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Poverty and Time

Walter Bossert,[1] Satya R. Chakravarty,[2] and Conchita d'Ambrosio[3]

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Abstract

We examine the measurement of individual poverty in an intertemporal context. Our aim is to capture the importance of persistence in a state of poverty and we characterize a corresponding individual intertemporal poverty measure. Our first axiom requires that intertemporal poverty is identical to static poverty in the degenerate single-period case. The remaining two properties express decomposability requirements within poverty spells and across spells in order to reflect the persistence issue. In addition, we axiomatize an aggregation procedure to obtain an intertemporal poverty measure for societies and we illustrate our new index with an application to EU countries.

Keywords: Intertemporal poverty measurement, equity

JEL classification: C43, D63, I32

[1] University of Montreal, E-mail: walter.bossert@umontreal.ca; [2] Indian Statistical Institute, Kolkata, E-mail: satya@isical.ac.in [3] Università di Milano-Bicocca, DIW Berlin and Econpubblica, Università Bocconi, E-mail: conchita.dambrosio@unibocconi.it

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UNU World Institute for Development Economics Research (UNU-WIDER)
Katajanokanlaituri 6 B, 00160 Helsinki, Finland

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1 Introduction

In a seminal contribution, Sen (1976) distinguished two fundamental issues in poverty measurement, namely, (i) identifying the poor among the total population; and (ii) constructing an index of poverty using the available information on the poor. The first problem has been solved in the literature by setting a poverty line (which may or may not depend on the income distribution under consideration) and identifying as poor the individuals whose incomes fall below this threshold. Regarding the second, the aggregation problem, many indices have been proposed capturing not only the fraction of the population which is poor (the *head-count ratio*), that is, the incidence of poverty, but also the extent of individual poverty and the inequality among those who are poor.

The literature on poverty measurement has advanced to a high degree of sophistication since Sen (1976). However, there remain substantial issues to be addressed. One of these issues is concerned with the measurement of *intertemporal* poverty as opposed to limiting attention to single-period considerations. For instance, consider an observer comparing two individuals both of whom are poor today to the same degree. Suppose that, while the first was not poor in any of the previous two periods, the second individual experienced poverty in both previous periods in addition to the present. Is the degree of intertemporal poverty of those two individuals the same? This does not seem to be the case—the second individual is poorer as soon as the entire intertemporal income distribution is taken into consideration. Now consider again two individuals both of whom are poor today to the same degree but the first was poor also last year, while the second was out of poverty last year but in poverty the year before that. Is the intertemporal poverty of those two individuals the same? Again, we believe not. Both individuals were poor twice (and we are assuming that they were poor to the same degree) but the first individual experienced poverty in two *consecutive* periods while the second did not.

The relative degree of overall poverty when comparing the two individuals over time depends on the role and evaluation of *persistence* in a state of poverty. To us, the negative effects of being in poverty are cumulative, hence a two-period poverty spell is much harder to handle than two one-period spells that are interrupted by one (or more) period(s) out of poverty. We believe that intertemporal information should not be neglected in assessing individual poverty. Nowadays, the availability of panel data for most of the countries in the world makes it possible for researchers to expand the information set when evaluating poverty. In addition to poverty lines, per-period poverty values and inequality among the poor, the lengths of individual poverty spells can be incorporated. We propose a way to add this time dimension to the information used in poverty measurement.

There are several approaches to the measurement of *chronic* poverty (some of which are discussed below). Without going into specifics at this stage, it may nevertheless be useful to distinguish our notion of persistence of poverty from what we think of as being in chronic poverty. Generally speaking, we think of chronic poverty as a term to apply to situations in which an individual is in a state of poverty for a 'large' *total* proportion of the number of time periods under consideration. This, we think, does not necessarily mean that attention is paid to the *durations* of poverty spells given a total number of periods spent in poverty. Our notion of persistence explicitly takes the duration of these spells into consideration by assigning, in a sense to be made precise once our formal framework is introduced, higher weights to longer spells. In other words, chronic poverty occurs when there is a frequent recurrence of poverty states while persistent poverty requires in addition to frequency that poverty manifests itself in periods that are consecutive.

This paper is similar in spirit to Hoy and Zheng (2006) but the individual intertemporal poverty measure we characterize differs from theirs due to the properties that are deemed relevant to capture the role of time and persistence. Hoy and Zheng (2006) demand that aggregating first across individuals and then across time periods should be equivalent to aggregating in the reverse order—first across time periods for each single individual and then across members of the society. This leads to a notion of *path independence.* In contrast to Hoy and Zheng (2006), we consider the phenomenon of persistence to be crucial in assessing individual intertemporal poverty. Aggregating across individuals first means that this information is lost when we reach the second stage of aggregation. Hence we characterize an index of intertemporal poverty for each member of the society under analysis and then aggregate across members of society.

Foster (2009) expresses a similar view in proposing chronic poverty indices by aggregating first across time. In contrast to our contribution, persistence in the state of poverty is not assigned any relevance. The measures Foster (2009) proposes—generalizations of the Foster-Greer-Thorbecke (1984) class that allow for time to matter—do satisfy a property of *time anonymity* under which the sequencing of incomes in individual intertemporal profiles does not affect poverty. Foster (2009) defines an individual as chronically poor if its income is below the poverty line for at least a given number of periods. Thus, in addition to a poverty line, there is a second cut-off point in defining the chronically poor—a point defined in terms of the incidence of poverty over time. As is the case for our contribution, the order of aggregation matters in Foster's approach—to identify the chronically poor, the first aggregation step has to be performed across periods for each individual.

The individual Foster indices are means over time of per-period Foster-Greer-Thorbecke indices. The aggregate indices are obtained by calculating average poverty among the chronically poor. Recall that, in Foster (2009), only individuals who are poor for at least a given number of periods are considered. Thus, if an individual is poor, but rarely so, it is treated in the analysis as one of the individuals who are never poor. This is not the case in the present contribution. We do not restrict our sample to chronically poor individuals, hence we take into account spells of poverty of any length.

The path-independence property mentioned above can be called into question in other models of social evaluation as well. For example, in a framework where well-being is to be aggregated across time and across individuals, aggregating across individuals first means that, in the second step of the procedure, we do not have information on the period of life of an *individual*—only *aggregate* per-period information is available. Hence, a given per-period level of individual well-being has to be treated in the same way, no matter in which period of life this level is achieved. This seems to be rather counter-intuitive and restrictive, and the same reasoning applies to the issue of intertemporal poverty measurement considered here. See, for instance, Blackorby, Bossert and Donaldson (1996, 2005) for discussions.

