E C O N O M I C S B U L L E T I N

A new factorial decomposition for the atkinson measure

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Abstract

In this article we explore an alternative factorial decomposition for Atkinson indices and taking Sala−i−Martin's (2002) article "The Disturbing 'Rise' of Global Income Inequality" as a reference, the possibilities of Atkinson indices are shown in regard to completing and detailing information in studies of inequality among populations and populations subgroups.

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1. Introduction

The aim of this paper is two-fold. First it proposes an alternative factorial decomposition for Atkinson indices (Section 3). Secondly, we discuss that this decomposition represents a good compromise between selecting an inequality measure that satisfies major defensible properties and making use of the measure for a more in-depth subgroup decomposition analysis. Taking Sala-i-Martin's (2002) article "The Disturbing 'Rise' of Global Income Inequality" as a reference, the possibilities of Atkinson indices are shown in regard to completing and detailing information in studies of inequality among populations and populations subgroups (Section 4). Section 2 gives a review of some of the basic properties that are fulfilled by the most popular inequality measures.

2. A review of some of the basic properties

The vast literature on inequalities has produced a substantial number of measures. Among the most widely accepted are the Gini coefficient, the variance of incomes or the variance of the logarithm of income, Generalized Entropy indices and Atkinson indices. We will next review some of the basic properties that are satisfied by these measures.

The Gini coefficient, the Generalized Entropy family and the Atkinson family satisfy the *Pigou-Dalton Transfer Principle*, the *Income Scale Independence Principle* and the *Principle of Population*.

The *Principle of Additive Decomposability* states that the total inequality can be written down as the sum of inequality within groups and inequality between groups. This property can be extremely useful for analysing income inequality in a population partitioned according to identifiable characteristics. Bourguignon (1979) and Shorrocks (1980, 1984) show that the only inequality indices that satisfy all the above principles are the Generalized Entropy indices.

The possibilities of additive decomposition of Gini's index have been widely studied (e.g. Pyatt (1976), Lambert & Aronson (1993), Dagum (1997), Mussard, Seyte & Terraza (2003)).

J. Foster & A. Shneyerov (2000) take earlier studies (A. Shorrocks (1980) and S. Anand (1983)) as a basis and call into question the traditional definition of within- and between-group terms. They explore an additive decomposition property for inequality measures that they call *path independent decomposition* and characterize the class of measures that have this property.

They notice that the components traditionally considered are not independent since variations in between-group inequality result in modifications not only in the between-group component but also in the within-group one, even though there may have been no change in within-group inequality. This is because the within group term is a weighted average of group inequalities where the weights depend on the population and income shares. Whenever income shares are involved in the weights of the within-group component the resulting value is not independent of the between- component. Of the above family of measures only the MLD index (which is the Generalized Entropy index with coefficient 0), in weights whose within- component involves only population percentages, satisfies the condition that the within and between components be independent. For the same reason the within and between group Gini terms are not independent.

There is another property that is usually considered as secondary in selecting a measure for practical studies: values must fall within the interval [0,1]. We think that this is an important property for empirical studies. The main advantage of normalising an inequality measure is that it is possible to quantify the level of inequality and know at all times what progress has been made towards equality and how far there is still to go. Moreover, comparisons can be drawn between the inequality levels for income distributions in different regions or between different periods in the same region, regardless of the population size. If the bounds of a measure are not established, it is of no use in this type of analysis. And if the bounds of the measure depend on population size, it is not suitable for comparing inequalities of different-sized populations. Only if the measure has fixed bounds can it be used for such comparisons.

Of the family of measures considered in this section only the Gini index and Atkinson indices are included in the interval [0,1]. Generalized Entropy indices are unbounded above for $c \leq 0$ and they cannot be normalised, and if $c>0$ and all incomes are positive the upper bound depends on the size of the population and the normalisation is achieved at the cost of giving up the population replication condition and the property of additive decomposition. Also the variance of incomes or the logarithm of income are unbounded above.

3. Factorial Decomposition of the Atkinson Equality Measure.

Atkinson's indices are not additively decomposable. However they do have very good properties. Any Atkinson's index fulfils the basic axioms, makes explicit value judgements through the parameter ε, and is included in the interval [0,1]. The present section opens up the possibility of an alternative decomposition for Atkinson's equality indices as the product of the within-group and between-group equality terms. In 1981 C. Blackorby et al. presented a factorial decomposition for the indices of the Atkinson-Kolm-Sen family from a welfare theory approach, although their "ethical" decomposition has a rather different motivation and a different formula than the present one.

