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Composite Indices of Development and Poverty: An Application to MDGs

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Abstract The measurement of development or poverty as multidimensional phenomena is very difficult because there are several theoretical, methodological and empirical problems involved. The literature of composite indicators offers a wide variety of aggregation methods, all with their pros and cons. In this paper, we propose a new, alternative composite index denoted as MPI (Mazziotta-Pareto Index) which, starting from a linear aggregation, introduces penalties for the countries or geographical areas with 'unbalanced' values of the indicators. As an example of application of the MPI, we consider a set of indicators in order to measure the Millennium Development Goals (MDGs) and we present a comparison between HDI (Human Development Index) methodology, HPI (Human Poverty Index) methodology and MPI.

Keywords Composite indices · Development · Poverty · Ranking

1 Introduction[1]

Many socioeconomic phenomena are complex and therefore difficult to measure and evaluate. Complexity also implies multidimensionality. Development and poverty are two socioeconomically important concepts that have been substantially regarded as unidimensional, especially by economists, for a long time: the first has usually been measured by personal income or per capita product whereas the second has been measured by lack of income or low expenditure.

[1] The paper is the result of combined work of the authors: P. De Muro has written Sects. 1 and 2; M. Mazziotta has written Sects. 4.1 and 5; A. Pareto has written Sects. 3, 4.2 and 4.3.

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Recently, there is growing international consensus about the multidimensional nature of both development and poverty, and their irreducibility to the income dimension.[2] The Millennium Development Goals, adopted by the United Nations General Assembly in 2000, reflect this advanced vision.[3]

The shift from a single dimension to multiple dimensions by enlarging and enriching the scope of the analysis, represents an important theoretical progress and has some relevant advantages in terms of policy. However, notwithstanding those benefits, multidimensionality makes the measurement and evaluation of development and poverty more difficult. Indeed, while measuring and assessing a given single dimension can be done with a single indicator, multiple dimensions require a set of different indicators. This multiplicity involves a number of theoretical and statistical problems especially when we need to make comparisons over time and/or space.

The fundamental question is what is the better approach to (re)present complex phenomena and multidimensional realities. This work attempts to provide some answers. The aim of the work is twofold. First, we briefly discuss the main theoretical and methodological problems related to the multidimensional analysis of development and poverty (Sect. 2). Secondly, we consider the need to build composite indices of development and poverty that have some desirable properties. To this end, we propose a new composite index, the Mazziotta-Pareto Index (MPI) and compare it with existing composite indices (Sects. 3 and 4). The empirical comparison is made by using a number of national and regional single indicators that are included in the set of indicators chosen by the UN to monitor progress towards the MDGs (Sect. 5). Finally, we briefly discuss the results of the comparison and draw some conclusions (Sect. 6).

2 Measuring Development and Poverty

2.1 From One to Many Dimensions

The modern concept of development entered the international political and economic discourse shortly after the end of World War II. Since then, most international development scholars and organizations have evaluated the development level and process mainly by using the per capita product or income. Of course, many other variables have been generally used to analyze the development process but per capita product or income has been always used as the main—and often only—measurement of the ultimate outcome of this process. In other terms, per capita product or income has been the paramount measure of development for decades. In this dominant view, development was essentially unidimensional and largely coincided with economic growth.

From the end of the 1950s (Galbraith 1958), but especially in the 1960s and 1970s, there has been increasing dissatisfaction with this approach: « …it has become increasingly evident, particularly from the experience of the developing countries, that rapid growth at the national level does not automatically reduce poverty or inequality or provide sufficient productive employment » (World Employment Conference 1976, p. 15). « Dudley Seers talked about "dethroning the GNP" » (Ranis 2005) and in the *The Meaning of Development* he defined development as « the reduction and elimination of poverty, inequality and

[2] This also concerns other related socioeconomic phenomena such as well-being, quality of life, and standard of living.

[3] For further information on the MDGs, see the web site http://www.un.org/millenniumgoals.

unemployment within a growing economy » (Seers 1969). The critique about the meaning of development gave birth in the Sixties and Seventies to new lines of research on unconventional measures of development. If the main goal of development was meeting (basic) human needs (World Employment Conference 1976, 1977), than the appropriate measure of development should not be based on (per capita) income, but rather on the quality of life of people and its progress.

The scientific research on alternative measures of development was carried out first at the United Nations Research Institute for Social Development (UNRISD), where composite indices of development were elaborated using a bundle of physical, social and cultural indicators (UNRISD 1970). Another important contribution was made by two researchers (Morris and Liser 1977) at the Overseas Development Council that created the Physical Quality of Life Index (PQLI).

By the end of the Seventies, there was large consensus among social scientists that « the phenomenon of "development" or the existence of a chronic state of "underdevelopment" is not only a question of economics or the simple quantitative measurement of incomes, employment and Gini coefficient » but « is now viewed as a multidimensional process » (Todaro 1979, p. 224).

A further fundamental contribution in this direction has been made in the following decades by Sen (1985, 1992, 1999) and other scholars, that elaborated the "capability approach", and by the *Human Development Reports* (HDRs)[4], prepared by the United Nations Development Programme (UNDP), that put some of Sen's ideas together with the research experience of the previous decades into practice. The HDRs propose a comprehensive multidimensional approach to development—the human development paradigm—that has a sound theoretical reference (the capability approach) and includes a battery of composite indices of development and poverty. Two of these indices, the Human Development Index (HDI) and the Human Poverty Index (HPI), will be discussed and used in the following sections of this work.