Porter and Quinn (2008) and Calvo and Dercon (2009) consider intertemporal measures of individual poverty as well. Porter and Quinn (2008, p.27) propose one class of measures with the property that "fluctuations in wellbeing have a greater negative impact, the poorer the individual." Calvo and Dercon (2009) suggest measures some of which allow for different treatment of different time periods by means of discounting. They also address the persistence issue but the proposed measure is very different from ours and deals only with poverty in the immediately preceding period without allowing the entire history of individuals to matter.

It seems to us that the negative effects of being in poverty are cumulative. Empirical evidence is in favor of this view. Individuals who have been persistently poor are often discriminated against and "have little access to productive assets and low capabilities in term of health, education and social capital" (Chronic Poverty Research Centre, 2004, p.3). In addition, there is true state dependence in poverty status since the chances of being poor in the future are higher for individuals who are already poor, even after controlling for individual heterogeneity, observed and unobserved. "For example, the experience of poverty itself might induce a loss of motivation, lowering the chances that individuals with given attributes escape poverty in the future" (Cappellari and Jenkins, 2004, p.598). Bradbury, Jenkins and Micklewright (2001) report that children who have been poor for a long time are worse off than those who are poor in a single period only. Walker (1995, p.103) writes that "When poverty predominantly occurs in long spells (...) the poor have virtually no chance of escaping from poverty and, therefore, little allegiance to the wider community."

The empirical and econometric literature on poverty measurement has recognized for some time the importance of being able to distinguish between chronic and transitory poverty and proposes alternative methods for capturing the relevant phenomenon; for surveys of this literature, see, among others, Rodgers and Rodgers (1993) and Jenkins (2000). Numerous applied contributions provide a detailed description of poverty persistence in various countries and help in shaping social policies but the measures used are established in an *ad hoc* fashion without much of a theoretical foundation. Our paper contributes to this literature by filling this gap. Specifically, some of the empirical literature involving persistence in poverty proceed by counting the proportion of people being poor in each period. Alternatively, the percentage of 'long' poverty spells or the sequence of multiple spells is used as a crude measure of intertemporal poverty. In order to try to include information on the intensity of poverty, some authors capture the temporal aspect of individual poverty by using a measure of permanent income and then applying standard (static) indices of poverty such as members of the Foster-Greer-Thorbecke class to the resulting distribution of permanent incomes. See, for instance, Rodgers and Rodgers (1993, p.31) who use as permanent income "the maximum sustainable annual consumption level that the agent could achieve with his or her actual income stream over the same T years, if the agent could save and borrow at prevailing interest rates."

The main purpose of this paper is to provide an axiomatic foundation for the measurement of intertemporal poverty that differs from earlier approaches such as those of Hoy and Zheng (2006), Porter and Quinn (2008), Calvo and Dercon (2009) and Foster (2009) in the way persistence is taken into consideration. Our measure pays attention to the length of individual poverty spells by assigning a higher level of poverty to situations where, *ceteris paribus,* poverty is experienced in consecutive rather than separated periods. The length of breaks between spells is also accounted for by associating longer breaks between spells with lower intertemporal poverty. In the theoretical part of the paper, we provide a characterization of our new measure. Furthermore, we characterize aggregate intertemporal poverty as the arithmetic mean of the individual intertemporal poverty indices. We do not restrict attention to environments with a fixed poverty line—we allow for any method to obtain individual per-period poverty indicators; in particular, the commonly-used procedure of using a percentage of average or median income as the poverty line is compatible with our setup, and this is the procedure that is used in the applied part of this paper.

We use our new aggregate index as well as measures suggested in the earlier literature to illustrate the commonalities and the differences with alternative approaches. The application pertains to poverty patterns among EU countries in the years from 1994 to 2001.

2 Individual Intertemporal Poverty Measures

This paper is concerned with the intertemporal aggregation of per-period individual poverty indicators (such as relative poverty gaps or their square values) over time and the across-society aggregation of these individual measures into a social measure of intertemporal poverty. We begin with a discussion of individual intertemporal poverty and its link to what we refer to as persistence.

Suppose that individual poverty indicators are observed in each of a non-empty and finite set of consecutive periods. A standard way of generating these per-period indicators consists of defining them, in each period, as the difference between a (constant or income-distribution-dependent) poverty line and the individual's income divided by the poverty line if the income is below this poverty line and as equal to zero otherwise. We do not need to commit to a specific way of obtaining these indicators and treat them, for simplicity, as the primary inputs for our analysis.

The novel feature we suggest in intertemporal poverty measurement is to take into consideration the length of the poverty spells an individual is subjected to. For example, suppose two per-period individual poverty profiles are compared, where the first profile is given by $(1/3, 1/2, 1/4, 1/2, 0)$ and the second by $(1/3, 0, 1/2, 1/4, 1/2)$. We claim that individual intertemporal poverty should be higher in the first than in the second: in the second profile, the individual experiences a break from being in poverty rather than being poor in four *consecutive* periods.

Moreover, the length of spells out of poverty matters in the sense that a longer break between poverty spells is better than a shorter break if the lengthening of the break by adding a period out of poverty is *the only* change when moving from one profile to another. For instance, suppose we have two per-period individual poverty profiles $(1/2, 0, 1/3, 1/4, 0, 1/2)$ and $(1/2, 0, 0, 1/3, 1/4, 0, 1/2)$. According to our hypothesis, the first of these profiles is associated with a higher value of individual intertemporal poverty. The two profiles involve an identical triple of spells—namely, a one-period spell with a per-period poverty of 1/2, a two-period spell with poverty values of 1/3 and 1/4, and another one-period spell with poverty 1/2. However, there is one zero-poverty period separating the spells in the first profile but a break of two periods in the second and, thus, intertemporal poverty is lower in the second option.

The above two properties are not sufficient to narrow down the class of possible measures to any significant degree; they are merely monotonicity conditions that are satisfied by a large class of measures. For that reason, although we note that these are properties of importance, they need to be supplemented by further restrictions with some intuitive appeal. We employ notions of *decomposability* in our axioms, and these properties represent a (we think, very plausible) way of formalizing a notion of individual intertemporal poverty that conforms to the features illustrated in the above examples. Of course, these are not the only possibilities of doing so but, given that decomposability properties have a long and well-established standing in the theory of social index numbers, they appear to constitute a well-motivated choice. As is apparent from the formal definition of our axioms, they accommodate the features alluded to above by requiring different types of decompositions depending on whether we decompose a profile *across* spells or *within* a single spell.