Suppose that the population of N individuals is split into J mutually exclusive groups and let N_j be the size of group $j=1,\dots,J$. Given a distribution of income $\mathbf{y} = (y_1,\dots,y_N)$ we let $\mathbf{y}_j = (y_{j1},\dots,y_{jN_j})$ indicate the distribution for group j, so that $\mathbf{y} = (\mathbf{y}_1,\dots,\mathbf{y}_J)$.

Denoting as μ the mean of distribution $\mathbf{y}$, we let $\mathbf{e} = (\mu,\dots,\mu)$ represent the distribution where all individuals in the population receive the mean income of $\mathbf{y}$. Similarly $\mathbf{e}_j = (\mu_j,\dots,\mu_j)$ is the distribution where every individual in group j is given the mean income μ_j of distribution $\mathbf{y}_j$.

Let p_j and s_j be the respective population and income shares, i.e.:

$$p_j = \frac{N_j}{N} \text{ and } s_j = \frac{N_j \mu_j}{N\mu} \qquad (1)$$

The Atkinson's inequality index of the distribution $\mathbf{y}$ according to the positive values of parameter ε is by Atkinson (1970):

$$I_\varepsilon^A(\mathbf{y}) = \begin{cases} 1 - \dfrac{\left(\sum_{i=1}^{N} \frac{1}{N} (y_i)^{1-\varepsilon} \right)^{\frac{1}{1-\varepsilon}}}{\mu} & \text{if} \quad \varepsilon > 0 \quad \varepsilon \neq 1 \\ 1 - \dfrac{\prod_{i=1}^{N} (y_i)^{1/N}}{\mu} & \text{if} \quad \varepsilon = 1 \end{cases} \qquad (2)$$

Let $E_\varepsilon^A(\mathbf{y}) = 1 - I_\varepsilon^A(\mathbf{y})$ be the Atkinson's equality index.

Similarly let $I^A_{j\varepsilon}(\mathbf{y}_j)$ be the Atkinson's inequality index of the distribution $\mathbf{y}_j$ for each group j. Then the Atkinson's equality index $E^A_{j\varepsilon}(\mathbf{y}_j) = 1 - I^A_{j\varepsilon}(\mathbf{y}_j)$ is given by:

$$E^A_{j\varepsilon}(\mathbf{y}_j) = \begin{cases} \dfrac{\left(\sum_{i=1}^{N_j} \dfrac{1}{N_j}(y_{ji})^{1-\varepsilon}\right)^{\frac{1}{1-\varepsilon}}}{\mu_j} & \text{if} \quad \varepsilon > 0 \quad \varepsilon \neq 1 \\ \dfrac{\prod_{i=1}^{N_j}(y_{ji})^{1/N_j}}{\mu_j} & \text{if} \quad \varepsilon = 1 \end{cases} \tag{3}$$

Let $EB^A_\varepsilon(\mathbf{y}) = E^A_\varepsilon(\mathbf{e}_1, ..., \mathbf{e}_J)$ be the "between-group" term, i.e. the equality associated with a population of J equalitarian subgroups which is defined by:

$$EB^A_\varepsilon(\mathbf{y}) = \begin{cases} \dfrac{\left(\sum_{j=1}^{J} \dfrac{N_j}{N}(\mu_j)^{1-\varepsilon}\right)^{\frac{1}{1-\varepsilon}}}{\mu} & \text{if} \quad \varepsilon > 0 \quad \varepsilon \neq 1 \\ \dfrac{\prod_{j=1}^{J}(\mu_j)^{N_j/N}}{\mu} & \text{if} \quad \varepsilon = 1 \end{cases} \tag{4}$$

Atkinson's equality measure satisfies the following elementary factorial decomposability property:

$$E^{\mathbf{A}}_\varepsilon(\mathbf{y}) = E^{\mathbf{A}}_\varepsilon(\mathbf{y}^1, ..., \mathbf{y}^J) = \frac{E^{\mathbf{A}}_\varepsilon(\mathbf{y}^1, ..., \mathbf{y}^J)}{EB^{\mathbf{A}}_\varepsilon} EB^{\mathbf{A}}_\varepsilon \tag{5}$$

Let

$$EW^A_\varepsilon = \frac{E^A_\varepsilon(\mathbf{y}_1, ..., \mathbf{y}_J)}{EB^A_\varepsilon} \tag{6}$$

Equation (5) can then be rewritten:

$$E^A_\varepsilon(\mathbf{y}) = EW^A_\varepsilon \; EB^A_\varepsilon \tag{7}$$

Theorem 1 below establishes the relation between EW^A_ε and the equality indices for each group. In particular it is demonstrated that EW^A_ε can be expressed solely as a function of the levels of equality of the subgroups and their population and income shares. It should be something like an "average" of the equality of each individual group.

