

Periodical measurement of multidimensional phenomena

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Received: August 26, 2021 • Revised manuscript received: June 18, 2022 • Accepted: September 1, 2022

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ABSTRACT

Synthesizing multidimensional phenomena such as well-being in the form of composite indicators has been gaining popularity in recent years. The Mazziotta-Pareto Index is one of the methods of constructing non-compensatory composite indices. The paper proposes a modification of this method, which (unlike the original) enables periodical measurements and can be used to compare countries in research on East European transition. The essence of this modification is the use of anti-pattern normalization, during which only current data is used, and yet after normalization, the indicators are in a certain way comparable over time. The Anti-Pattern Normalized Mazziotta-Pareto Index (APMPI), unlike the original, does not change the previously determined values after the inclusion of new data. Both the imperfection of the original approach and the new proposal are illustrated by an empirical example. Indices of well-being for the OECD countries are constructed. The example shows that although AMPI and APMPI values are not comparable, the rankings based on them are not very different.

KEYWORDS

data aggregation, normalization, well-being

JEL CLASSIFICATION

C43, C38, I31

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1. INTRODUCTION

Synthesizing multidimensional phenomena such as well-being, poverty, socio-economic development, etc. in the form of composite indices (composite indicators) has been gaining popularity in recent years. For example, many official indices (i.e. constructed for various types of organizations) have been created to compare countries in terms of economic, political, social or environmental aspects. [Bandura \(2011\)](#) identifies over 400 such indices. Composite indicators are also used in research on East European transition ([Piatkowski 2003](#)), this approach enriches the analyses based on single indicators such as e.g., in [Mihályi \(2014\)](#) or [Podkaminer \(2015\)](#).

Many scientists use official synthetic results in their analyses, but many researchers construct their own measures according to already established rules. Basic rules and methods of indices construction can be found in [Nardo et al. \(2005\)](#). [Greco et al. \(2019\)](#) present the results of searching for ‘composite indices’ in SCOPUS. They write ‘The increase over the past 20 years is exponential, and the number of yearly publications shows no sign of a decline.’ Both applications and methodological articles are created.

Among many methods of constructing composite indicators, a popular one is introduced by [Matteo Mazziotta and Adriano Pareto \(2007\)](#). They proposed an aggregation which includes a penalty for unbalancing individual indicators. Although the Mazziotta-Pareto Index (MPI) is a rather new proposition, the first publication in English came in 2011 ([De Muro et al. 2011](#)), it has applications (e.g., [Agovino – Garofalo 2014](#); [Ivaldi et al. 2016](#); [Sessa 2016](#); [Agovino – Rapposelli 2017](#); [Agovino et al. 2018](#); [Müller-Frączek 2020b](#)), and some modifications proposed by other researchers (e.g., [Chelli et al. 2016](#)) and the Adjusted Mazziotta-Pareto Index (AMPI) was proposed in 2015 and 2016. The improved version differs from the original in terms of the normalization method, which allows the use of AMPI in comparisons over time.

However, AMPI has a certain imperfection. It is difficult to apply to regularly repeated (periodic) studies when the data set is enlarged. This is a significant inconvenience, because in the study of complex phenomena, we often want to be able to repeat the research and compare the results with the previous ones. With the original version of AMPI, this comparison can be problematic (see Subsection 4.2). We asked whether this imperfection could be removed, i.e., whether it was possible to construct a composite indicator that retained the main features of AMPI and at the same time could be used in the periodic analyses. A positive answer to this research question seems to be our modification called Anti-pattern Normalized Mazziotta-Pareto Index (APMPI).

Our concept concerns the indicators’ normalization. The main idea of Mazziotta and Pareto, namely the aggregation method, does not change and is not discussed in this paper. The motivation to try to improve AMPI was an imperfection of the scaling used in this construction. AMPI allows one-time comparison of objects (e.g., countries) in different periods of time, but it is difficult to use for periodical measurements. The so-called ‘goalposts’ used in the normalization of a single indicator depend on the ‘all available information’, i.e., all (in space and time) values of this indicator. The question arises what to do when new observations are available. ‘Goalposts’ based on a longer series of observations may change. This change seems small, but the empirical example shows that it can significantly affect the ‘old’ values of indices and distort the previously determined rankings (compare Subsection 4.2). In this paper we refer only to the normalization method given in [Mazziotta – Pareto 2015](#) and [2016](#). ‘Goalposts’ may be determined differently, based on expert opinions, but this is beyond the scope of this paper.



The proposed modification comes from the concept of the so-called pattern and anti-pattern normalization. Both were previously used in composite indices in combination with other aggregation methods (Müller-Frączek 2018, 2019a, 2020a). Their common feature is a specific comparability of the normalized indicators over time, despite the fact that only their current values are used during normalization. Therefore, the indices constructed on the basis of such normalized indicators can be used in periodical studies. AMPI was modified using anti-pattern normalization. Anti-pattern normalization has a property - an increase in the value of a normalized indicator for a given object does not necessarily mean an increase in the value of the raw indicator. It only means an improvement in the situation of the object against the background of other objects of the analysed system. For example, if for all the objects the value of the raw indicator has decreased, then the object for which the decrease was the smallest will record an increase in the normalized indicator. This specific feature of anti-pattern normalization means that the AMPI-based results are not comparable with those based on APMPI. However, the analysis of the empirical example showed that the resulting rankings are not significantly different.