Comparisons of poverty profiles of different length (and profiles coming from societies of possibly different populations and population sizes) are possible according to our measure; this is essential in order to perform international comparisons involving data sets with different sampling periods. Let $\Omega = \cup_{T \in \mathbb{N}} \mathbb{R}^T_+$. For $T \in \mathbb{N}$, an individual per-period individual poverty *profile* of dimension T is a vector $p_i \in \mathbb{R}^T_+$, where p_i^t is individual i's poverty experienced in period $t \in \{1, \ldots, T\}$. An individual intertemporal poverty measure is a function $\mathbf{P}_i \colon \Omega \to \mathbb{R}_+$ where, for all $p_i \in \Omega$, $\mathbf{P}_i(p_i)$ is the intertemporal poverty experienced by person i. We choose the domain consisting of the union of the entire spaces $\mathbb{R}^T_+$ merely for expositional convenience. All of our arguments go through if this rich space is replaced with a subset of $\mathbb{R}^T_+$ containing the origin—for example, we can deal with environments where per-period poverty can assume the values zero and one only (one when the individual is below the per-period poverty line, zero otherwise).

The result of this section consists of a characterization of an individual intertemporal poverty measure that reflects the length-of-spell hypothesis mentioned above. This basic idea also motivates a characterization in the context of deriving measures of social exclusion from measures of individual deprivation (Bossert, D'Ambrosio and Peragine, 2007), where similar considerations apply. However, the axioms we employ are different and we obtain a different measure as a consequence.

According to the measure we propose in this paper, individual intertemporal poverty is calculated as the weighted average of the individual per-period poverty values where, for each period, the weight is given by the length of the spell to which this period belongs. To formalize this notion, consider any $T \in \mathbb{N}$ and $p_i \in \mathbb{R}^T_+$. For $t \in \{1, \ldots, T\}$ such that $p_i^t > 0$, let $\mathbf{D}^t(p_i)$ be the maximal number of consecutive periods including t with positive per-period poverty values. For $t \in \{1, \ldots, T\}$ such that $p_i^t = 0$, let $\mathbf{D}^t(p_i)$ be the maximal number of consecutive periods including t with zero per-period poverty. To illustrate this definition, consider the profile $p_i = (1/2, 0, 0, 1/3, 1/4, 0, 1/2) \in \mathbb{R}^7_+$. The length of the first poverty spell is one and, thus, $\mathbf{D}^1(p_i) = 1$. This is followed by a non-poverty spell of length two, which implies $\mathbf{D}^2(p_i) = \mathbf{D}^3(p_i) = 2$. The next two periods are periods in poverty and we obtain $\mathbf{D}^4(p_i) = \mathbf{D}^5(p_i) = 2$. Period 6 is a single period out of poverty and, thus, $\mathbf{D}^6(p_i) = 1$. Finally, there is a one-period poverty spell and we have $\mathbf{D}^7(p_i) = 1$.

Our individual intertemporal poverty measure is now defined as

$$\mathbf{P}_i^*(p_i) = \frac{1}{T} \sum_{\tau=1}^{T} \mathbf{D}^\tau(p_i) p_i^\tau \tag{1}$$

for all $T \in \mathbb{N}$ and for all $p_i \in \mathbb{R}^T_+$. Returning to our earlier examples, the individual intertemporal poverty associated with the relevant profiles is

$$\begin{aligned}
\mathbf{P}_i^*\left(\frac{1}{3}, \frac{1}{2}, \frac{1}{4}, \frac{1}{2}, 0\right) &= \frac{1}{5} \cdot \left(4 \cdot \left(\frac{1}{3} + \frac{1}{2} + \frac{1}{4} + \frac{1}{2}\right) + 1 \cdot 0\right) = \frac{19}{15}, \\
\mathbf{P}_i^*\left(\frac{1}{3}, 0, \frac{1}{2}, \frac{1}{4}, \frac{1}{2}\right) &= \frac{1}{5} \cdot \left(1 \cdot \frac{1}{3} + 1 \cdot 0 + 3 \cdot \left(\frac{1}{2} + \frac{1}{4} + \frac{1}{2}\right)\right) = \frac{49}{60}, \\
\mathbf{P}_i^*\left(\frac{1}{2}, 0, \frac{1}{3}, \frac{1}{4}, 0, \frac{1}{2}\right) &= \frac{1}{6} \cdot \left(1 \cdot \frac{1}{2} + 1 \cdot 0 + 2 \cdot \left(\frac{1}{3} + \frac{1}{4}\right) + 1 \cdot 0 + 1 \cdot \frac{1}{2}\right) = \frac{13}{36}, \\
\mathbf{P}_i^*\left(\frac{1}{2}, 0, 0, \frac{1}{3}, \frac{1}{4}, 0, \frac{1}{2}\right) &= \frac{1}{7} \cdot \left(1 \cdot \frac{1}{2} + 2 \cdot 0 + 2 \cdot \left(\frac{1}{3} + \frac{1}{4}\right) + 1 \cdot 0 + 1 \cdot \frac{1}{2}\right) = \frac{13}{42}.
\end{aligned}$$

$\mathbf{P}_i^*$ treats persistence in the way we suggest in the introduction and at the beginning of this section: *ceteris paribus,* longer breaks between spells reduce individual intertemporal poverty and longer poverty spells increase individual intertemporal poverty. As mentioned earlier, this measure represents one possible way of doing so, and the reason we focus on it is that, in addition to these monotonicity properties, $\mathbf{P}_i^*$ satisfies notions of decomposability that we consider to be very natural in this setting.

The first property we impose on an individual intertemporal poverty measure requires that, in degenerate cases where there is only one period, individual intertemporal poverty and individual per-period poverty coincide.

One-period equivalence. For all $p_i \in \mathbb{R}_+$,

$$\mathbf{P}_i(p_i) = p_i.$$

In agreement with many issues involving social index numbers (see, for instance, Ebert and Moyes, 2000, in the context of individual deprivation measurement), we impose *decomposability* properties. As opposed to the standard single-period approach, we are dealing with a richer domain and wish to distinguish features across spells and within spells. Across spells, that is, in situations where two groups of periods in poverty are separated by at least one period with zero poverty, we require individual intertemporal poverty to be equal to a weighted average of poverty experienced in each spell, where the weights are given by the proportional lengths of the two spells. The scope of the axiom is restricted to separate spells due to one of the features we want to highlight—the importance of the lengths of poverty spells and spells out of poverty. This requirement captures the main novel feature of our approach: the length of a spell emerges as an important criterion when assessing intertemporal poverty.

