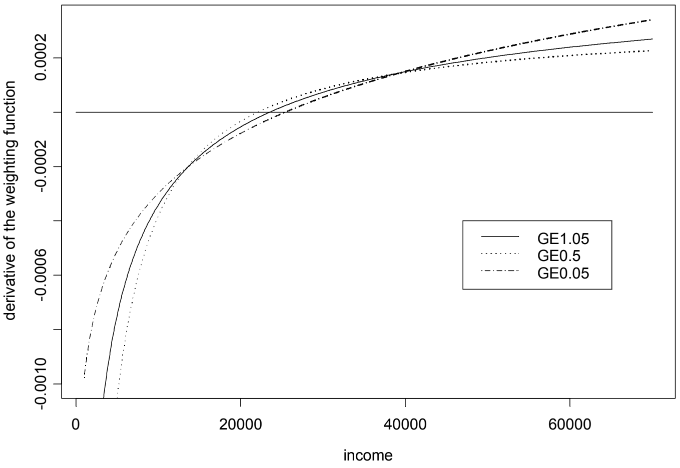

Figure 3: The derivative of the weighting function for M_{GE_α} with $\alpha \in \{1.05, 0.5, 0.05\}$.

5 Conclusion

The framework of mobility as distributional difference presented in this paper unifies a diverse literature on mobility measurement since many popular measures are shown to be members of our new class. Leading examples are Shorrocks-type measures ("Stability Indices"), the Prais-Shorrocks index, and ethical mobility indices.

Measures of distributional difference require three ingredients: a reference distribution, an actual distribution and a weighting scheme that weights the deviations of the actual distribution from the reference distribution. In our framework we make explicit the way in which local distributional differences are aggregated into the (global) mobility index: mobility is measured as integrated weighted distributional difference and the weights can be related to the desirability of Atkinson Bourguignon transformations. An important property of this new class of mobility measures for empirical analysis is the fact these measures are easily decomposable by population subgroups or "trigger events." Writing the leading mobility measures enumerated above in their equivalent form as measures of distributional difference thus permits a straightforward decomposition analysis.

Many mobility measures are explicit on their choice of the reference and actual distribution, but remain silent on the weighting schemes they use. We have used the framework of distributional difference to derive properties of these weighting schemes. The concept of mobility is used to describe the evolution of an individual's income over time, or to describe the extent to which children's incomes are influenced by their parents' incomes. These contexts are very different and require a different normative framework: equality of lifetime incomes and equality of opportunity. The weighting schemes that correspond to these concerns directly follow from the properties of

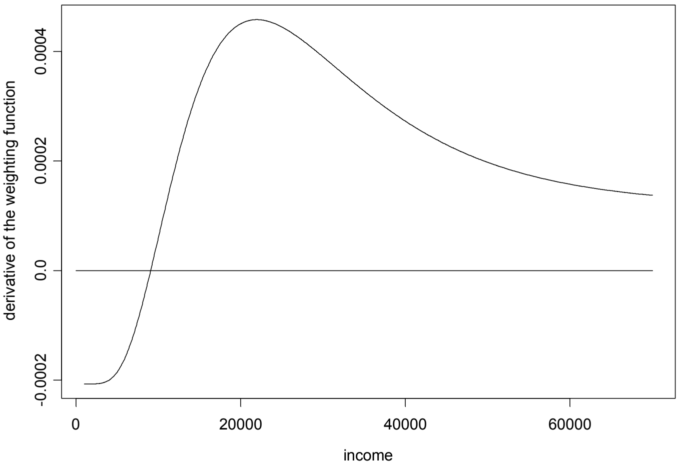

Figure 4: The derivative of the weighting function for M_{Gini}.

the social welfare function: the weights are decreasing and convex. This is in sharp contrast to the actual weighting scheme embodied in leading "statistical" measures of mobility. Stability Indices, for instance, have weights that are at first decreasing, but which increase for higher incomes, and the Prais-Shorrocks index has constant weights. Whether stability indices have convex weights or not depends on the particular inequality index used in their construction. The weighting schemes, identified in these statistical measures of mobility, are unlikely to command a lot of support among practitioners. Our numerical illustration suggests that the weighting function for Stability Indices can start to increase already in the main body of the income distribution, rather than in the upper tail. Hence this problem cannot be dismissed on pragmatic grounds.

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Appendix

A Proofs

We start with a lemma which will be applied repeatedly.

Lemma 15 *A first order Taylor expansion, valid under the usual regularity conditions, of the functional $I(G)$ about H yields*

$$I(G) = I(H) + \int IF(x; I, H) d(G(x) - H(x)). \tag{17}$$

Proof. of Theorem 3:

(17) applied to (3) implies that

$$w(x, H) = IF(x, M_{CDW}, H).$$

Since

$$IF(x, M_{CDW}, H) = \frac{IF(x, y^e, H)}{y^e(H)},$$

we have immediately the implied definition of the weighting function

$$w(x, H) = -\frac{IF(x, y^e, H)}{y^e(H)}. \tag{18}$$

It is now immediate that (3) can be written in the generic form (1).