The UNDP indices are not the only composite indices that have been produced in the last thirty years. In fact, along with mounting attention to multidimensional development,[5] there are a growing number of composite indices that have been proposed worldwide by scholars and institutions. We cannot present a review of these indices here. The OECD Global Project "Measuring Progress of Societies"[6] is working on indicators that go beyond GDP and undertakes methodological research on accounting frameworks and composite indices.

With regard to poverty, the persistence of the unidimensional income-based approach has been longer and stronger than for development. As a matter of fact, most of the official measurements of poverty at national or international level are made even now with reference to monetary income or consumption. In the scientific literature, there are still a few examples of multidimensional poverty indices. The HPI (Anand and Sen 1997), introduced by UNDP in the 1997 HDR, has been one the first examples of non-monetary composite index of poverty.

[4] See the web site http://hdr.undp.org.

[5] See the important International Conference "Beyond GDP" organised jointly by the European Commission, the European Parliament, the Club of Rome, the WWF and the OECD in 2007.

[6] See the web site http://www.oecd.org/progress.

2.2 Working with Many Dimensions

Once multidimensionality is recognized, measuring development has a number of theoretical and methodological problems that are not present in the conventional unidimensional approach.

The first problem concerns the choice of development dimensions: which and how many dimensions are relevant and should be considered or privileged. Sen calls this the problem of the appropriate "informational basis" (Sen 1999), i.e., which information is included or excluded in the evaluation exercise. This selection is often driven by the availability of statistics but it actually has deep theoretical implications and strongly affects the results of the evaluation. In fact, each informational basis corresponds to a particular concept of justice or ethics (Sen 1999). Therefore, the choice of informational basis should not avoid an explicit discussion and value judgement. A related technical problem concerns the choice of indicators that adequately represent each of the selected dimensions. In this work we will not discuss the problem of the informational basis because it is outside the scope of the work. In the following sections, we will use the eight MDGs and their related indicators as an informational basis.

The second problem concerns the use of the included information. The following sections will focus on this problem. Once the relevant dimensions and indicators have been selected and normalized, we often need to compare them in time and/or space in order to make evaluations. There are at least two alternative ways to make comparisons with multiple indicators: the first is to use "development profiles"; the second is to combine the various indicators in a composite index.

A development profile shows how the various indicators of development vary across dimensions. This approach has some advantages: there is no loss of information and the performance in each single dimension is transparent, allowing for a detailed check-up. However, there is also an important drawback: unless all the values of the indicators are lower or higher for one country (or in one period) compared with the others, we cannot rank the countries (or the periods). In order to illustrate this problem, Fig. 1 presents a comparison between development profiles in four countries. The eight indicators that have been used are a sample taken from the official list of 60 MDGs indicators. Each indicator refers to a different development goal (or dimension). Looking at the figure, it is clear that by simply comparing the four profiles, while we can say which country is doing better in each single dimension, we cannot say which country is globally doing better. In other words, the countries cannot be ranked if we do not aggregate the indicators.

The second way to make a comparison in time and/or space is to combine the various indicators in a composite index. Composite indices have the advantage of allowing ranking of countries (or periods) because they represent the overall development level in one number. Nevertheless, building composite indices implies losing a certain amount of information and producing results that are less transparent. Furthermore, composite indices have been criticized because, in a way, they re-introduce unidimensionality.

However, as monitoring progress toward development goals often requires overall comparison over space or time, composite indices are very useful for specific purposes.

For instance, if we want to know which countries are making more progress towards the overall eight MDGs and which countries are making less progress, we need to build a composite index.

The main problem in the construction of composite indices of development is how to aggregate the information. The aggregation problem concerns two interrelated aspects: the assignment of weights to the components when combining them (Scott 2004) and the

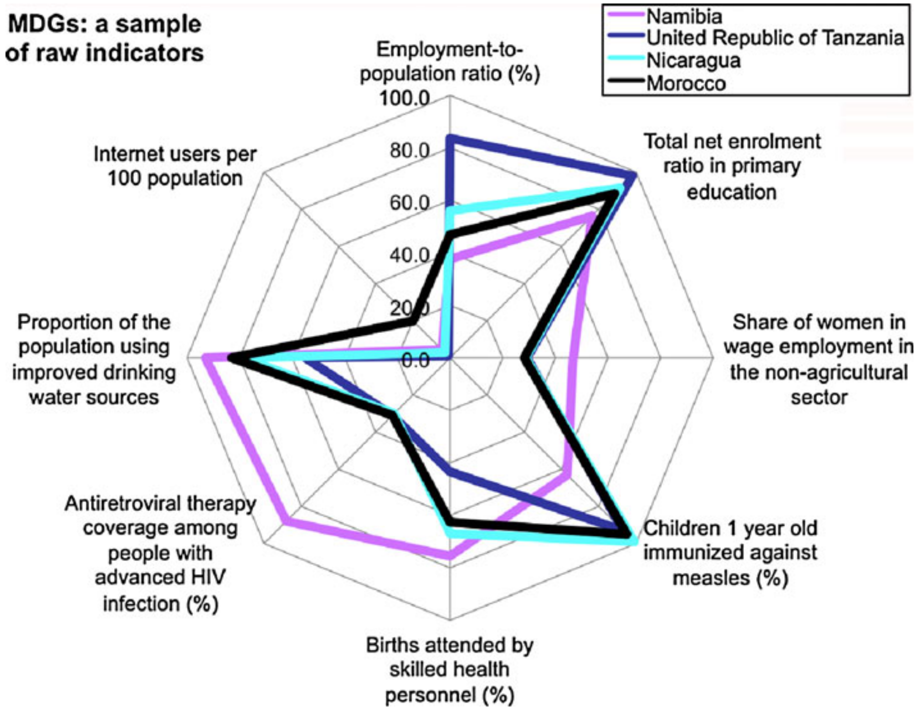

Fig. 1 Comparing development profiles

choice of the synthetic function. After having normalized (or also standardized) the indicators,[7] there are a number of possible aggregation strategies:

1. Using the arithmetic mean. This approach is often used because is very simple and easy to apply and interpret. An implication of the arithmetic mean is that the weights of the components are completely arbitrary. The approach has two versions:

   a. Simple (non weighted) mean. This implies that all the weights are equal and that all the components (dimensions) are perfectly substitutable. Although the equal weights give the impression that this is a "neutral" approach in which there is no hierarchy between dimensions, this approach makes an implicit very strong assumption about the perfect substitutability between dimensions. This assumption has weak theoretical justification especially when the components are fundamental dimensions like health and knowledge. This approach has been used to build the HDI by the UNDP;
   b. Weighted mean. In this case, if the weights are not equal, this implies that the substitutability between components is not perfect. This approach is more theoretically consistent but the weights remains arbitrary;

2. Using factorial analysis (e.g. principal components, correspondence analysis). At first sight, this approach appears to be more "objective" because the weights are not assigned by the researcher but by a statistical technique. In this way, weights do not

[7] This part of the methodology will be discussed in the following sections.

seem to be arbitrary and appear to be more "scientific" because they are extracted from the data. However, this approach has a couple of serious shortcomings. First, given that the weights are obtained from the data, they are not constant over both time and space and this makes comparisons very difficult. Second, the factorial analysis assigns weights to the original variables on the basis of their variance and covariance. This criteria does not necessarily reflect the relative socioeconomic importance of the various dimensions. Therefore, even if the weights seem to be objective with this statistical approach, they do not have a sound theoretical foundation;

3. Using a power mean or an adjusted mean. With this approach, we can have both imperfect substitutability and implicit non-arbitrary weights.
   a. A power (or generalized) mean of order greater than one is very useful when we wish to build composite indices of poverty. This mean « places greater weight on those dimensions in which deprivation is larger » (Anand and Sen 1997, p. 16). This approach has been used to build the HPI by UNDP. Similarly, a power mean of order smaller than one (but greater than zero) can be used to build composite indices of development when we wish to place greater weight on those dimensions in which development is lower. In this case, the power mean penalizes countries (or periods) that have a more "unbalanced" development across dimensions.
   b. An adjusted mean. Another way to penalize unbalanced performances is to adjust the arithmetic mean by using a penalty coefficient or function. This can be done in different ways. In Sect. 4, we will present a methodology for building a class of composite indices of development or poverty (MPI) which includes a penalty coefficient that is a function of the variability across dimensions ("horizontal variability").

According to Sen (1999, p. 81): « there is … a strong methodological case for emphasizing the need to assign explicitly evaluative weights to different components of quality of life (or of well-being) and then to place the chosen weights for open public discussion and critical scrutiny » . In principle, this would require use of approach "1b" rather than « some wonderful formula that would simply give us ready-made weights that are "just right" » (Sen 1999, p. 79). However, in some cases, assigning evaluative weights and then submitting them to open public discussion is not possible. In the latter cases, approach "3" is the best one.

In the following sections, we will present and compare three composite indices of development and poverty and their properties—the HDI, the HPI and the MPI. The indices use different aggregation criteria: we will apply those aggregation criteria to a set of MDGs indicators in order to discuss how the different approaches affect the results.

3 HDI and HPI Methodologies

In this section, we consider the methodological aspects related to the Human Development Index (HDI) and Human Poverty Index (HPI) construction (UNDP 2007).

3.1 The Human Development Index

The HDI is a composite indicator of human development based on the arithmetic mean. It measures the average achievements in a country or geographical area in three basic

Table 1 List of individual indicators of the HDI

N.	Description	Minimum value	Maximum value
Wellbeing			
1	Life expectancy at birth (years)	25	85
Knowledge			
2	Adult literacy rate (%)	0	100
3	Combined gross enrolment ratio (%)	0	100
Standard of living			
4	Gross domestic product per capita (PPP US$)	100	40,000

dimensions: (i) wellbeing, (ii) knowledge, (iii) standard of living. The indicators used are listed in Table 1.

The steps in the construction of the HDI are the following.

(i) Normalization

Let $\mathbf{X} = \{x_{ij}\}$ be the matrix with n rows (countries or geographical areas) and 4 columns (indicators in Table 1). The normalized matrix $\mathbf{Y} = \{y_{ij}\}$ is computed as follows:

$$y_{ij} = \frac{x_{ij} - \min(x_j)}{\max(x_j) - \min(x_j)}$$

where $\min(x_j)$ and $\max(x_j)$ are the minimum and maximum values (*goalposts*) for the j-th indicator reported in Table 1.[8]

(ii) Aggregation

The HDI is given by:

$$\mathrm{HDI}_i = \frac{y_{i1} + y_{i5} + y_{i4}}{3}$$

where

$$y_{i5} = \frac{2y_{i2} + y_{i3}}{3}.$$

The HDI is then computed as a simple arithmetic mean of the three dimension indices. The main characteristic of this methodology is that it assumes complete substitutability between the dimensions of human development: a deficit in one dimension can be compensated by a surplus in another (e.g., a good standard of living can always substitute any knowledge deficit).