Theorem 1. The term Ew_ε^A *given in equation (6) can be expressed in the following functional form:*

$$Ew_\varepsilon^A = \begin{cases} \left(\sum_{j=1}^{J} \frac{p_j^\varepsilon s_j^{1-\varepsilon}}{\sum_{j=1}^{J} p_j^\varepsilon s_j^{1-\varepsilon}} \left(E_{j_\varepsilon}^A \right)^{1-\varepsilon} \right)^{\frac{1}{1-\varepsilon}} & \text{if } \varepsilon > 0 \quad \varepsilon \neq 1 \\ \prod_{j=1}^{J} \left(E_{j_1}^A \right)^{p_j} & \text{if } \varepsilon = 1 \end{cases} \qquad (8)$$

Demonstration: If ε>0 and ε≠1 considering equations (2) and (3), we can operate to obtain:

$$E_\varepsilon^A(\mathbf{y}) = \frac{\left(\sum_{i=1}^{N} \frac{1}{N} (y_i)^{1-\varepsilon} \right)^{\frac{1}{1-\varepsilon}}}{\mu} = \frac{\left(\sum_{j=1}^{J} \frac{N_j}{N} \left(\frac{\sum_{i=1}^{N_j} \frac{1}{N_j} (y_{ji})^{1-\varepsilon}}{\mu_j^{1-\varepsilon}} \right) \mu_j^{1-\varepsilon} \right)^{\frac{1}{1-\varepsilon}}}{\mu} = \qquad (9)$$

$$\frac{\left(\sum_{j=1}^{J} \frac{N_j}{N} \left(E_{j\varepsilon}^A \mu_j \right)^{1-\varepsilon} \right)^{\frac{1}{1-\varepsilon}}}{\mu} = \frac{\left(\sum_{j=1}^{J} p_j \left(E_{j\varepsilon}^A \mu_j \right)^{1-\varepsilon} \right)^{\frac{1}{1-\varepsilon}}}{\mu}$$

Now taking into account equations (4) and (9), equation (6) can then be rewritten:

$$Ew_\varepsilon^A = \frac{\frac{\left(\sum_{j=1}^{J} p_j \left(E_{j_\varepsilon}^A \mu_j \right)^{1-\varepsilon} \right)^{\frac{1}{1-\varepsilon}}}{\mu}}{\frac{\left(\sum_{j=1}^{J} p_j (\mu_j)^{1-\varepsilon} \right)^{\frac{1}{1-\varepsilon}}}{\mu}} = \frac{\left(\sum_{j=1}^{J} (p_j)^\varepsilon (s_j)^{1-\varepsilon} \left(E_{j_\varepsilon}^A \right)^{1-\varepsilon} \right)^{\frac{1}{1-\varepsilon}}}{\left(\sum_{j=1}^{J} (p_j)^\varepsilon (s_j)^{1-\varepsilon} \right)^{\frac{1}{1-\varepsilon}}} = \left(\sum_{j=1}^{J} \frac{(p_j)^\varepsilon (s_j)^{1-\varepsilon}}{\sum_{j=1}^{J} (p_j)^\varepsilon (s_j)^{1-\varepsilon}} \left(E_{j_\varepsilon}^A \right)^{1-\varepsilon} \right)^{\frac{1}{1-\varepsilon}}$$

A similar result is obtained for ε=1 by appropriately substituting products for summations. ∎

Remarks.

Here we wish to justify considering the term Ew_ε^A in (8) as a within group equality term.

Consider the Generalized Entropy (GE) measures (Cowell (1977)) given by:

$$I_c^{GE}(\mathbf{y}) = \begin{cases} \sum_{i=1}^{N} \frac{1}{N} \frac{\left(y_i / \mu \right)^\alpha - 1}{c^2 - c} & \text{if } c \neq 0,1 \\ -\sum_{i=1}^{N} \frac{1}{N} \log\left(y_i / \mu \right) & \text{if } c = 0 \\ \sum_{i=1}^{N} \frac{1}{N} \frac{y_i}{\mu} \log\left(y_i / \mu \right) & \text{if } c = 1 \end{cases}$$

As mentioned in the preceding section, any GE index I_c^{GE} can be additively decomposed and the within-group term is (Bourguignon (1979) and Shorrocks (1980, 1984)):

$$Iw_c^{GE} = \sum_{j=1}^{J} p_j^{1-c} s_j^c I_{j_c}^{GE} \qquad (10)$$

where $I_{j_c}^{GE}$ is be the GE inequality index of the distribution $\mathbf{y}_j$ for each group j.