The mentioned empirical example (well-being of the OECD countries) was taken from Mazziotta and Pareto (2016). That is, we used the same individual indicators and, on their basis, we constructed composite indicators using the considered methods. It should be emphasized that empirical research is only an illustration of the theoretical considerations. This paper is methodological, it develops the theory of composite indicators, we focused on demonstrating the imperfections of AMPI, and also, presenting our modification in practice. However, the obtained results can be used for a synthetic analysis of well-being, for example in the context of the East European transition. Our study includes six countries of the former Eastern Bloc (Czechia, Estonia, Hungary, Poland, Slovakia and Slovenia). Among them, we can indicate the leader in terms of welfare (in all the analysed years it was Slovenia), we can assess the dynamics of this phenomenon (the biggest change was recorded in Estonia), and we can also compare the situation of these countries with other OECD countries. Importantly, the environment of the countries in which the analysis was carried out (reference group) is significant, because the normalization of the indicators in APMPI is based on the observations (data) for all objects. By changing the environment of the analysis, for example by limiting the study to the EU countries only, we would get a slightly different picture of well-being in the post-communist countries.

The structure of the paper is subordinated to the assumed goal. Section 2 presents the Mazziotta and Pareto method of aggregation, which is common to all considered indices, i.e., MPI, AMPI and APMPI. Section 3 presents in turn: standardization, scaling and anti-pattern normalization. The next section is dedicated to demonstrating the imperfections of AMPI. In Section 5, APMPI was calculated for empirical data. The results were compared with those in Section 4. The paper ends with conclusions.

2. MAZZIOTTA AND PARETO METHOD OF AGGREGATION

Constructing a composite index is complex, but you can identify four main steps (Mazziotta – Pareto 2015):

1. defining the phenomenon to be measured,



2. selecting a group of individual indicators,
3. normalizing the individual indicators, and
4. aggregating the normalized indicators.

The first two steps are beyond the scope of this paper. We assume that the phenomenon to be measured has been already determined and the indicators describing this phenomenon have been correctly selected. Last step of the scheme is also established. We assume that the indicators have been aggregated using the Mazziotta-Pareto method. We only present but do not discuss this method. Our interest is focused on the third step of the scheme, i.e., normalizing the indicators.

Mazziotta and Pareto described in detail their aggregation method in [De Muro et al. \(2011\)](#) and the following papers. In [Mazziotta – Pareto \(2016\)](#), the authors wrote: “The MPI (Mazziotta-Pareto Index) is a formative composite index for summarizing a set of indicators that are assumed to be non-substitutable, i.e., all components must be balanced (...). It is based on a non-linear function which, starting from the arithmetic mean, introduces a penalty for the units with unbalanced values of the indicators.” The original MPI is static, i.e., index values are not comparable over time. The modified (dynamic) version of MPI used for comparisons over time is called the Adjusted Mazziotta-Pareto Index, or AMPI ([Mazziotta – Pareto 2015](#)). MPI and AMPI do not differ in the way the indicators are aggregated; they differ only by the method of normalization. In this paper, we focus on the dynamic version of the index, e.g., AMPI.

Let $X = \{x_{ijt}\}$ be a three-dimensional data matrix, where i numbers statistical units, e.g. countries ($i = 1, \dots, n$), j numbers individual indicators, e.g. indicators of well-being ($j = 1, \dots, m$), t numbers time periods, e.g. years ($t = 1, \dots, p$). We calculate rescaled matrix $R = \{r_{ijt}\}$ (normalization details are described in the next section). Adjusted Mazziotta-Pareto Index (AMPI) is given by:

$$AMPI_{it}^{+/-} = M_{rit} \pm S_{rit} cv_{it} = M_{rit} \pm P_{rit} \quad (1)$$

where M_{rit} and S_{rit} are, respectively, the mean and the standard deviation of the rescaled values for unit i , at time t , and $cv_{it} = S_{rit}/M_{rit}$. The sign $\pm$ depends on the kind of phenomenon to be measured. If the composite index is ‘positive’, then the $AMPI^-$ is used. If the composite index is ‘negative’, the $AMPI^+$ is used. Index is ‘positive’ if its increasing values correspond to an improvement of the phenomenon (e.g., well-being). Index is ‘negative’ if its increasing values correspond to a worsening of the phenomenon (e.g., poverty) ([De Muro et al. 2011](#)). The AMPI is a non-compensatory index (compare [Greco et al. 2019](#)). It decomposes the score of each unit into two parts: mean level (M_{rit}) and penalty ($P_{rit} = S_{rit}cv_{it}$). The aim is to reward the units that have a greater balance among the individual. The penalty equals 0 for the units that have equal values of the normalized indicators.

3. NORMALIZATION

Normalizing makes the individual indicators comparable. Normalization deprives the indicators of their measurement units and unifies their ranges and ‘polarity’. In this paper we divide the indicators into stimulants and destimulants. A stimulant has a positive impact (positive



‘polarity’) on the phenomenon to be measured, while a destimulant has a negative impact (negative ‘polarity’) on this phenomenon. We will denote the set of stimulants by S , and the set of destimulants by D .

There are various methods of normalization, but we quote only those that are used in the Mazziotta-Pareto method, i.e., standardization for MPI, scaling for AMPI and anti-pattern normalization for modification of AMPI.

3.1. Static standardization

Mazziotta and Pareto used a static version of standardization in MPI. We define MPI for a fixed moment (period of time), therefore the time index is omitted in the notation. For given data matrix $X = \{x_{ij}\}$ a standardized matrix $Z = \{z_{ij}\}$ is calculated as follows:

$$z_{ij} = \begin{cases} 100 + \frac{(x_{ij} - M_{x_j})}{S_{x_j}} \cdot 10 & \text{if } X_j \in S \\ 100 - \frac{(x_{ij} - M_{x_j})}{S_{x_j}} \cdot 10 & \text{if } X_j \in D \end{cases}, \quad (2)$$

where $M_{x_j} = \frac{1}{n} \sum_{i=1}^n x_{ij}$ and $S_{x_j} = \sqrt{\frac{1}{n} \sum_{i=1}^n (x_{ij} - M_{x_j})^2}$.