Across-spells average decomposability. For all $T \in \mathbb{N} \setminus \{1\}$, for all $p_i \in \mathbb{R}^T_+$ and for all $t \in \{1, \ldots, T-1\}$, if $p_i^t = 0$ or $p_i^{t+1} = 0$, then

$$\mathbf{P}_i(p_i) = \frac{t}{T}\,\mathbf{P}_i(p_i^1, \ldots, p_i^t) + \frac{T-t}{T}\,\mathbf{P}_i(p_i^{t+1}, \ldots, p_i^T).$$

The second decomposability property applies to situations where there is but a single poverty spell—that is, the individual is in poverty in all T periods. In particular, we impose an additive-decomposability axiom that focuses on *total* rather than average poverty when the single spell is separated into two sets of periods.

Single-spell additive decomposability. For all $T \in \mathbb{N} \setminus \{1\}$, for all $p_i \in \mathbb{R}^T_{++}$ and for all $t \in \{1, \ldots, T-1\}$,

$$\mathbf{P}_i(p_i) = \mathbf{P}_i(p_i^1, \ldots, p_i^t) + \mathbf{P}_i(p_i^{t+1}, \ldots, p_i^T).$$

The novelty in our approach is that we distinguish between decomposability across and within spells: (i) averages matter across spells to take into consideration the hypothesis that, *ceteris paribus,* longer breaks between spells are associated with lower degrees of intertemporal poverty, and (ii) totals matter within spells so that, *ceteris paribus,* longer poverty spells lead to higher intertemporal poverty. As usual, these decomposability properties impose an additive structure on the measure.

The axioms introduced above characterize $\mathbf{P}_i^*$. We obtain

Theorem 1 *An individual intertemporal poverty measure* $\mathbf{P}_i\colon \Omega \to \mathbb{R}_+$ *satisfies one-period equivalence, across-spells average decomposability and single-spell additive decomposability if and only if* $\mathbf{P}_i = \mathbf{P}_i^*$.

Proof. 'If.' That $\mathbf{P}_i^*$ satisfies one-period equivalence is straightforward to verify.

To prove across-spells average decomposability, let $T \in \mathbb{N} \setminus \{1\}$, $p_i \in \mathbb{R}_+^T$ and $t \in \{1, \ldots, T-1\}$ be such that $p_i^t = 0$ or $p_i^{t+1} = 0$. By definition of $\mathbf{P}_i^*$, we have

$$\begin{aligned}\frac{t}{T}\,\mathbf{P}_i^*(p_i^1, \ldots, p_i^t) + \frac{T-t}{T}\,\mathbf{P}_i^*(p_i^{t+1}, \ldots, p_i^T) &= \frac{1}{T}\sum_{\tau=1}^{t} \mathbf{D}^\tau(p_i^1, \ldots, p_i^t)p_i^\tau \\ &+ \frac{1}{T}\sum_{\tau=t+1}^{T} \mathbf{D}^\tau(p_i^{t+1}, \ldots, p_i^T)p_i^\tau. \qquad (2)\end{aligned}$$

Because $p_i^t = 0$ or $p_i^{t+1} = 0$, it follows that $\mathbf{D}^\tau(p_i^1, \ldots, p_i^t) = \mathbf{D}^\tau(p_i)$ for all $\tau \in \{1, \ldots, t\}$ such that $p_i^\tau > 0$ and $\mathbf{D}^\tau(p_i^{t+1}, \ldots, p_i^T) = \mathbf{D}^\tau(p_i)$ for all $\tau \in \{t+1, \ldots, T\}$ such that $p_i^\tau > 0$. Therefore, (2) implies

$$\frac{t}{T}\,\mathbf{P}_i^*(p_i^1, \ldots, p_i^t) + \frac{T-t}{T}\,\mathbf{P}_i^*(p_i^{t+1}, \ldots, p_i^T) = \frac{1}{T}\sum_{\tau=1}^{T} \mathbf{D}^\tau(p_i)p_i^\tau = \mathbf{P}_i^*(p_i),$$

as was to be established.

Let $T \in \mathbb{N} \setminus \{1\}$, $p_i \in \mathbb{R}_{++}^T$ and $t \in \{1, \ldots, T-1\}$. By definition of $\mathbf{P}_i^*$ and because $\mathbf{D}^\tau(p_i) = T$ for all $\tau \in \{1, \ldots, T\}$, $\mathbf{D}^\tau(p_i^1, \ldots, p_i^t) = t$ for all $\tau \in \{1, \ldots, t\}$ and $\mathbf{D}^\tau(p_i^{t+1}, \ldots, p_i^T) = T - t$ for all $\tau \in \{t+1, \ldots, T\}$, it follows that

$$\begin{aligned}\mathbf{P}_i^*(p_i) &= \frac{1}{T}\sum_{\tau=1}^{T} \mathbf{D}^\tau(p_i)p_i^\tau = \sum_{\tau=1}^{T} p_i^\tau = \sum_{\tau=1}^{t} p_i^\tau + \sum_{\tau=t+1}^{T} p_i^\tau \\ &= \frac{1}{t}\sum_{\tau=1}^{t} \mathbf{D}^\tau(p_i^1, \ldots, p_i^t)p_i^\tau + \frac{1}{T-t}\sum_{\tau=t+1}^{T} \mathbf{D}^\tau(p_i^{t+1}, \ldots, p_i^T)p_i^\tau \\ &= \mathbf{P}_i^*(p_i^1, \ldots, p_i^t) + \mathbf{P}_i^*(p_i^{t+1}, \ldots, p_i^T)\end{aligned}$$

and single-spell additive decomposability is proven.

'Only if.' Now suppose $\mathbf{P}_i$ satisfies the axioms of the theorem statement. Let $T \in \mathbb{N}$ and $p_i \in \mathbb{R}^T_+$.

If $T = 1$, $\mathbf{P}_i(p_i) = p_i = \mathbf{P}^*_i(p_i)$ follows immediately from one-period equivalence.

Now consider the case $T \geq 2$.