Now let us compare this expression with the one obtained in Theorem 1.

It must be stressed that the within-group term in (8) closely resembles that of the GE measures in (10). The within contribution Iw_c^{GE} is a weighted average of the inequality of each individual group and the within term Ew_ε^A is a (1-ε)-order weighted mean of the group equalities. The weights in (8) are the same as in (10) but normalised. If the level of equality coincides in all groups, the mean and the mean of order (1-ε) lead to the same result. The bigger the difference in the levels of equality of the groups, the smaller the value of the mean of order (1-ε), so that the mean of order (1-ε) indicates not only the mean levels of equality of groups but also the differences between those levels. In this sense, we consider that the mean of order (1-ε) has advantages over the arithmetic mean, especially in situations where the distributions within groups are very unequal.

This is why we consider Ew_ε^A to be a measure of equality within groups, and equation (7) therefore provides a decomposition as a product of Atkinson's equality indices in the within- and between-groups components.

The conclusion with regard to the independence of components is that it is only for ε=1 in within- component weights that population share alone is involved, making this the only case for which the within- and between- components are independent.

4. Application.

The paper by Sala-i-Martin (2002) estimates global income inequality using seven different popular indices and concludes, among other results, that all indices show a reduction in global income inequality between 1980-1998 and that within-county inequalities have increased slightly over the last thirty years.

Without questioning for a moment any of these conclusions, this section seeks to make two small contributions to the relevant results on the basis of the foregoing sections, which help us to detail and complete information and serve as an example for analyses of inequality.

The first refers to the size of the inequality. As indicated in Section 2 above, only with normalised measures is it possible to make any affirmation in this regard. Of the indices selected by Sala-i-Martin, only the Gini coefficient and Atkinson's index for inequality aversion levels of 0.5, $I_{0.5}^A$, and 1, I_1^A, enable us to assess the level of inequality at all times and estimate how much progress has been made and how far there is to go before the most egalitarian situation is reached. As an example, let us take the figures for these three indices for 1998: Gini=0.609, $I_{0.5}^A$=0.310 and I_1^A=0.522. Taking into account that they vary within the range [0,1], these figures are a long way 0, which indicates the most egalitarian situation, i.e. the absence of inequality. Moreover, the levels of Gini and I_1^A are greater than the 0.5 that represents the average situation. For these two indices we may conclude that the road that remains to be travelled before equality is reached is longer than that travelled so far.

Results of this type cannot be concluded with non normalised indices. For example, let us take a figure of I_0^{GE}=0.739 for the same year. Since this index is not bounded above the figure for the most unegalitarian situation is not known, and therefore it is not possible to estimate how much progress has been made from that situation and how far there is to go, i.e. whether we are above or below the mean figures.

The situation in regard to studying trends in inequality is similar. With normalised measures variations in inequality can be worked out directly by calculating the variations in the relevant indices. Thus, it can be observed that since 1980 inequality has decreased by 2.9% according to Gini, 3.3% according to $I_{0.5}^{A}$ and 4,1% according to I_1^{A}. The figures for I_0^{GE} range from 0.828 to 0.739, indicating that inequality has decreased, but with the measure being unbounded there is no indication as to how much progress has been made in regard to inequality.

The second contribution we wish to make is concerned with the property of independence of paths. As indicated in Section 2, it is only in the case of the MLD index, I_0^{GE} that the within- and between- components are independent. In all other additively decomposable measures, e.g. I_1^{GE} and I_2^{GE}, variations in the within-country components cannot be interpreted directly as increases or decreases in inequality within countries, since they could be due to variations in the between-country component. It is only the trend in the within-country component for I_0^{GE} that enables us to conclude whether inequality has increased or decreased within countries, but once again without being able to estimate the current level or the amount of progress made.

In this regard we believe that Section 3 enables more information to be added. Let us take in particular the Atkinson index for value 1 of the inequality aversion parameter, which is not only normalised but also decomposable and has independent within- and between-country components. Let us consider the figures for overall inequality and between- inequality calculated by Sala-i-Martin for 1970-1998. From these figures the overall equality and between-country equality can immediately be calculated (merely by subtracting the inequality indices from 1 in both cases). Using equation (6), the within-country equality can also be calculated. All these figures are presented in Table 1.