In order to derive (7), note that

$$y^e(H + \varepsilon(\iota_x - H)) = v^{-1}\left((1-\varepsilon)\int v(y)\, dH + \varepsilon v(x)\right).$$

Differentiating with respect to ε and setting $\varepsilon = 0$ yields

$$IF(x, y^e, H) = \frac{1}{v'\left(\int v(y)\, dH\right)}\left[-\int v(y)\, dH + v(x)\right]. \tag{19}$$

Substituting this into (18) yields (7). ■

Proof. of Theorem 6:

Use the definition $y^E(F_{2|1}, F_1) = W^{-1}\left(\int W\left(y^e\left(F_{2|1}\right)\right) dF_1\right)$ to obtain the following first order Taylor expansion

$$\begin{aligned} y^E\left(F_{2|1}, F_1\right) &= y^E(F_2, F_1) + \left[W'\left(W\left(y^E(F_2, F_1)\right)\right)\right]^{-1} \times \\ &\quad \int_1 \int_2 W'(y^e(F_2))\, IF(x, y^e, F_2)\, d\left(F_{2|1} - F_2\right) dF_1. \end{aligned}$$

Substituting $y^E\left(F_{2|1}, F_1\right)$ into (8) yields

$$\begin{aligned} M &\simeq y^E\left(F_2,F_1\right)^{-1}\left[W'\left(W\left(y^E\left(F_2,F_1\right)\right)\right)\right]^{-1}W'\left(y^e\left(F_2\right)\right)\times \\ &\int_1\int_2 IF\left(x,y^e,F_2\right)d\left(F_{2|1}-F_2\right)dF_1. \end{aligned}$$

Using the expression for $IF\left(x,y^e,F_2\right)$ given by (19) we get

$$IF\left(x,y^e,F_2\right)=\left[v'\left(y^e\left(F_2\right)\right)\right]^{-1}\left[v\left(x\right)-v\left(y^e\left(F_2\right)\right)\right]$$

and therefore

$$\begin{aligned} M &\simeq y^E\left(F_2,F_1\right)^{-1}\left[W'\left(W\left(y^E\left(F_2,F_1\right)\right)\right)\right]^{-1}\left[v'\left(y^e\left(F_2\right)\right)\right]^{-1}W'\left(y^e\left(F_2\right)\right)\times \\ &\int_1\int_2\left[v\left(x\right)-v\left(y^e\left(F_2\right)\right)\right]d\left(F_{2|1}-F_2\right)dF_1. \end{aligned}$$

(10) follows now immediately. ■

Proof. of Theorem 8:

Apply (17) to the inequality functional I to obtain the following expansion about the reference distribution H: $I\left(G\right)=I(H)+\int IF(x;I,H)d(G(x)-H(x))$. It remains to choose a convenient reference distribution. We select $H=F_m$ where

$$F_m=\lambda F_1+(1-\lambda)F_2. \tag{20}$$

is the mixture of the single period income distributions since

$$I\left(F_m\right)\simeq\lambda I\left(F_1\right)+\left(1-\lambda\right)I\left(F_2\right). \tag{21}$$

We discuss this approximation in Remark 3 below.

Finally, using (21) and (17) in (11) yields the first order approximation to the aggregation rule

$$\begin{aligned} M_I &= -\frac{1}{I(F_m)}\int IF(x;I,F_m)d(G(x)-F_m(x)) \qquad (22)\\ &= \int w(x;F_m)d(F_m(x)-G(x)), \end{aligned}$$

with the weighting function given by

$$w(x;F_m)=IF(x;I,F_m)/I(F_m). \tag{23}$$

■

Remark 3 *The approximation (21) is typically very good. This can be seen from two applications of expansions of the type (17),*

$$\begin{aligned} I\left(\lambda F_1+\left(1-\lambda\right)F_2\right) &\simeq I\left(F_1\right)+\left(1-\lambda\right)\int IF\left(x;I,F_1\right)d\left(F_2-F_1\right) \\ &\simeq I\left(F_2\right)+\lambda\int -IF\left(x;I,F_2\right)d\left(F_2-F_1\right). \end{aligned}$$

The convex combination of these two equations yields

$$I\left(\lambda F_1+(1-\lambda)F_2\right)\simeq\lambda I\left(F_1\right)+(1-\lambda)I\left(F_2\right)+ \qquad (24)$$
$$\lambda(1-\lambda)\int\left(IF\left(x;I,F_1\right)-IF\left(x;I,F_2\right)\right)d\left(F_2-F_1\right).$$

The approximation (21) is therefore good if the two distributions F_1 and F_2 are close or the difference of the influence functions $\left(IF\left(x;I,F_1\right)-IF\left(x;I,F_2\right)\right)$ is small.

Proof. of Corollary 10:

We note that for $\alpha<0$, we have $(A_1<0,\ B_1>0,\ C_1>0)$, and for $\alpha>1$ $(A_1,\ B_1>0,\ C_1<0)$. For $\alpha\in(0,1)$ the sign of A_1 and C_1 depends on whether $GE_\alpha \gtreqless [\alpha(\alpha-1)]^{-1}$. Since $\alpha(\alpha-1)$ is maximized at $\alpha=0.5$, a necessary condition for $A_1,C_1<0$ is $GE_\alpha>4$, a magnitude never encountered in empirical work. We conclude that typically for $\alpha\in(0,1)$, $A_1,C_1>0$ and $B_1<0$. These signs imply that for all α (12) consists of a decreasing and an increasing part. Although the coefficients are distribution-dependent and GE_α is not monotonic in α, differentiating (13) yields the stated result. ■

Proof. of Corollary 12:

Consider the slope of (14), $g(x):=B_2+dC_2/dx$ with $B_2=(1-Gini)/\mu_1\geq 0$ since $Gini\in[0,1]$. Integrate $GL(F(x))$ by parts to obtain $g(x)=2\mu_1^{-1}[2xf(x)+F(x)-1]+(1-Gini)\mu_1^{-1}$. At $x=0$ the slope is $g(0)=[(1-Gini)-2]\mu_1^{-1}<0$. By contrast $g(\infty)>0$, so the influence function eventually increases. Whether g increases monotonically depends on the elasticity of the income density at x, $\eta(x)=d\log f(x)/d\log x$, since $g'(x)=2\mu_1^{-1}f(x)[3+2\eta(x)]$. ■

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