If $p_i^\tau = 0$ for all $\tau \in \{1, \ldots, T\}$, repeated application of one-period equivalence and across-spells average decomposability implies $\mathbf{P}_i(p_i) = 0 = \mathbf{P}^*_i(p_i)$.

If $p_i^\tau > 0$ for all $\tau \in \{1, \ldots, T\}$, we have $\mathbf{D}^\tau(p_i) = T$ for all $\tau \in \{1, \ldots, T\}$. By repeated application of one-period equivalence and single-spell additive decomposability,

$$\begin{aligned}
\mathbf{P}_i(p_i) &= \mathbf{P}_i(p_i^1, \ldots, p_i^{T-1}) + \mathbf{P}_i(p_i^T) = \mathbf{P}_i(p_i^1, \ldots, p_i^{T-1}) + p_i^T \\
&\vdots \\
&= \sum_{\tau=1}^{T} p_i^\tau = \frac{1}{T} \sum_{\tau=1}^{T} \mathbf{D}^\tau(p_i) p_i^\tau = \mathbf{P}^*_i(p_i)
\end{aligned}$$

because $\mathbf{D}^\tau(p_i) = T$ for all $\tau \in \{1, \ldots, T\}$.

Finally, suppose there exist $\tau, \tau' \in \{1, \ldots, T\}$ such that $p_i^\tau > 0$ and $p_i^{\tau'} = 0$. In this case, we can decompose p_i into spells in and out of poverty. Without loss of generality, suppose the first spell is associated with a positive level of per-period poverty. Thus, there exist $K \in \mathbb{N} \setminus \{1\}$ and $t^1, \ldots, t^K \in \{1, \ldots, T\}$ such that $\sum_{k=1}^K t^k = T$, $p_i^1, \ldots, p_i^{t^1} > 0$, $p_i^{t^1+1} = \ldots = p_i^{t^1+t^2} = 0$, etc. The t^k are the lengths of the spells in poverty for all odd k and the length of the spells out of poverty for all even k. By applying across-spells average decomposability as many times as necessary, we obtain

$$\mathbf{P}_i(p_i) = \frac{t^1}{T} \mathbf{P}_i(p_i^1, \ldots, p_i^{t^1}) + \ldots + \frac{t^K}{T} \mathbf{P}_i(p_i^{t^1+\ldots+t^{K-1}+1}, \ldots, p_i^T). \tag{3}$$

Applying one-period equivalence and single-spell additive decomposability, we obtain

$$\frac{t^k}{T} \mathbf{P}_i(p_i^{t^1+\ldots+t^{k-1}+1}, \ldots, p_i^{t^1+\ldots+t^k}) = \frac{t^k}{T} (p_i^{t^1+\ldots+t^{k-1}+1} + \ldots + p_i^{t^1+\ldots+t^k}) \quad \text{for all odd } k. \tag{4}$$

Analogously, using one-period equivalence and across-spells average decomposability as many times as needed, it follows that

$$\frac{t^k}{T} \mathbf{P}_i(p_i^{t^1+\ldots+t^{k-1}+1}, \ldots, p_i^{t^1+\ldots+t^k}) = 0 \quad \text{for all even } k. \tag{5}$$

Recall that the t^k are the lengths of the spells in and out of poverty and, thus, substituting (4) and (5) back into (3) yields (1). ■

3 Aggregate Intertemporal Poverty Measures

Given the individual intertemporal poverty measures $\mathbf{P}_i^*$ for each individual in a society, we use an *aggregate intertemporal poverty index* to obtain an overall measure of poverty that allows us to compare intertemporal poverty across societies, possibly involving different sampling periods and different populations and population sizes. Although it is possible to define an aggregate intertemporal measure from first principles (that is, using individual per-period poverty indicators as the basic objects to be aggregated into overall poverty), we proceed by implicitly assuming that the intertemporal aggregation is performed first (see the discussion in the introduction) and the second step consists of aggregating these indicators across individuals in a society to arrive at an overall measure of intertemporal poverty. This choice is motivated primarily by our desire to keep the exposition simple.

To describe the second part of the aggregation process, let $\Pi = \cup_{n\in\mathbb{N}} \mathbb{R}^n_+$ and consider a function $\mathbf{P}\colon \Pi \to \mathbb{R}_+$, to be interpreted as a measure that assigns an aggregate value of intertemporal poverty to each vector of individual intertemporal poverty values.

The aggregate intertemporal poverty measure we propose is defined as average individual intertemporal poverty, that is, we employ the index $\mathbf{P}^*$ defined by

$$\mathbf{P}^*(\mathbf{p}) = \frac{1}{n}\sum_{i=1}^{n} \mathbf{p}_i \tag{6}$$

for all $n \in \mathbb{N}$ and for all $\mathbf{p} \in \mathbb{R}^n_+$. We view aggregate poverty as an *ordinal* variable and, thus, any increasing transformation of $\mathbf{P}^*$ can equivalently be employed. Of course, *individual* intertemporal poverty measures must contain more than ordinal and interpersonally non-comparable information—clearly, the definition of $\mathbf{P}^*$ is incompatible with the assumption that the $\mathbf{p}$ carry ordinally measurable and interpersonally non-comparable information only. We provide a characterization of $\mathbf{P}^*$ that is based on results in population ethics due to Blackorby, Bossert and Donaldson (2002, 2005). However, we provide a self-contained proof because the domain we consider here is different from the one in these contributions. We note that, although we use the indices $\mathbf{P}_i^*$ in the application discussed in the following section, our characterization is valid for *any* way of defining the individual intertemporal poverty values $\mathbf{p}_i$.

The first axiom is a weak monotonicity property. It requires that, in situations where the level of individual intertemporal poverty is equal across individuals, aggregate intertemporal poverty is increasing in individual intertemporal poverty. The scope of the axiom is restricted to comparisons involving a given population size. For any $n \in \mathbb{N}$, let $\mathbf{1}_n$ denote the vector consisting of n ones.

Minimal increasingness. For all $n \in \mathbb{N}$ and for all $a, b \in \mathbb{R}_+$, if $a > b$, then

$$\mathbf{P}(a\mathbf{1}_n) > \mathbf{P}(b\mathbf{1}_n).$$

Minimal increasingness is a very mild monotonicity requirement because it applies to equal distributions of individual intertemporal poverty and to fixed-population-size comparisons only.