For spatio-temporal analyses, we calculate the mean and the standard deviation in (2) only on the basis of the current values. After such standardization, the indicators (and thus MPI values) are not comparable over time. We can only compare rankings.

The indicators, standardized according to formula (2), have an arithmetic mean of 100 and a standard deviation of 10. Their values are very likely to be in the range of [70,130]. Moreover, regardless of the initial character of j -th indicator, after the transformation defined by (2) Z_j becomes a stimulant for the studied phenomenon. An increase in the normalized indicators corresponds to the increase in the composite index.

3.2. Dynamic scaling

Mazziotta and Pareto used dynamic version of the scaling in AMPI (2015). For a given matrix $X = \{x_{ijt}\}$ a normalized matrix $R = \{r_{ijt}\}$ is calculated as follows:

$$r_{ijt} = \begin{cases} \frac{x_{ijt} - \text{Min}_{x_j}}{\text{Max}_{x_j} - \text{Min}_{x_j}} \cdot 60 + 70 & \text{if } X_j \in S \\ 200 - \left(\frac{x_{ijt} - \text{Min}_{x_j}}{\text{Max}_{x_j} - \text{Min}_{x_j}} \cdot 60 + 70 \right) & \text{if } X_j \in D \end{cases} \quad (3)$$

where Min_{x_j} , Max_{x_j} , called ‘goalposts’, determine the range of indicators after normalization. If Min_{x_j} and Max_{x_j} denote the simple minimum and maximum value of an indicator j at time t , then the range of the rescaled variables would be equal to [70; 130]. Such normalization cannot be used if we want to compare index values over time.

However, for AMPI, the range of the rescaled indicators is only approximately equal to this interval. [Mazziotta and Pareto \(2015, 2016, 2018\)](#) gave the following procedure for determining the ‘goalposts’:



$$\begin{cases} \text{Min}_{x_j} = \text{Ref}_{x_j} - \Delta \\ \text{Max}_{x_j} = \text{Ref}_{x_j} + \Delta \end{cases}, \quad (4)$$

where¹

$$\Delta = \frac{\text{Sup}_{x_j} - \text{Inf}_{x_j}}{2}, \quad (5)$$

and

$$\begin{cases} \text{Inf}_{x_j} = \min_{it} \{x_{ijt}\} \\ \text{Sup}_{x_j} = \max_{it} \{x_{ijt}\} \end{cases}, \quad (6)$$

while Ref_{x_j} is the fixed reference value for indicator j , e.g., the average in a given year.

Just like for standardization after the transformation defined by (3), (4), (5) and (6), R_j becomes a stimulant for the studied phenomenon. Unlike standardization, the scaled values are comparable over time.

In the quoted method, equation (6) is problematic. Inf_{x_j} , Sup_{x_j} are determined on the basis of all available data, and thus, they change when new data arrive (Tarantola 2008). The question arises how to conduct research periodically, since new data change previously normalized indicators, and thus, they change the index. The empirical example shows (Section 4) that adding new data may cause changes in already established rankings. This means that the current situation works backwards. Therefore, the original AMPI with such a normalization method is suitable for a single analysis of the phenomenon over time, but not for the periodical research. This feature initiated the search for another method of normalization.

3.3. Anti-pattern normalization

The original version of the normalization used in the paper is the pattern normalization (Müller-Frączek 2019b). This method transforms an individual indicator with respect to a pattern, the most favourable value of the indicator. Such a normalized indicator is a destimulant, therefore the pattern normalization cannot be used with AMPI. An anti-pattern normalization is a modification of the basic version. It transforms an individual indicator with respect to an anti-pattern, i.e., the least favourable value of the indicator. In this way the indicator becomes a stimulant, therefore this normalization can be used with AMPI.

In this paper we modify the anti-pattern normalization so that the range and average of the normalized indicators are similar, such as in the case of scaling from Subsection 3.1. We start with the data matrix $X = \{x_{ijt}\}$. For each individual indicator X_j ($j = 1, \dots, m$) we define an anti-pattern:

¹The Sup and Inf notation in formula (5) comes from the original paper of Mazziotta – Pareto (2015) and has a different meaning than in mathematical analysis.



$$x_{jt}^- = \begin{cases} \min_{i=1,\dots,n} x_{ijt} & \text{if } X_j \in S, \\ \max_{i=1,\dots,n} x_{ijt} & \text{if } X_j \in D. \end{cases} \quad (7)$$

x_{jt}^- is the least favourable value of the indicator j at time period t . And d_{ijt} denotes the distance of i -th unit from the anti-pattern (for indicator j at time period t). Then, a normalized matrix $U = \{u_{ijt}\}$ is calculated as follows:

$$u_{ijt} = 30 \cdot n \cdot \frac{d_{ijt}}{\sum_{k=1}^n d_{kjt}} + 70 = \begin{cases} \frac{30n(x_{ijt} - x_{jt}^-)}{\sum_{k=1}^n (x_{kjt} - x_{jt}^-)} + 70 & \text{if } X_j \in S, \\ \frac{30n(x_{jt}^- - x_{ijt})}{\sum_{k=1}^n (x_{jt}^- - x_{kjt})} + 70 & \text{if } X_j \in D. \end{cases} \quad (8)$$

$\sum_{k=1}^n d_{kjt}$ in (8) denotes the total distance of all units from the anti-pattern, so it is a certain characteristic of a set of all units (similar to mean and standard deviation in standardizing). We should emphasize that a change in the environment in which the analysis is carried out (adding or removing a unit) significantly affects the results of the anti-pattern normalization.