3.2 The Human Poverty Index

While the HDI measures average achievement, the HPI measures deprivations.

There are two type of HPI: the HPI-1 for developing countries and the HPI-2 for selected OECD countries. Both the indices are based on the mean of order three. The HPI-1 measures deprivations in the three basic dimensions of human development captured in the

[8] Note that the logarithm of income is used for the GDP per capita normalization.

Table 2 List of individual indicators of the HPI-1

N.	Description	Minimum value	Maximum value
Wellbeing			
1	Probability at birth of not surviving to age 40 (times 100)	0	100
Knowledge			
2	Adult illiteracy rate (%)	0	100
Standard of living			
3	Percentage of population not using an improved water source	0	100
4	Percentage of children under weight-for-age	0	100

HDI while the HPI-2 captures social exclusion too. Calculating HPI-1 and HPI-2 is more straightforward than calculating HDI since the indicators used to measure the deprivations are already normalized between 0 and 100.

In this context, we will refer to HPI-1. The indicators used are listed in Table 2.

Being $\mathbf{X} = \{x_{ij}\}$ the matrix with n rows (countries or geographical areas) and 4 columns (indicators in Table 2), the formula used to compute the HPI-1 is:

$$\text{HPI - }1_i = \left(\frac{x_{i1}^3 + x_{i2}^3 + x_{i5}^3}{3}\right)^{1/3}$$

where

$$x_{i5} = \frac{x_{i3} + x_{i4}}{2}.$$

In this case, the use of the mean of order three for calculating the composite indicator allows greater weight to be given to the dimension in which there is the most deprivation.

4 An Alternative Methodology: The MPI

4.1 General Aspects

The MPI (Mazziotta and Pareto 2007) wants to supply a composite measurement of a set of indicators that are considered "non-substitutable" (all components must be "balanced").

It is designed in order to satisfy the following properties:

(i) normalization of the indicators by a specific criterion that deletes the unit of measurement and the variability effect (Delvecchio 1995);
(ii) synthesis independent from an "ideal unit", since a set of "optimal values" is arbitrary, non-univocal and can vary with time (Aureli Cutillo 1996);
(iii) simplicity of computation.

These properties can be satisfied by the following approach. It is known that the distributions of different indicators, measured in different ways, can be compared by the transformation in standardized deviations. Therefore, the individual indicators can be converted to a common scale with a mean M = 100 and standard deviation S = 10: the obtained values will fall approximately in the range (70; 130).[9]

In this type of normalization the "ideal vector" is the set of mean values and it is easy to identify both the units that are over the mean (values greater than 100) and the units that are under the mean (values less than 100).

In this context, a penalty coefficient can be introduced that is a function, for each territorial unit, of the indicators' variability in relation to the mean value ("horizontal variability"): this variability can be measured by the *coefficient of variation*. The proposed approach penalizes the score of each unit (the mean of the standardized values) with a quantity that is directly proportional to the "horizontal variability". The purpose is to favour the units that, mean being equal, have a greater balance among the indicator values.

Finally, the use of standardized deviations provides a "robust" measurement that is less influenced by *outliers* (Mazziotta et al. 2010).

4.2 Steps for Computing The MPI

The MPI building proceeds in the following stages.

(i) Normalization

Let $\mathbf{X} = \{x_{ij}\}$ be the matrix with n rows (countries or geographical areas) and m columns (development or poverty indicators) and let M_{x_j} and S_{x_j} denote the mean and the standard deviation of the j-th indicator:

$$\mathrm{M}_{x_j} = \frac{\sum_{i=1}^{n} x_{ij}}{n}; \ \mathrm{S}_{x_j} = \sqrt{\frac{\sum_{i=1}^{n} \left(x_{ij} - \mathrm{M}_{x_j}\right)^2}{n}}$$

The standardized matrix $\mathbf{Z} = \{z_{ij}\}$ is defined as follows:

$$z_{ij} = 100 \pm \frac{\left(x_{ij} - \mathrm{M}_{x_j}\right)}{\mathrm{S}_{x_j}} 10$$

where the sign $\pm$ depends on the relation of the j-th indicator with the phenomenon to be measured ($+$ if the individual indicator represents a dimension considered positive and $-$ if it represents a dimension considered negative).

(ii) Aggregation

Let cv_i be the coefficient of variation for the i-th unit:

$$\mathrm{cv}_i = \frac{\mathrm{S}_{z_i}}{\mathrm{M}_{z_i}}$$

where:

$$\mathrm{M}_{z_i} = \frac{\sum_{j=1}^{m} z_{ij}}{m}; \ \mathrm{S}_{z_i} = \sqrt{\frac{\sum_{j=1}^{m} \left(z_{ij} - \mathrm{M}_{z_i}\right)^2}{m}}$$

[9] On the basis of Bienaymé-Cebycev theorem, the terms of the distribution within the range (70; 130) are at least 89% of total terms.

Then, the generalized form[10] of MPI is given by:

$$\mathrm{MPI}_i^{+/-} = \mathrm{M}_{z_i}(1 \pm \mathrm{cv}_i^2) = \mathrm{M}_{z_i} \pm \mathrm{S}_{z_i}\mathrm{cv}_i$$

where the sign of the penalty (the product $\mathrm{S}_{z_i}\mathrm{cv}_i$) depends on the kind of phenomenon to be measured and the direction of the individual indicators.