The second axiom we impose on $\mathbf{P}$ is an impartiality property with respect to increases or decreases in individual poverty. If a single individual's intertemporal poverty level changes by a given amount, it does not matter whose poverty changes. Let $n \geq 2$. We use the notation $\mathbf{1}_n^j$ for the vector $w \in \mathbb{R}_+^n$ such that $w_j = 1$ and $w_i = 0$ for all $i \in \{1, \ldots, n\} \setminus \{j\}$.

Incremental equity. For all $n \in \mathbb{N} \setminus \{1\}$, for all $\mathbf{p} \in \mathbb{R}_+^n$, for all $d \in \mathbb{R}$ and for all $j, k \in \{1, \ldots, n\}$ with $j \neq k$, if $(\mathbf{p} + d\mathbf{1}_n^j) \in \mathbb{R}_+^n$ and $(\mathbf{p} + d\mathbf{1}_n^k) \in \mathbb{R}_+^n$, then

$$\mathbf{P}\left(\mathbf{p} + d\mathbf{1}_n^j\right) = \mathbf{P}\left(\mathbf{p} + d\mathbf{1}_n^k\right).$$

Incremental equity incorporates a notion of *anonymity* in terms of gains and losses in individual poverty. If there is an increase or decrease of a given value in individual intertemporal poverty, the measure is insensitive to the identity of the person experiencing this gain or loss. Clearly, gains and losses of poverty values have to be comparable across individuals in order for this axiom to be well-defined. In particular, poverty has to employ *translation-scale comparable* values; see, for instance, Blackorby, Donaldson and Weymark (1984) and Bossert and Weymark (2004) for a discussion.

Minimal increasingness and incremental equity together characterize ordinal aggregate poverty measures based on average (or total) individual poverty for any fixed population size; see Blackorby, Bossert and Donaldson (2002, 2005). However, further axioms are needed to extend this characterization to the entire domain Π, that is, to aggregate poverty comparisons that may involve different population sizes. One possibility is to require that average individual poverty is a *critical level* for any poverty vector $\mathbf{p} \in \Pi$; see, again, Blackorby, Bossert and Donaldson (2005) for a detailed discussion. That is, aggregate poverty is unaffected if an individual with average poverty is added to a given distribution $\mathbf{p} \in \Pi$. This reflects the position that aggregate poverty is a per-capita notion, a view that is shared in most of the literature on poverty measurement.

Average critical levels. For all $n \in \mathbb{N}$ and for all $\mathbf{p} \in \mathbb{R}^n_+$,

$$\mathbf{P}\left(\mathbf{p}, \frac{1}{n}\sum_{i=1}^{n}\mathbf{p}_i\right) = \mathbf{P}(\mathbf{p}).$$

Recall that the arguments $\mathbf{p}_i$ of $\mathbf{P}$ are themselves intertemporal aggregates of individual per-period poverty values and, thus, all information concerning per-period poverty lines has already been fully taken into consideration when arriving at the individual intertemporal poverty indices. Thus, treating average poverty as a critical level does not conflict in any way with whatever method is chosen to identify these per-period poverty lines.

The three axioms defined above characterize the class of all aggregate poverty measures that are ordinally equivalent to $\mathbf{P}^*$. The axioms can be motivated further by noting that they are implied by other properties with intuitive interpretations. For instance, minimal increasingness is a consequence of standard increasingness, incremental equity is implied by a fixed-population information-invariance property and average critical levels is implied by increasingness, the existence of critical levels and a variable-population information-invariance condition; see Blackorby, Bossert and Donaldson (2005, Chs. 4–6) for a detailed discussion.

Theorem 2 *An aggregate intertemporal poverty measure* $\mathbf{P}$ *satisfies minimal increasingness, incremental equity and average critical levels if and only if* $\mathbf{P}$ *is an increasing transformation of* $\mathbf{P}^*$*.*

Proof. That any increasing transformation of $\mathbf{P}^*$ satisfies minimal increasingness, incremental equity and average critical levels is straightforward to verify.

Conversely, suppose that $\mathbf{P}$ satisfies the three axioms.

If $n = 1$, minimal increasingness alone implies the result.

Now let $n \geq 2$. Consider $\mathbf{p} \in \mathbb{R}^n_+$ and $j, k \in \{1, \ldots, n\}$ with $j \neq k$, and suppose $d \in \mathbb{R}_+$ is such that $\mathbf{p}_j \geq d$. By incremental equity,

$$\mathbf{P}(\mathbf{p} - d\mathbf{1}^j_n + d\mathbf{1}^k_n) = \mathbf{P}(\mathbf{p} - d\mathbf{1}^j_n + d\mathbf{1}^j_n) = \mathbf{P}(\mathbf{p}). \tag{7}$$

Let $\mathbf{p} \in \mathbb{R}^n_+$ and suppose, without loss of generality, that $\mathbf{p}_1 \geq \mathbf{p}_2 \geq \ldots \geq \mathbf{p}_n$. By (repeated if necessary) application of (7), it follows that

$$\mathbf{P}(\mathbf{p}) \;\; = \;\; \mathbf{P}\left(\mathbf{p}_1 - \left(\mathbf{p}_1 - \frac{1}{n}\sum_{i=1}^{n}\mathbf{p}_i\right), \mathbf{p}_2, \ldots, \mathbf{p}_n + \left(\mathbf{p}_1 - \frac{1}{n}\sum_{i=1}^{n}\mathbf{p}_i\right)\right)$$

$$
\begin{aligned}
&= \mathbf{P}\left(\frac{1}{n}\sum_{i=1}^{n}\mathbf{p}_i, \mathbf{p}_2, \ldots, \mathbf{p}_n + \mathbf{p}_1 - \frac{1}{n}\sum_{i=1}^{n}\mathbf{p}_i\right) \\
&\vdots \\
&= \mathbf{P}\left(\frac{1}{n}\sum_{i=1}^{n}\mathbf{p}_i, \frac{1}{n}\sum_{i=1}^{n}\mathbf{p}_i, \ldots, \sum_{i=1}^{n}\mathbf{p}_i - \frac{n-1}{n}\sum_{i=1}^{n}\mathbf{p}_i\right) \\
&= \mathbf{P}\left(\left(\frac{1}{n}\sum_{i=1}^{n}\mathbf{p}_i\right)\mathbf{1}_n\right).
\end{aligned}
$$