For each individual indicator and each time period $d_{ijt}/\sum_{k=1}^n d_{kjt}$ distributes the same ‘mass’ equal to 1 between all units. If the value of this quotient for a given unit (and given indicator) increases in time, it means that the situation of this unit has improved² in comparison to others. Therefore, the indicators transformed by (8) are comparable in space (units) as well as in time (in a certain way), although only current data are used. This is a main advantage of anti-pattern normalization because the new data do not affect previous results. However, the comparability over time for anti-pattern normalization is different than in the case of scaling from Subsection 3.1, for which an increase in a normalized value means an increase in the value of the raw indicator.

As in the case of standardization, the average value of the indicator after the anti-pattern normalization is equal to 100,³ while all its values are within the range of $[70, 30n + 70]$. Reaching $30n + 70$ in practical research is impossible because it occurs only when one unit has a raw indicator value different from the anti-pattern. The exact maximum value depends on the indicator polarization and is equal to:

²This does not necessarily mean that the value of the indicator has increased. In addition, the weakest object always has a normalized value of 0, even when the value of its raw indicator has increased over time (Müller-Frączek 2019b).

³For any X_{jt} holds $\overline{u}_{jt} = \frac{1}{n} \sum_{i=1}^n u_{ijt} = \frac{1}{n} \sum_{i=1}^n \left(\frac{30n \cdot |x_{ijt} - x_{jt}^-|}{\sum_{k=1}^n |x_{kjt} - x_{jt}^-|} + 70 \right) = \frac{1}{n} \left(\frac{\sum_{i=1}^n 30n \cdot |x_{ijt} - x_{jt}^-|}{\sum_{k=1}^n |x_{kjt} - x_{jt}^-|} + 70n \right) = 100$.



$$\max_{i=1,\dots,n} u_{ijt} = \begin{cases} 30 \frac{\max_{i=1,\dots,n} x_{ijt} - \min_{i=1,\dots,n} x_{ijt}}{\bar{x}_{jt} - \min_i x_i} + 70 & \text{if } X_j \in S, \\ 30 \frac{\max_{i=1,\dots,n} x_{ijt} - \min_{i=1,\dots,n} x_{ijt}}{\max_{i=1,\dots,n} x_i - \bar{x}_{jt}} + 70 & \text{if } X_j \in D, \end{cases} \quad (9)$$

where $\bar{x}_{jt} = \frac{1}{n} \sum_{i=1}^n x_{ijt}$. In practice, the maximum value is significantly lower than $30n + 70$.

After combining anti-pattern normalization with Mazziotta and Pareto method of aggregation we get the Anti-pattern Normalized Mazziotta-Pareto Index (APMPI). In this case, the penalty is 0 for units that have all normalized indicators equal to 100 (then APMPI is also 100). In addition, APMPI does not punish the units that have all indicators on the weakest level. In this (and only this) situation, APMPI is 70.

In the context of object comparisons over time, APMPI is something in between MPI and AMPI. It enables not only comparison of rankings (like MPI) but also comparison of index values. However, these are not absolute comparisons (as for AMPI), but relative comparisons - compared to other units.

4. EMPIRICAL EXAMPLE

Similarly to the original, the Mazziotta-Pareto aggregation is used to construct indices of well-being for the OECD countries based on the following individual indicators ⁴ (all of them are stimulants):

1. Life expectancy (years),
2. Educational attainment (% of people, aged 15–64),
3. Employment rate (% of people, aged 15–64),
4. Household disposable income (USD–PPPs adjusted).

The Mazziotta-Pareto method can be used to aggregate these indicators, because “all the indicators are very important in order to represent the well-being. Therefore, we may assume that the variables are non-substitutable, i.e., a complete compensability among them is not desirable; they have the same weight and a balanced distribution of the values is requested.” (Mazziotta – Pareto 2016: 995). Because the phenomenon is positive, $AMPI^-$ is used (compare formula (1)).

In the original article, the authors calculated the indices for two years: 2011 and 2014. In this study, the indices for the years 2011, 2014 and 2017 are calculated using the same method, and then results are compared with the original ones. This comparison shows the imperfection of the normalization used in the original paper.

⁴The values of the indicators are included in the [Appendix Table A1](#). A detailed description of the indicators can be found in [OECD \(2013\)](#).



4.1. Study description

For the years 2011 and 2014, 3 well-being indices are calculated.⁵ They differ in the method of the indicator normalization. First is MPI, in which the indicators are standardized. The other are two versions of AMPI (marked as AMPI1 and AMPI2), in which the indicators are scaled according to formulas (3)–(6). Two possible situations are considered:

1. Data only for 2011 and 2014 are available (AMPI1),
2. Data for 2011, 2014 and 2017 are available (AMPI2).

In both versions, the same reference values are used (compare formula (3)), these are the average values of the indicators in 2011. The values of AMPI1 indices coincide with the results presented in [Mazziotta – Pareto \(2016\)](#). The values of AMPI2 differ, because of the change in (6).

4.2. Comparison of AMPI for both data sets

This subsection examines the impact of adding new observations on the previously calculated indices and on previously established rankings. First, after taking into account the 2017 observations, the average values of the indices for 2011 and 2014 changed. The average values of their components (mean and penalty) also changed. The AMPI1 index prevailed on average in 2014, while AMPI2 in 2011. However, generally the same countries are above the average for both AMPI in both years, the only exception is Belgium in 2011, which has an AMPI1 index above the average and AMPI2 below.

[Table 1](#) shows the changes in the indices for individual countries. There is no rule that would determine how the subsequent observations affect previous calculations of the indices (as well as mean – the main component). Each year there are changes in both directions. However, it can be stated that adding observations resulted in a reduction of the penalty (the only exception is Canada in 2011), and a reduction of the ratio of the penalty to the mean for almost all countries.