Table 1. Atkinson Indices for ε=1.

Figure 2 displays three curves: the overall, between-country and within-country equality. It must be said at this point that both overall and between-country equality are around the average levels. In spite of a slight drop early in the period, from 1980 onwards both equality levels increase. The within-country component, the figures for which are closer to equality, decreases steadily over the whole period.

Figure 2. Atkinson Indices for ε=1.

Moreover, with any index in the Atkinson family it is possible to represent the factorial decomposition with both its components in graphic form. Consider a square with sides of unit length, as shown in Figure 3, and the level curves of function $E_1^{A}(\mathbf{y}) = F\left(EB_1^{A}, EW_1^{A}\right) = EB_1^{A}\ EW_1^{A}$. On the x-axis we can represent the figures for EB_1^{A} and on the y-axis those for EW_1^{A}.

Figure 3. Equality Decomposition: Atkinson (1).

Each level curve represents an overall equality index value, and equivalently an inequality index value. Thus, for instance, level curve 0.447 allows us to represent the situation in 1970 and curve 0,478 that in 1998. Let us consider the points (0.530, 0.843) and (0.599, 0.798), which correspond to the factorial decomposition for these years.

Their projections enable levels of equality (and equivalently inequality) between and within groups to be assessed. Thus the comparison between the inequality levels of two income distributions is reduced to a comparison between their respective level curves and the corresponding projections on the axes, with information being provided at all times on how much progress has been made towards equality in each component, and how far there is still to go. In Figure 2 it can be seen that while between-country equality increased between 1970 and 1998 by 6.9%, within-country equality decreased by 4.5%.

So while it is true, as Sala-i-Martin states, that "within-country inequalities have increased slightly over the last thirty years. However, this increase has been so small that it does not offset the substantial reduction in across-country disparities" (p 39), we can add that the extent of the increase in within-country inequality is approximately 2/3 that of the decrease in between-country inequality.

Finally, it is true that factorial decomposition does not enable the contribution of each component to overall inequality to be established directly, but given that I_0^{GE} =-Ln($E^A{}_1$), a logarithmic transformation of index $E^A{}_1$ suffices to determine the contributions. This information is indicated in Sala-i-Martin (2002).

5. Conclusions.

Any Atkinson's index fulfils the basic axioms: the Pigou-Dalton Transfer Principle, the Income Scale Independence Principle and the Principle of Population, it makes explicit value judgements through the parameter ε, and it is included in the interval [0,1].

From a policy point of view, it is also desirable to understand the relationship between the inequality measures and their within and between components and indices that permit an additively decomposition by population subgroups, such as GE class, are often used in empirical studies. While Atkinson's indices do not satisfy this axiom and although they possess desirable properties, they have lost popularity in practical studies in which sources of and variation in inequality need to be known and analysed.

In this paper we propose a factorial decomposition by population groups. It is clear that this result may be less favored because of its multiplicative nature. However this decomposition (1) permits us to make use of the Atkinson's indices for the subgroup decomposition analysis, (2) enables us to complete and detail the information obtained from the inequality indices generally used, and to estimate how much progress has been made from the most unegalitarian situation and how far there is to go, and (3) allows the overall equality with both its components to have an useful geometric representation.

In this context what we are seeking to do is to recover Atkinson's indices for practical work in this field, and we hope that this paper will convince the reader that these indices are an important and useful tool for the study of inequality among populations and population subgroups.

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Table 1. Atkinson Indices for ε=1.