If the indicator is "increasing" or "positive", i.e., increasing values of the indicator correspond to positive variations of the phenomenon (e.g., the development of the country or geographical area), then MPI^- is used. Vice versa, if the indicator is "decreasing" or "negative", i.e., increasing values of the indicator correspond to negative variations of the phenomenon (e.g., the poverty of the country or geographical area), then MPI^+ is used.

4.3 MPI as a Development and Poverty Measurement

The possibility to add or subtract the penalty depending on the phenomenon nature allows appropriate measurements of development and poverty to be constructed.

(1) Development Index

The MPI of development is given by:

$$\mathrm{MPI}_i^- = \mathrm{M}_{z_i} - \mathrm{S}_{z_i}\mathrm{cv}_i$$

where the mean of the standardized values is adjusted by subtracting a quantity proportional to the standard deviation and direct function of the coefficient of variation.

The higher the index, the more developed the country or geographical area. The index assumes high value when the mean is high and the standard deviation is low.

The MPI^- results are different from HDI methodology because the second one does not penalize if there is an "unbalanced" set of indicators.

(2) Poverty Index

The MPI of poverty is obtained as:

$$\mathrm{MPI}_i^+ = \mathrm{M}_{z_i} + \mathrm{S}_{z_i}\mathrm{cv}_i$$

where the mean of the standardized values is adjusted adding a quantity proportional to the standard deviation and direct function of the coefficient of variation.

The higher the index, the poorer the country or geographical area. The index assumes high values when the mean is high and the standard deviation too.

The MPI^+ results are very similar to the HPI methodology because both indices penalize in the same "direction".

5 An Application to MDGs Indicators

In order to compare the different methodologies considered, a double application is presented where seven human development indicators (the data refer to the years 2006–2008) and seven poverty indicators (years 2003–2006) from MDGs are selected. The indicators are listed in Table 3.

[10] It is a generalized form since it includes "two indices in one".

Table 3 List of individual indicators of human development and poverty

Description	Label
Human development	
Total net enrolment ratio in primary education (%)	D1
Literacy rate of 15–24 year-olds (%)	D2
Employees in non-agricultural wage employment who are women (%)	D3
Proportion of seats held by women in national parliament	D4
Proportion of 1 year-old children immunised against measles	D5
Proportion of population using an improved drinking water source	D6
Number of internet users per 100 population	D7
Human poverty	
Proportion of population living below $1 (PPP) per day	P1
Prevalence of underweight children under-5 years of age (%)	P2
Proportion of population below minimum level of dietary energy consumption	P3
Infant mortality rate	P4
Under-5 mortality rate per 1,000 live births	P5
Maternal deaths per 100,000 live births	P6
Number of tubercolosis cases per 100,000 population	P7

Table 4 Composite indices of human development by region—2006–2008

Region	D1	D2	D3	D4	D5	D6	D7	Mean (HDI method)	Mean of order 3 (HPI method)	MPI^{-}
CIS Europa	92.8	99.7	52.2	13.9	99.0	97.0	20.2	109.847	110.130	109.561
Latin America	95.5	97.0	42.3	22.2	93.0	92.0	18.7	109.190	109.317	109.065
Eastern Asia	94.3	99.2	41.1	19.8	93.0	88.0	12.5	106.416	106.482	106.351
CIS Asia	93.9	99.6	47.9	13.9	95.0	88.0	6.0	104.227	104.637	103.807
South-Eastern Asia	95.0	95.6	37.8	17.4	82.0	86.0	9.9	102.756	102.893	102.619
Northern Africa	95.0	86.5	21.3	8.3	96.0	92.0	10.4	99.579	100.178	98.974
Western Asia	88.3	92.8	20.3	9.1	88.0	90.0	13.5	98.951	99.367	98.524
Southern Asia	89.9	79.9	18.6	12.9	66.0	87.0	9.7	94.215	94.745	93.676
Sub-Saharan Africa	70.7	72.1	30.8	17.3	72.0	58.0	3.4	88.652	89.598	87.721
Oceania	78.0	70.6	36.4	2.5	70.0	50.0	5.2	86.166	86.775	85.570
Mean	89.3	89.3	34.9	13.7	85.4	82.8	11.0			
SD	8.0	10.8	11.2	5.6	11.5	14.8	5.2			

The indicators are intentionally chosen so that they have the property of non-substitutability: it is very important that there are no compensative effects among indicators that are relevant to the description of the regions' development and poverty. In fact, the indicators have been selected to treat different development and poverty subjects. The geographical domains are the ten world macro-areas (Tables 4, 5) but single countries are also focused on (Tables 6, 7, 8 and Figs. 2 and 3).