[Table 2](#) presents more important comparisons. It contains differences in rankings for both AMPIs. Such differences are not numerous, but they do occur: two in 2011 (France and New Zealand) and seven in 2014 (Belgium, France, Korea, New Zealand, Poland, Slovenia and Spain). These are small differences in both directions (usually one position up or down in the ranking). In contrast, the rankings for index components tend to be very different, e.g., according to the penalty in 2011. In this case, half of the countries have different positions in both approaches (Japan even by three places down).

[Table 3](#) presents the dynamic situation of the countries in regards to both AMPI indices: increases over time, as well as corresponding differences in the rankings. In general, the directions of changes over time for both indices are in line with each other, but there are 2 exceptions. The AMPI1 index for Mexico decreased between 2014 and 2017, while the AMPI2 index increased. Belgium, on the other hand, reported a different change in classification. The position of this country according to AMPI1 improved over time, and according to AMPI2 it worsened.

⁵Due to the limited length of the article, we do not provide index values, but only the results of comparisons.



Table 1. Comparison of AMPI values (Subtraction of index values and index components)

Country	Mean1–Mean2		Penalty1–Penalty2		Ratio1–Ratio2		AMPI1–AMPI2	
	2011	2014	2011	2014	2011	2014	2011	2014
Australia	0.81	1.17	0.06	0.10	0.55	0.85	0.75	1.07
Austria	0.70	0.93	0.01	0.01	0.04	0.13	0.69	0.92
Belgium	0.25	0.49	0.06	0.10	0.56	0.96	0.19	0.39
Canada	0.71	0.98	−0.01	+0.00	−0.10	0.03	0.73	0.98
Chile	−1.25	−0.78	0.20	0.08	2.44	0.91	−1.45	−0.86
Czech Rep.	−0.66	−0.45	0.15	0.12	1.67	1.24	−0.81	−0.57
Denmark	0.10	0.44	0.04	0.01	0.35	0.06	0.07	0.44
Estonia	−1.55	−0.95	0.61	0.30	7.53	3.29	−2.16	−1.25
Finland	0.31	0.65	0.00	0.00	−0.03	0.00	0.31	0.65
France	0.60	0.93	0.10	0.18	0.91	1.65	0.50	0.75
Germany	0.65	0.98	0.00	0.01	−0.03	0.12	0.65	0.97
Greece	−0.07	−0.21	0.06	0.25	0.59	2.83	−0.13	−0.47
Hungary	−1.68	−1.34	0.48	0.31	6.36	3.82	−2.16	−1.65
Ireland	0.12	0.21	0.06	0.09	0.58	0.92	0.07	0.11
Italy	0.30	0.57	0.26	0.38	2.68	3.68	0.04	0.19
Japan	0.81	0.96	0.11	0.06	0.96	0.52	0.70	0.90
Korea	−0.28	0.06	0.09	0.13	0.96	1.23	−0.38	−0.06
Mexico	−1.62	−1.69	0.01	0.10	0.47	1.69	−1.63	−1.79
Netherlands	0.57	0.75	0.02	0.04	0.18	0.38	0.54	0.70
New Zealand	0.11	0.44	0.08	0.06	0.77	0.56	0.03	0.38
Norway	0.89	1.22	0.01	0.04	0.11	0.29	0.87	1.18
Poland	−1.26	−0.86	0.31	0.16	3.72	1.89	−1.57	−1.02
Portugal	−0.39	−0.14	0.10	0.19	1.30	2.20	−0.49	−0.33
Slovak Rep.	−1.30	−0.93	0.42	0.24	5.07	2.74	−1.72	−1.17
Slovenia	−0.19	0.00	0.02	0.04	0.22	0.42	−0.22	−0.05
Spain	0.19	0.35	0.20	0.38	2.08	3.88	−0.01	−0.03
Sweden	0.79	1.01	0.00	0.01	−0.01	0.07	0.79	1.00
Switzerland	1.15	1.46	0.01	0.03	0.08	0.22	1.13	1.43
U.K.	0.44	0.66	0.04	0.02	0.33	0.21	0.41	0.64

(continued)



Table 1. Continued

Country	Mean1–Mean2		Penalty1–Penalty2		Ratio1–Ratio2		AMPI1–AMPI2	
	2011	2014	2011	2014	2011	2014	2011	2014
U.S.	0.78	1.05	0.41	0.40	3.64	3.51	0.38	0.65
Mean	0.00	0.27	0.13	0.13	1.47	1.34	–0.13	0.14
Std. deviation	0.83	0.82	0.16	0.12	1.94	1.28	0.94	0.87

Note: Ratio = Penalty/Mean*1,000.

Table 2. Comparison of AMPI ranks (Subtraction of ranks)

Country	Mean1–Mean2		Penalty1–Penalty2		Ratio1–Ratio2		AMPI1–AMPI2	
	2011	2014	2011	2014	2011	2014	2011	2014
Australia	0	–1	1	0	–2	0	0	0
Austria	0	1	0	0	0	0	0	0
Belgium	0	–1	–1	0	1	0	0	–2
Canada	0	0	0	0	0	0	0	0
Chile	0	0	–2	0	1	1	0	0
Czech Rep.	1	0	–1	0	0	0	0	0
Denmark	1	0	2	0	–2	–1	0	0
Estonia	0	1	0	0	0	0	0	0
Finland	0	0	0	0	0	0	0	0
France	–1	0	–1	0	1	0	–1	–1
Germany	0	0	0	0	0	0	0	0
Greece	0	0	1	0	–1	0	0	0
Hungary	0	0	0	0	1	0	0	0
Ireland	–1	0	2	0	–1	0	0	0
Italy	0	0	0	0	0	0	0	0
Japan	0	0	–3	–1	2	0	0	0
Korea	0	1	–1	0	2	0	0	1
Mexico	0	0	1	0	–1	0	0	0
Netherlands	0	0	0	0	–1	0	0	0
New Zealand	1	0	1	0	0	0	1	1