	Atkinson Indexes ε=1				
	Inequality		Equality		
	Global	Between	Global	Between	Within
Year	I^A_1	IB^A_1	$E^A_1 = 1 - I^A_1$	$EB^A_1 = 1 - IB^A_1$	$EW^A_1 = E^A_1 / EB^A_1$
1970	0.553	0.47	0.447	0.53	0.843
1971	0.555	0.472	0.445	0.528	0.843
1972	0.564	0.483	0.436	0.517	0.843
1973	0.571	0.49	0.429	0.51	0.841
1974	0.569	0.487	0.431	0.513	0.840
1975	0.561	0.478	0.439	0.522	0.841
1976	0.571	0.489	0.429	0.511	0.839
1977	0.568	0.485	0.432	0.515	0.839
1978	0.572	0.488	0.428	0.512	0.836
1979	0.569	0.485	0.431	0.515	0.837
1980	0.563	0.476	0.437	0.524	0.834
1981	0.558	0.47	0.442	0.53	0.834
1982	0.549	0.458	0.451	0.542	0.832
1983	0.544	0.451	0.456	0.549	0.830
1984	0.542	0.448	0.458	0.552	0.830
1985	0.539	0.443	0.461	0.557	0.828
1986	0.537	0.439	0.463	0.561	0.825
1987	0.538	0.439	0.462	0.561	0.824
1988	0.539	0.439	0.461	0.561	0.822
1989	0.546	0.447	0.454	0.553	0.821
1990	0.545	0.444	0.455	0.556	0.818
1991	0.54	0.436	0.46	0.564	0.816
1992	0.534	0.427	0.466	0.573	0.813
1993	0.525	0.415	0.475	0.585	0.812
1994	0.526	0.414	0.474	0.586	0.809
1995	0.523	0.408	0.477	0.592	0.806
1996	0.521	0.403	0.479	0.597	0.802
1997	0.521	0.402	0.479	0.598	0.801
1998	0.522	0.401	0.478	0.599	0.798

Figure 2. Atkinson Equality Indices for ε =1.

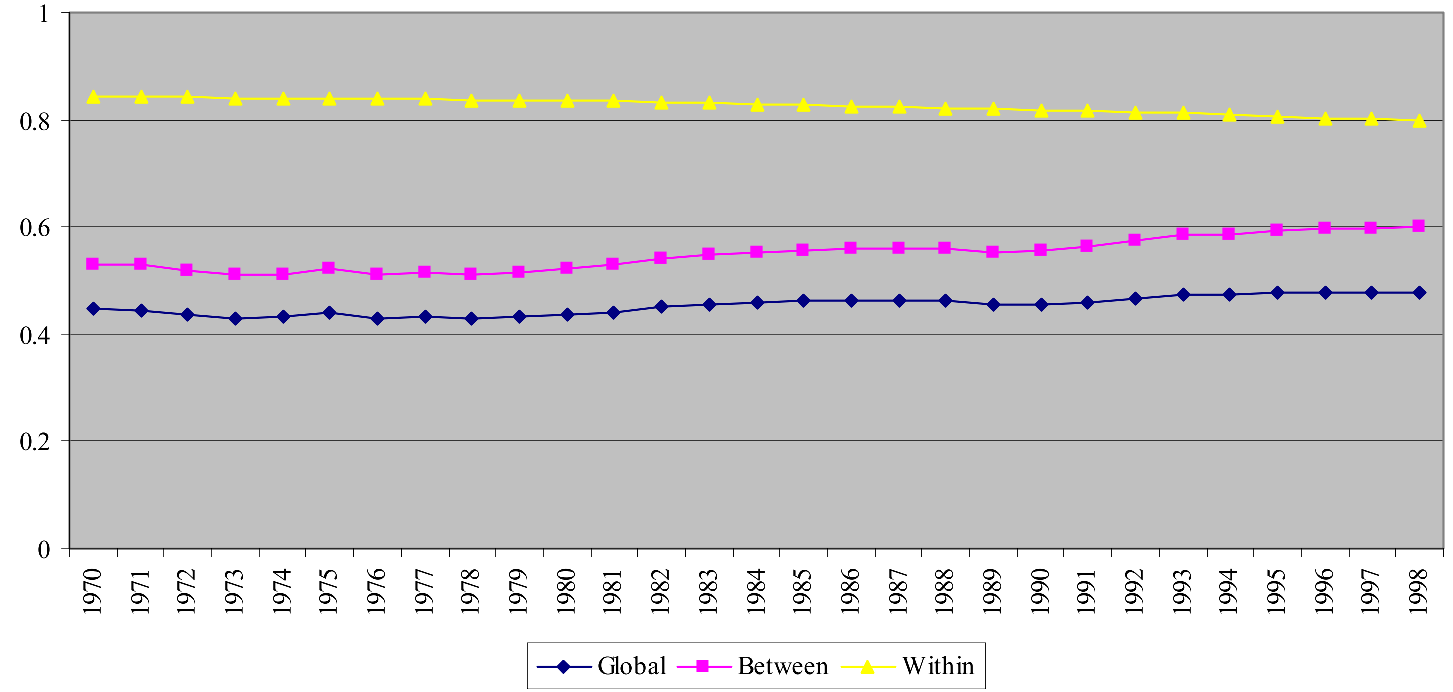

Figure 3. Equality Decomposition: Atkinson (1).