The individual indicators are normalized by MPI method (Sect. 4.2) and they therefore have the same mean ($M = 100$) and variability ($S = 10$) (in Tables 4 and 5, the indicators'

Table 5 Composite indices of human poverty by region—2003–2006

Region	P1	P2	P3	P4	P5	P6	P7	Mean (HDI method)	Mean of order 3 (HPI method)	MPI$^+$
Sub-Saharan Africa	50.3	28.0	31.0	94.0	157.0	900.0	521.0	121.088	121.306	121.312
Southern Asia	38.6	46.0	21.0	61.0	81.0	490.0	287.0	111.089	111.323	111.319
South-Eastern Asia	17.8	25.0	12.0	27.0	35.0	300.0	264.0	100.564	100.728	100.728
CIS Asia	5.4	7.5	20.0	40.0	47.0	51.0	140.0	97.584	97.849	97.846
Eastern Asia	17.8	7.0	12.0	20.0	24.0	50.0	197.0	95.840	95.972	95.972
Western Asia	3.8	13.0	9.0	32.0	40.0	160.0	51.0	95.142	95.218	95.219
Latin America	8.0	8.0	10.0	22.0	27.0	130.0	67.0	94.098	94.115	94.115
Northern Africa	3.8	6.0	4.0	30.0	35.0	160.0	45.0	93.200	93.295	93.296
CIS Europa	5.4	2.4	3.0	15.0	17.0	51.0	118.0	91.394	91.450	91.450
Mean	16.8	15.9	13.6	37.9	51.4	254.7	187.8			
SD	15.9	13.5	8.4	23.6	41.2	265.0	144.4			

values are not standardized). The aim is to compare three different aggregation methods in order to measure the development and the poverty of the ten macro-areas. The functions are the simple mean (HDI method), the mean of order three (HPI method) and the MPI. In Table 4, the MPI is calculated with the negative sign because we are measuring development (MPI$^-$).

The differences between the methods are very slight and there is no point in computing the respective rankings. Nevertheless, it is interesting to note that the MPI$^-$ values are lower than the mean values (HDI method) because there is the penalty effect.

In Table 5, the MPI is calculated with the positive sign because we are measuring poverty (MPI$^+$). The main aspect seems to be the convergence between the mean of order three and MPI$^+$ results; in fact, for many areas more than three decimals must be added in order to find the differences. Therefore, if the aim is to evaluate poverty in areas, the HPI and MPI$^+$ methods produce the same results.

The results of the three methodologies, both for development and for poverty indicators, are very similar because the normalization method of the elementary data is the same. Besides, it is difficult to find many differences when there are few geographical areas (especially in world macro regions) and this is a positive aspect because there would be an index robustness problem if the regions changed rank. This last assumption is not true when there are many territorial units.

In Table 6, composite indices of human development by countries (the first ten and the last ten ordered by MPI$^-$) are presented. In this case, there are many differences: for example, Barbados is the first country for the simple mean and the mean of order three but is in fourth position for MPI. This difference is due to the MPI's penalty function that penalizes the unbalanced distribution of the elementary indicators. The ranks of the last ten countries are decidedly more stable than the first ten.

In Table 7, composite indices of poverty development by countries (the first ten and the last ten ordered by MPI$^+$) are presented. The results of mean of order three and MPI$^+$ are identical since the functions penalize in the same direction.

In Table 8, countries with greater absolute difference of rank between mean and MPI are presented. With regard to human development, the biggest difference is represented by

Table 6 Composite indices of human development by country—2006–2008

Country	Mean		Mean of order 3		MPI^{-}	
	Value	Rank	Value	Rank	Value	Rank
The first ten countries						
Hong Kong S.A.R.	112.750	2	113.296	2	112.206	1
Belarus	112.421	4	112.851	4	111.994	2
Singapore	112.475	3	113.020	3	111.942	3
Barbados	113.198	1	115.468	1	111.037	4
Niue	111.085	5	111.351	7	110.823	5
Macao S.A.R.	110.340	8	110.643	8	110.039	6
Seychelles	109.797	9	109.943	10	109.650	7
Antigua and Barbuda	110.605	6	111.723	5	109.499	8
Korea, Republic of	110.393	7	111.546	6	109.283	9
Cayman Islands	109.733	10	110.282	9	109.179	10
The last ten countries						
Haiti	89.238	162	90.867	159	87.531	162
Burkina Faso	88.619	163	89.730	163	87.481	163
Papua New Guinea	87.919	166	88.396	167	87.437	164
Angola	88.060	165	88.723	166	87.396	165
Sierra Leone	87.645	167	88.272	168	87.017	166
Central African Rep.	88.466	164	90.098	162	86.810	167
Afghanistan	86.448	168	89.370	165	83.490	168
Niger	81.888	169	82.860	169	80.933	169
Chad	80.237	170	81.545	170	78.879	170
Somalia	78.740	171	81.059	171	76.314	171

Rwanda (22 positions); obviously, many ranks of the MPI are greater than the ranks of the mean because of the penalization effect. With regard to human poverty, the biggest difference is represented by Tajikistan (7 positions); the comparison between mean of order three and MPI presents very slight differences since the mean of order three formula implicitly contains a penalization function.

In Fig. 2, a specific example is presented of human development measurement. There are two countries: Rwanda has many indicators that are approximately on the same level and only one with a very high value (high development in the indicator D4); Ghana has all indicators more or less at the same low level. The mean is calculated and the result is a ranking of the world countries: Rwanda is in position 73 and Ghana in the position 126; subsequently the MPI^{-} is computed and Rwanda passes in position 95 and Ghana in position 123. Rwanda loses 22 positions because the indicators distribution is not uniform and the "horizontal variability" is the function that penalizes the arithmetic mean. The Ghana ranks (mean vs. MPI^{-}) are similar because the variability of the indicators' distribution is very low.