(continued)



Table 2. Continued

Country	Mean1–Mean2		Penalty1–Penalty2		Ratio1–Ratio2		AMPI1–AMPI2	
	2011	2014	2011	2014	2011	2014	2011	2014
Norway	0	0	0	0	0	1	0	0
Poland	0	0	–1	0	0	–1	0	1
Portugal	0	0	0	0	0	0	0	0
Slovak Rep.	0	0	0	0	–1	0	0	0
Slovenia	0	0	0	1	0	0	0	1
Spain	0	–1	1	0	0	0	0	–1
Sweden	0	0	0	0	0	0	0	0
Switzerland	0	0	1	0	0	–1	0	0
U.K.	–1	0	0	0	0	0	0	0
U.S.	0	0	0	0	1	1	0	0
*	6	6	20	2	18	6	2	8
**	6	6	15	2	14	6	2	7

Note: * Sum of absolute values; ** Number of countries with differences; Ratio = Penalty/Mean*1,000.

Table 3. Changes over time for various well-being indices

Country	Value in 2014 – Value in 2011			Rank in 2014 – Rank in 2011			
	AMPI1	AMPI2	APMPI	AMPI1	AMPI2	MPI	APMPI
Australia	3.73	3.40	0.44	0	0	–1	–1
Austria	2.67	2.44	–0.52	0	0	0	2
Belgium	2.14	1.94	0.93	–1	1	–1	–1
Canada	2.65	2.40	–0.21	0	0	1	0
Chile	6.07	5.48	3.30	–1	–1	–2	–2
Czech Rep.	2.96	2.72	–0.78	–1	–1	–1	1
Denmark	3.55	3.17	–0.45	0	0	0	1
Estonia	9.36	8.44	4.63	–5	–5	–4	–4
Finland	4.16	3.82	1.32	–1	–1	–1	–2
France	2.91	2.66	1.24	0	0	0	–2
Germany	3.64	3.32	0.78	0	0	0	–2
Greece	–5.01	–4.67	–6.41	6	6	6	6

(continued)



Table 3. Continued

Country	Value in 2014 – Value in 2011			Rank in 2014 – Rank in 2011			
	AMPI1	AMPI2	APMPI	AMPI1	AMPI2	MPI	APMPI
Hungary	4.79	4.27	3.19	0	0	0	0
Ireland	0.87	0.82	–0.30	1	1	2	1
Italy	2.89	2.74	2.60	–1	–1	–1	–3
Japan	2.91	2.71	–0.47	0	0	–1	1
Korea	3.50	3.19	0.42	0	–1	–1	–1
Mexico	–0.11	0.05	–3.80	0	0	0	0
Netherlands	1.42	1.26	–2.71	2	2	1	2
New Zealand	3.22	2.87	–0.93	0	0	0	1
Norway	3.32	3.01	–0.18	0	0	0	0
Poland	4.74	4.19	2.27	0	–1	0	–1
Portugal	2.66	2.51	–2.35	0	0	1	4
Slovak Rep.	4.77	4.22	2.55	1	1	0	–1
Slovenia	1.17	1.00	–2.29	1	0	1	1
Spain	0.07	0.08	–0.89	0	1	0	0
Sweden	2.77	2.56	–0.82	0	0	0	0
Switzerland	2.62	2.32	–1.10	0	0	0	0
U.K.	4.31	4.08	0.25	0	0	0	1
U.S.	2.57	2.30	0.90	–1	–1	1	–1
Mean	2.91	2.64	0.02				
Std. deviation	2.29	2.08	2.20				

In summary, the results obtained for both datasets are similar, but in some cases, they are significantly different. These differences are the imperfections of the described method. The results substantially depend on the method of determining goalposts, which causes problems in the periodical research.

4.3. Comparison of AMPIs with MPI

In this subsection, as in [Mazziotta-Pareto \(2016\)](#), both AMPIs are compared with the original version, i.e., MPI. [Table 4](#) shows the differences in rankings. We can see that AMPI1 is slightly more similar to MPI than AMPI2.

The right section of [Table 3](#) contains more important differences between AMPIs and MPI. There are cases when AMPI shows dynamics differently in the classification than MPI. In one case (United States) both AMPIs show different dynamics than MPI. AMPIs show



Table 4. Comparison of AMPIs and MPI rankings (Subtractions of ranks)

Country	Rank by MPI – Rank by AMPI1								Rank by MPI – Rank by AMPI2							
	Mean		Penalty		Ratio		Index		Mean		Penalty		Ratio		Index	
	2011	2014	2011	2014	2011	2014	2011	2014	2011	2014	2011	2014	2011	2014	2011	2014
Australia	0	2	–1	0	0	–1	1	0	0	1	–2	0	–2	–1	1	0
Austria	1	0	1	1	1	1	0	0	1	1	1	1	1	1	0	0
Belgium	0	0	1	–1	0	–1	0	0	0	–1	2	–1	1	–1	0	–2
Canada	–1	0	0	1	0	1	–1	0	–1	0	0	1	0	1	–1	0
Chile	0	0	1	4	1	4	2	1	0	0	3	4	2	5	2	1
Czechia	–1	0	0	0	1	0	0	0	0	0	1	0	1	0	0	0
Denmark	0	0	2	1	2	2	0	0	1	0	0	1	0	1	0	0
Estonia	0	–1	0	3	0	4	–1	0	0	0	0	3	0	4	–1	0
Finland	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
France	0	0	–1	0	–2	0	0	0	–1	0	0	0	–1	0	–1	–1
Germany	1	0	1	3	1	3	0	0	1	0	1	3	1	3	0	0
Greece	0	0	–1	–4	–1	–4	0	0	0	0	–2	–4	–2	–4	0	0
Hungary	0	0	–2	–1	–1	–1	0	0	0	0	–2	–1	0	–1	0	0
Ireland	–1	0	0	–2	0	–2	–1	0	–2	0	–2	–2	–1	–2	–1	0
Italy	0	0	0	–2	0	–2	0	0	0	0	0	–2	0	–2	0	0
Japan	1	0	–6	–5	–4	–4	1	0	1	0	–3	–4	–2	–4	1	0
Korea	2	1	4	0	2	1	1	0	2	2	5	0	4	1	1	1
Mexico	0	0	–1	0	–2	–1	0	0	0	0	–2	0	–3	–1	0	0
Netherl.	0	0	1	3	2	2	1	0	0	0	1	3	1	2	1	0