Together with minimal increasingness, this implies

$$
\begin{aligned}
\mathbf{P}(\mathbf{p}) \geq \mathbf{P}(\mathbf{q}) \;&\Leftrightarrow\; \mathbf{P}\left(\left(\frac{1}{n}\sum_{i=1}^{n}\mathbf{p}_i\right)\mathbf{1}_n\right) \geq \mathbf{P}\left(\left(\frac{1}{n}\sum_{i=1}^{n}\mathbf{q}_i\right)\mathbf{1}_n\right) \\
&\Leftrightarrow\; \frac{1}{n}\sum_{i=1}^{n}\mathbf{p}_i \geq \frac{1}{n}\sum_{i=1}^{n}\mathbf{q}_i \\
&\Leftrightarrow\; \mathbf{P}^*(\mathbf{p}) \geq \mathbf{P}^*(\mathbf{q}) \qquad (8)
\end{aligned}
$$

for all $n \in \mathbb{N}$ and for all $\mathbf{p}, \mathbf{q} \in \mathbb{R}^n_+$. Thus, all fixed-population-size comparisons must be performed according to $\mathbf{P}^*$.

Now consider $n, m \in \mathbb{N}$ such that $n \neq m$, $\mathbf{p} \in \mathbb{R}^n_+$ and $\mathbf{q} \in \mathbb{R}^m_+$. Without loss of generality, suppose $n > m$. By (repeated if necessary) application of average critical levels, we obtain

$$
\mathbf{P}(\mathbf{q}) = \mathbf{P}\left(\mathbf{q}, \frac{1}{m}\sum_{i=1}^{m}\mathbf{q}_i\right) = \ldots = \mathbf{P}\left(\mathbf{q}, \left(\frac{1}{m}\sum_{i=1}^{m}\mathbf{q}_i\right)\mathbf{1}_{n-m}\right)
$$

and, therefore,

$$
\mathbf{P}(\mathbf{p}) \geq \mathbf{P}(\mathbf{q}) \;\Leftrightarrow\; \mathbf{P}(\mathbf{p}) \geq \mathbf{P}\left(\mathbf{q}, \left(\frac{1}{m}\sum_{i=1}^{m}\mathbf{q}_i\right)\mathbf{1}_{n-m}\right). \qquad (9)
$$

Because $\mathbf{p}$ and $(\mathbf{q}, ((1/m)\sum_{i=1}^{m}\mathbf{q}_i)\mathbf{1}_{n-m})$ have the same population size n, (8) implies

$$
\begin{aligned}
\mathbf{P}(\mathbf{p}) \geq \mathbf{P}\left(\mathbf{q}, \left(\frac{1}{m}\sum_{i=1}^{m}\mathbf{q}_i\right)\mathbf{1}_{n-m}\right) \;&\Leftrightarrow\; \frac{1}{n}\sum_{i=1}^{n}\mathbf{p}_i \geq \frac{1}{n}\left(\sum_{i=1}^{m}\mathbf{q}_i + \frac{n-m}{m}\sum_{i=1}^{m}\mathbf{q}_i\right) \\
&\Leftrightarrow\; \sum_{i=1}^{n}\mathbf{p}_i \geq \sum_{i=1}^{m}\mathbf{q}_i + \frac{n-m}{m}\sum_{i=1}^{m}\mathbf{q}_i
\end{aligned}
$$

which implies

$$
\mathbf{P}(\mathbf{p}) \geq \mathbf{P}\left(\mathbf{q}, \left(\frac{1}{m}\sum_{i=1}^{m}\mathbf{q}_i\right)\mathbf{1}_{n-m}\right) \;\Leftrightarrow\; \frac{1}{n}\sum_{i=1}^{n}\mathbf{p}_i \geq \frac{1}{m}\sum_{i=1}^{m}\mathbf{q}_i.
$$

By (9), we obtain

$$\mathbf{P}(\mathbf{p}) \geq \mathbf{P}(\mathbf{q}) \Leftrightarrow \frac{1}{n}\sum_{i=1}^{n}\mathbf{p}_i \geq \frac{1}{m}\sum_{i=1}^{m}\mathbf{q}_i \Leftrightarrow \mathbf{P}^*(\mathbf{p}) \geq \mathbf{P}^*(\mathbf{q})$$

which completes the proof. ■

4 An Application to European Countries

The purpose of this section is to illustrate the aggregate measure of poverty, $\mathbf{P}^*$ as defined in (6) with individual intertemporal poverty measures $\mathbf{p}_i$ given by $\mathbf{P}_i^*(p_i)$, using the European Community Household Panel (ECHP). We base our analysis on all the waves available in ECHP, which cover the period from 1994 to 2001. The surveys are conducted at a European national level. We do not aim at providing an accurate analysis of poverty persistence in EU countries, hence we take the available years as such without considering the presence of any measurement errors and the possibility that poverty spells are censored at the beginning or at the end of the sample we observe. (For a discussion of these estimation techniques see, among others, Bane and Ellwood, 1986, and Jenkins, 2000.) The ECHP is an ambitious effort at collecting information on the living standards of the households of the EU member states using common definitions, information collection methods and editing procedures. It contains detailed information on incomes, socio-economic characteristics, housing amenities, consumer durables, social relations, employment conditions, health status, subjective evaluation of well-being, etc. Of the 15 EU member states, we could not consider Sweden since the data for this country is cross-sectional only. For Finland and Austria, data were not available for all the waves. While the former joined from wave three onwards, the Austrian data are available beginning with the second wave. The full ECHP data format for the UK, Germany and Luxembourg is available only for the years 1994–1996. We therefore use the ECHP data format derived from national surveys instead. These data are available for the UK and Germany for 1994–2001; for Luxembourg, on the other hand, they are available from 1995 onwards only. For this reason, Luxembourg, like Austria, was included from the second wave onwards. The unit of our analysis is the individual. The calculation uses required sample weights. Since we are interested in analyzing poverty spells and the effect of persistence in the state of poverty, we consider only individuals that were interviewed in all the waves for each country. The variable studied is net yearly household income equivalized using the OECD-modified equivalence scale in order to account for different household size and composition. For each country and for each period in the sample, the poverty line is set to 60% of the national median. Thus, for any given per-period income distribution y^t, the poverty line in this period, $z^t(y^t)$, is given by 0.6 times the median of y^t. An individual is classified as poor if its income is strictly below the poverty line.