In Fig. 3, an example of human poverty measurement is presented; so, in this case, the indicators move in opposite directions and the higher the indicator, the poorer the country: the penalty function is added to the mean. The mean is calculated: Tajikistan is in position

Table 7 Composite indices of human poverty by country—2003–2006

Country	Mean		Mean of order 3		MPI^{+}	
	Value	Rank	Value	Rank	Value	Rank
The first ten countries						
Sierra Leone	122.643	1	123.299	1	123.297	1
Afghanistan	120.903	2	122.053	2	122.103	2
Niger	117.839	4	118.779	3	118.798	3
Rep. of the Congo	118.246	3	118.722	4	118.716	4
Angola	117.340	5	117.990	5	117.994	5
Liberia	117.069	6	117.572	6	117.576	6
Burundi	116.913	7	117.185	7	117.180	7
Chad	115.269	8	115.598	8	115.600	8
Swaziland	112.704	11	115.389	9	115.308	9
Zambia	113.241	9	113.498	10	113.503	10
The last ten countries						
Uruguay	90.792	130	90.799	130	90.799	130
Antigua and Barbuda	90.733	131	90.735	131	90.735	131
Barbados	90.714	132	90.718	132	90.718	132
Belarus	90.281	133	90.330	133	90.330	133
Tunisia	90.178	135	90.315	134	90.318	134
Cuba	90.185	134	90.197	135	90.197	135
Israel	90.155	136	90.165	136	90.165	136
Cyprus	89.983	137	89.994	137	89.994	137
Singapore	89.946	138	89.970	138	89.970	138
Chile	89.641	139	89.675	139	89.675	139

37 and Turkey in position 111; the MPI^{+} is computed and Tajikistan is 30 and Turkey is 111. Tajikistan is penalized (7 positions) because the indicators' distribution is variable and presents two very different values than the others; the Turkey position is constant because the indicators' variability is very low.

In Fig. 4, a comparison of country rankings is shown and the "tool" used is the mean absolute difference of rank. With regard to poverty measurement, the differences between the three aggregation methods are very slight and less than 1 (the Spearman's rank correlation indices are all greater than 0.999). In particular, the mean absolute difference of rank between the mean of order three and MPI^{+} is substantially equal to 0.

For development measurement, the distances are more relevant particularly for the comparison between mean of order three and MPI^{-} in fact, on average, every country changes, more or less, 4 positions (Spearman's index equal to 0.993).

Finally, these two aggregation methods are coincident when poverty is measured and they are very different when development is measured.

6 Concluding Remarks

The change from unidimensional to multidimensional development and poverty measurement is without any doubt an important theoretical progress and presents many

Table 8 Countries with greater absolute difference of rank between mean and MPI

Country	Mean		Mean of order 3		MPI	
	Value	Rank	Value	Rank	Value	Rank
Human development						
Rwanda	102.367	73	104.698	53	100.160	95
Qatar	102.298	74	103.424	67	101.125	83
N. Mariana Islands	106.578	35	107.761	21	105.366	43
Nicaragua	100.859	95	101.121	96	100.597	87
Lao People's Rep.	96.910	121	98.300	118	95.491	129
Cuba	107.108	27	107.757	22	106.462	34
Paraguay	101.003	91	101.227	95	100.777	84
Saint Lucia	108.735	13	109.820	11	107.650	19
Malaysia	107.191	26	107.842	20	106.548	32
United Arab Emirates	104.721	49	105.515	46	103.879	55
Human poverty						
Tajikistan	105.961	37	107.091	30	107.069	30
South Africa	106.950	28	109.432	23	109.322	24
Timor-Leste	105.069	44	106.266	41	106.254	40
Namibia	104.964	45	106.269	40	106.216	41
Bangladesh	105.952	38	106.496	35	106.479	35
Mauritania	105.767	39	106.010	42	106.016	42
Cameroon	105.721	40	105.978	43	105.978	43
Togo	105.555	42	105.620	45	105.620	45
Thailand	93.003	93	93.259	90	93.259	90
Saint Vincent	93.019	91	93.042	94	93.042	94

advantages for policy-making. However, there is also a flip side since multidimensional measurement presents several theoretical, methodological and empirical problems.

The international literature on composite indices of development and poverty offers a wide variety of aggregation methods. We have discussed the pros and cons of some of these methods. Considering the desirable properties that a composite index should have, we have proposed a new and alternative composite index denoted as MPI (Mazziotta-Pareto Index) which, starting from a linear aggregation, introduces penalties for the countries or geographical areas with 'unbalanced' values of the indicators. In this way, MPI assumes imperfect substitutability between various dimensions of development or poverty.

We have applied the MPI to a set of MDG indicators. The MDGs represent a multi-dimensional approach to development: in fact, they include eight goals that are measured with 60 different indicators. In order to synthesise the information on each country or monitor overall progress towards reaching the goals, it is useful to aggregate the indicators and build composite indices. Using MDG data, we have presented a comparison between HDI (Human Development Index) methodology, HPI (Human Poverty Index) methodology and the MPI.