(continued)



Table 4. Continued

Country	Rank by MPI – Rank by AMPI1								Rank by MPI – Rank by AMPI2							
	Mean		Penalty		Ratio		Index		Mean		Penalty		Ratio		Index	
	2011	2014	2011	2014	2011	2014	2011	2014	2011	2014	2011	2014	2011	2014	2011	2014
New Zeal.	0	0	1	–1	1	–1	0	0	1	0	0	–1	1	–1	1	1
Norway	0	0	1	2	0	2	0	0	0	0	1	2	0	3	0	0
Poland	1	0	–1	0	–1	0	0	0	1	0	0	0	–1	–1	0	1
Portugal	0	0	0	0	0	0	–1	0	0	0	0	0	0	0	–1	0
Slovakia	–1	0	0	–1	1	2	0	–1	–1	0	0	–1	0	2	0	–1
Slovenia	0	–1	0	0	0	–1	0	0	0	–1	0	–1	0	–1	0	1
Spain	0	1	–1	–1	–1	0	0	0	0	0	–2	–1	–1	0	0	–1
Sweden	0	0	–2	–3	–2	–3	0	0	0	0	–2	–3	–2	–3	0	0
Switzerl.	0	0	0	–1	0	–1	0	0	0	0	–1	–1	0	–2	0	0
U.K.	0	0	–1	–2	0	–2	0	0	–1	0	–1	–2	0	–2	0	0
U.S.	–2	–2	4	6	2	2	–2	0	–2	–2	4	6	3	3	–2	0
*	12	8	34	48	28	48	12	2	16	8	38	48	30	52	14	10
**	10	6	20	21	18	24	10	2	13	6	19	22	18	25	12	9

Note: * Sum of absolute values; ** Number of countries with differences; Ratio = Penalty/Mean* 1,000.



Table 5. Comparison of APMPI rankings and others (Subtraction or ranks)

Country	2011			2014			Rank in 2014 – Rank in 2011			
	Rank by APMI – Rank by			Rank by APMI – Rank by						
	MPI	AMPI1	AMPI2	MPI	AMPI1	AMPI2	MPI	AMPI1	AMPI2	APMPI
Australia	–1	0	0	–1	–1	–1	–1	0	0	–1
Austria	–1	–1	–1	1	1	1	0	0	0	2
Belgium	0	0	0	0	0	–2	–1	–1	1	–1
Canada	0	–1	–1	–1	–1	–1	1	0	0	0
Chile	0	2	2	0	1	1	–2	–1	–1	–2
Czech Rep.	0	0	0	2	2	2	–1	–1	–1	1
Denmark	0	0	0	1	1	1	0	0	0	1
Estonia	1	0	0	1	1	1	–4	–5	–5	–4
Finland	1	1	1	0	0	0	–1	–1	–1	–2
France	1	1	0	–1	–1	–2	0	0	0	–2
Germany	1	1	1	–1	–1	–1	0	0	0	–2
Greece	0	0	0	0	0	0	6	6	6	6
Hungary	0	0	0	0	0	0	0	0	0	0
Ireland	0	–1	–1	–1	–1	–1	2	1	1	1
Italy	1	1	1	–1	–1	–1	–1	–1	–1	–3
Japan	0	1	1	2	2	2	–1	0	0	1
Korea	0	1	1	0	0	1	–1	0	–1	–1
Mexico	0	0	0	0	0	0	0	0	0	0
Netherlands	–1	0	0	0	0	0	1	2	2	2
New Zealand	–1	–1	0	0	0	1	0	0	0	1
Norway	0	0	0	0	0	0	0	0	0	0
Poland	1	1	1	0	0	1	0	0	–1	–1
Portugal	–3	–4	–4	0	0	0	1	0	0	4
Slovak Rep.	1	1	1	0	–1	–1	0	1	1	–1
Slovenia	0	0	0	0	0	1	1	1	0	1
Spain	–1	–1	–1	–1	–1	–2	0	0	1	0
Sweden	0	0	0	0	0	0	0	0	0	0
Switzerland	0	0	0	0	0	0	0	0	0	0

(continued)

Table 5. Continued

Country	2011			2014			Rank in 2014 – Rank in 2011			
	Rank by APMI – Rank by			Rank by APMI – Rank by						
	MPI	AMPI1	AMPI2	MPI	AMPI1	AMPI2	MPI	AMPI1	AMPI2	APMPI
U.K.	–1	–1	–1	0	0	0	0	0	0	1
U.S.	2	0	0	0	0	0	1	–1	–1	–1
*	18	20	18	14	16	24	26	22	24	42
**	15	16	14	12	14	19	16	12	14	23

Note: * Sum of absolute values; ** Number of countries with differences; Ratio = Penalty/Mean*1,000.

improvement, while MPI shows deterioration. However, for several countries the indications of only one AMPI are different than MPI (Belgium, Korea, Poland and Spain).