For the per-period individual poverty indicators, we choose three among those most commonly used in empirical studies, namely, the normalized relative gaps raised to the power $\alpha \in \{0, 1, 2\}$ so that, for any period $t \in \mathbb{N}$,

$$p_i^t = \begin{cases} \left(\frac{z^t(y^t) - y_i^t}{z^t(y^t)}\right)^\alpha & \text{if } y_i^t < z^t(y^t), \\ 0 & \text{if } y_i^t \geq z^t(y^t). \end{cases}$$

When $\alpha = 0$, the individual poverty indicator captures only the number of periods spent in poverty. In this case, p_i^t assumes the value one for those in poverty and zero for everybody else. This individual index is similar in spirit to the head-count ratio. When $\alpha = 1$, we consider not only the incidence of poverty but also its intensity since we take into account how poor each poor individual is, expressed as a proportion of the poverty line. In this case, the index resembles the normalized poverty gap. When $\alpha = 2$, the normalized gaps are squared. As a result, we give more importance to poorer individuals as opposed to those poor whose income is less distant from the poverty line.

We compare the values of the index we propose with those obtained with a weight equal to one independently of the duration of the spell. In this case persistence does not play a role. This is the only case where aggregating first across time and then across individuals produces exactly the same results as the reverse order of aggregation does, that is, aggregating first across individuals and then across time. The aggregate index coincides with the average of per-period standard poverty indices. If, in addition, $\alpha = 0$, the aggregate index is the average of the per-period head-count ratios; if $\alpha = 1$, it is the average of the aggregate normalized poverty gap indices; and, lastly, if $\alpha = 2$, it is the average of the aggregate squared normalized poverty gaps.

[**Insert Table 1 and Table 2 here**]

The results are contained in Table 1, while in Table 2 we report the rankings of the countries under alternative indices. In the first column the names of the countries are reported while the following pairs of columns present poverty indicators for the three different values of α. The first column of each pair contains the values of the index where persistence does not play any role. The values of the index we propose in this paper are reported in the second column of each pair. The results show that persistence in a state of poverty does play a role in poverty measurement. It constitutes relevant information and its omission would not give a correct picture of the phenomenon. The rankings of the countries change, particularly in the center of the rankings. Portugal, followed by Greece, is indeed always the poorest country among those under analysis. At the opposite end the Netherlands is always the least poor when $\alpha = 0$ while Denmark followed by Finland is the least poor for the other values of the parameter α. The majority of rank changes are observed for $\alpha = 0$. In this case Denmark, Austria and particularly Spain improve their position by one, two and three slots respectively, while Finland, Germany, Luxembourg, the UK and Ireland move one position down (the UK sees its position worsen by two). For $\alpha = 1$, no country experiences a movement of more than one position. In particular, Luxembourg and the Netherlands, Germany and Austria, Italy and Spain switch place in the rankings. For $\alpha = 2$, Ireland and the Netherlands switch position while Germany moves below both Belgium and France. From a social policy point of view the discovery of this temporal characteristic of poverty should lead to different recommendations: in a country like Germany, for example, policy should aim at helping individuals and households to escape from poverty; in the Netherlands, on the other hand, a more effective policy would be one preventing individuals from becoming poor.

5 Concluding Remarks

Time is an important aspect of individual lives. Experiences are accumulated over lifetimes and the assessment of the impact a poverty spell has on a person's situation may very well differ according to what happened to the individual in previous periods. The index of intertemporal poverty that we propose aims at including experiences in addition to the incidence of poverty and inequality among those who are poor when measuring poverty. The results of our simple application to EU countries show that a very different picture can emerge when we value individual experiences.

Clearly, we do not claim that our index is *the only* plausible measure of intertemporal poverty, just as no one would, we believe, declare the Gini coefficient to be the only possible choice as a tool to measure income inequality, to the exclusion of all other measures. However, we view our proposal as an attractive option and we think the properties used in its characterization have some strong intuitive appeal.

We restrict attention to the intertemporal aggregation of per-period overall poverty in this paper. Clearly, our approach can be modified easily in order to obtain measures of chronic poverty based on the idea underlying our new index. For instance, any particular definition of chronic poverty can be accommodated by adding a *duration* criterion and declaring an individual to be chronically poor if there is at least one poverty spell of at least that duration and then perform the aggregation over individuals by calculating the arithmetic mean of the poverty values only of all those satisfying this criterion.

Further work could be done by performing statistical inference with the index we propose and by considering the possibility that poverty spells are censored when estimating intertemporal poverty.

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Table 1: Aggregate Intertemporal Poverty in EU Member States, with (yes) and without (no) Weights for Persistence (Index Values).

	$\alpha = 0$		$\alpha = 1$		$\alpha = 2$	
Country	no	yes	no	yes	no	yes
Denmark	0.096	0.327	0.017	0.060	0.006	0.018
Finland	0.094	0.356	0.018	0.069	0.006	0.022
Luxembourg	0.114	0.468	0.021	0.092	0.006	0.026
Netherlands	0.087	0.298	0.023	0.079	0.012	0.038
Ireland	0.187	0.768	0.035	0.148	0.011	0.046
Austria	0.116	0.422	0.028	0.111	0.012	0.049
Belgium	0.134	0.534	0.031	0.127	0.013	0.052
France	0.144	0.583	0.033	0.141	0.013	0.054
Germany	0.107	0.434	0.028	0.121	0.013	0.056
UK	0.176	0.750	0.048	0.217	0.022	0.100
Spain	0.190	0.702	0.058	0.233	0.029	0.119
Italy	0.181	0.721	0.058	0.257	0.031	0.140
Greece	0.201	0.827	0.067	0.306	0.033	0.153
Portugal	0.220	1.005	0.071	0.357	0.037	0.188

Table 2: Aggregate Intertemporal Poverty in EU Member States, with (yes) and without (no) Weights for Persistence (Rankings).

	$\alpha = 0$		$\alpha = 1$		$\alpha = 2$	
Country	no	yes	no	yes	no	yes
Denmark	3	2	1	1	1	1
Finland	2	3	2	2	2	2
Luxembourg	5	6	3	4	3	3
Netherlands	1	1	4	3	5	4
Ireland	11	12	9	9	4	5
Austria	6	4	6	5	6	6
Belgium	7	7	7	7	8	7
France	8	8	8	8	9	8
Germany	4	5	5	6	7	9
UK	9	11	10	10	10	10
Spain	12	9	12	11	11	11
Italy	10	10	11	12	12	12
Greece	13	13	13	13	13	13
Portugal	14	14	14	14	14	14