HPI methodology and MPI results are similar when poverty is measured because both indices penalize in the same "direction". On the contrary, MPI is different from HDI

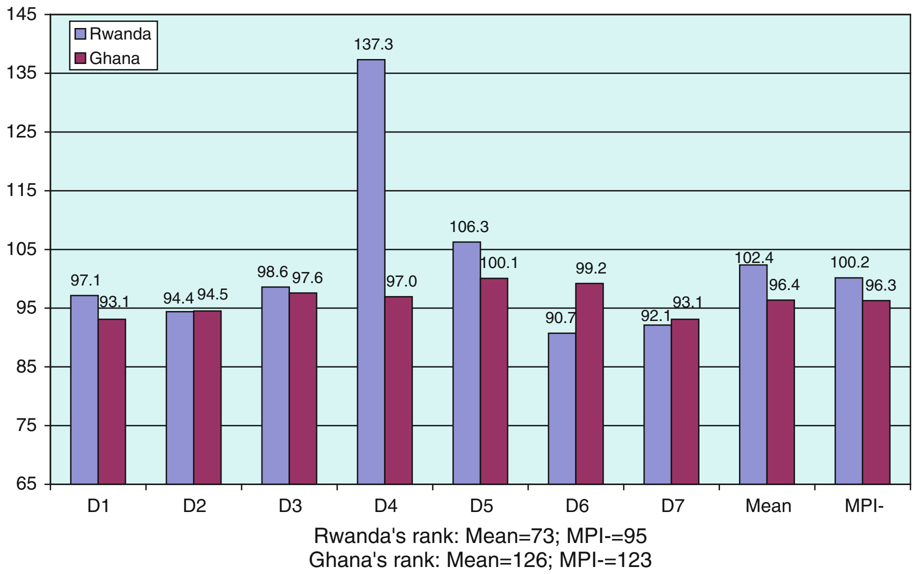

Fig. 2 Human development measurement: a comparison of countries

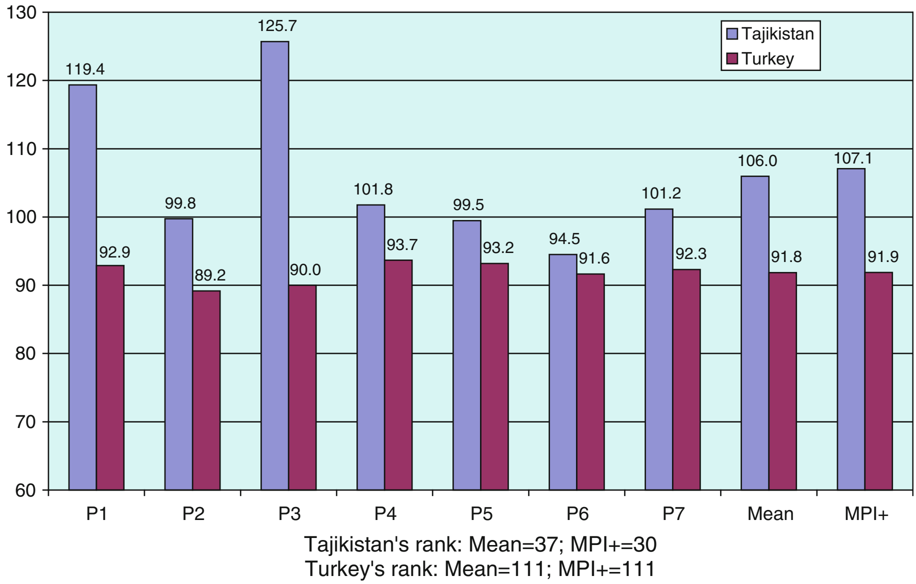

Fig. 3 Human poverty measurement: a comparison of countries

methodology when development is measured because the second one does not penalize if there is an "unbalanced" set of indicators.

To sum up, the MPI is an alternative composite index based on the property of non-substitutability of indicators that wants, in the scientific outline, both to respect the desirable characteristics of a composite index and to be validly applied to different

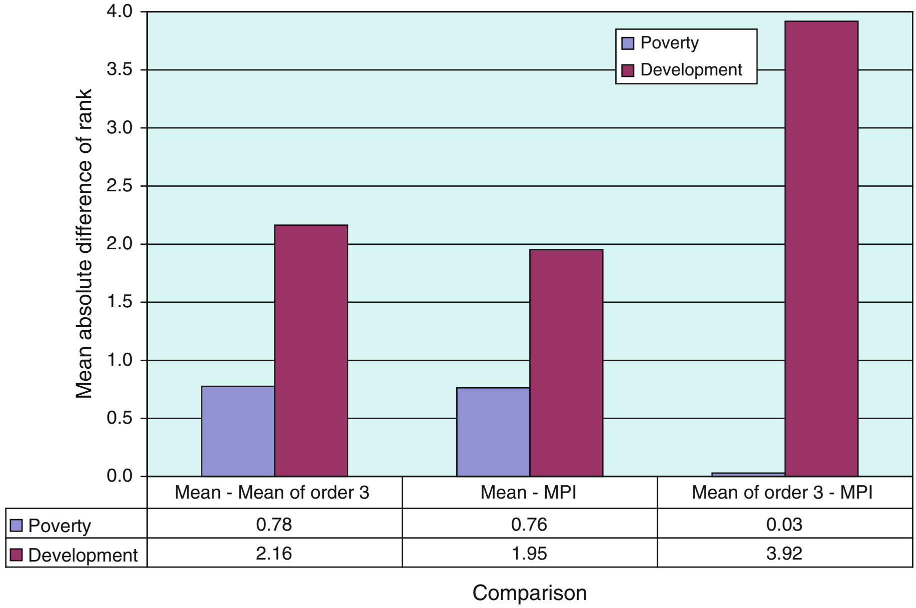

Fig. 4 Comparison of final rankings by different aggregation methods

scientific contexts. In fact, this methodology is independent of the direction and range of the elementary indicators. The MPI can therefore be a useful "tool" for synthesizing multidimensional phenomena, with regard to the measurement of poverty and development in particular.

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