4.4. Anti-pattern normalized Mazziotta-Pareto Index (APMPI)

The imperfection of the original approach was the motivation to use a different method of normalization. The resulting index APMPI, is suitable for periodical measurement, because the previously determined values do not change when observations appear for the next period.

It should be emphasized that although AMPI and APMPI use the same aggregation method, the results based on them are not comparable. The increase in AMPI means that the country's situation has improved objectively, while the increase in APMPI means that its situation has improved in relation to other countries. There are always countries for which APMPI increases and countries for which APMPI decreases.

While comparing the index values does not make sense, we can compare the rankings based on them. Table 5 presents such comparisons. As can be seen, the results are partly aligned, e.g., the top three countries for both indices and both years are the same. The differences occur for about half of the countries, most of them are different by only one rank. The right side of Table 5 shows the change in position over time. For most countries, the direction of changes according to the APMPI is consistent with the direction according to at least one of the other indices. The exception is the Czech Republic, which, according to APMPI, improved its position, but according to all other, it worsened its position.

5. CONCLUSIONS

Analysing multidimensional phenomena using composite indices is very popular due to the simplicity of the interpretation of the results. However, the correct synthesizing of indicators is not an easy task, especially when we want to construct an index that allows comparisons over time, for example, to study the transition of a country. There are different methods of construction of dynamic composite indicators. One of them is the Adjusted Mazziotta-Pareto Index, the topic of this paper. A characteristic feature of AMPI is the aggregation method, that



introduces a penalty for unbalancing the indicators. Comparability over time in AMPI is obtained by using one of the scaling variations. However, this type of normalization has a certain imperfection, which is presented on the example of the well-being index for the OECD countries. The results substantially depend on the method of determining ‘goalposts’. In the original approach (Mazziotta – Pareto 2015, 2016), we determine the ‘goalposts’ based on all available history of the indicator, which changes with the appearance of new observations. Therefore, AMPI is suitable for a one-time comparison over time, while with such normalization it cannot be used for periodical studies, because when new observations are added, the values of index for earlier periods change.

This paper proposes to use a different normalization method. APMPI has been introduced and has the advantage that new observations do not affect previous index values, and thus, previously determined rankings. Therefore, APMPI can be used for periodical measurements. The AMPI and APMPI values are not comparable, but the empirical example showed that the rankings based on them are not very different.

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Appendix

Table A1. Individual indicators of well-being – Original values rounded to the first decimal place

Country	Life expectancy			Educational attainment			Employment rate			Household disposable income		
	2011	2014	2017	2011	2014	2017	2011	2014	2017	2011	2014	2017
Australia	81.5	82.0	82.5	69.7	74.0	80.0	72.3	72.0	72.0	27.0	31.2	33.4
Austria	80.5	81.1	81.3	81.0	82.0	85.0	71.7	73.0	72.0	27.7	29.3	32.5
Belgium	79.8	80.5	81.1	69.6	71.0	75.0	62.0	62.0	62.0	26.0	27.8	30.0
Canada	80.7	81.0	81.5	87.1	89.0	91.0	71.7	72.0	73.0	27.0	30.2	29.9
Chile	77.8	78.3	79.1	68.0	72.0	65.0	59.3	62.0	62.0	8.7	13.8	16.6
Czech Rep.	77.3	78.0	78.7	90.9	92.0	93.0	65.0	67.0	72.0	16.7	17.3	21.1
Denmark	78.8	79.9	80.8	74.6	77.0	81.0	73.4	73.0	75.0	22.9	25.2	29.0
Estonia	73.9	76.3	77.7	88.5	89.0	89.0	61.0	67.0	72.0	13.5	14.4	18.7
Finland	79.9	80.6	81.6	81.1	84.0	88.0	68.1	70.0	69.0	24.2	26.9	29.4
France	81.0	82.2	82.4	70.0	72.0	78.0	64.0	64.0	65.0	27.5	29.3	31.1
Germany	80.2	80.8	80.7	85.3	86.0	86.0	71.1	73.0	75.0	27.7	30.7	33.7
Greece	80.0	80.8	81.1	61.1	67.0	72.0	59.6	51.0	52.0	21.5	19.1	17.0
Hungary	73.8	75.0	75.7	79.7	82.0	83.0	55.4	57.0	67.0	13.9	15.2	16.8
Ireland	79.9	80.6	81.5	69.5	73.0	80.0	60.0	59.0	65.0	24.3	23.7	25.4
Italy	81.5	82.7	82.6	53.3	56.0	60.0	56.9	58.0	57.0	24.4	24.7	26.1
Japan	82.7	82.7	83.9	87.0	93.0	94.0	70.1	71.0	74.0	23.2	25.1	28.6
Korea	79.9	81.1	82.1	79.1	81.0	87.0	63.3	64.0	66.0	16.3	18.0	21.7
Mexico	75.1	74.4	75.0	33.6	36.0	37.0	60.4	61.0	61.0	12.2	12.9	13.9
Netherlands	80.2	81.3	81.6	73.3	72.0	77.0	74.7	75.0	75.0	26.0	25.7	28.8
New Zealand	80.4	81.2	81.7	72.1	74.0	77.0	72.3	72.0	76.0	18.8	21.8	24.4
Norway	80.6	81.4	82.4	80.7	82.0	82.0	75.3	76.0	74.0	29.4	32.1	35.7
Poland	75.6	76.9	77.6	87.1	89.0	91.0	59.3	60.0	65.0	13.8	16.2	18.9
Portugal	79.3	80.8	81.2	28.2	35.0	47.0	65.6	62.0	65.0	18.5	18.8	20.5
Slovak Rep.	74.8	76.1	76.7	89.9	91.0	92.0	58.8	60.0	65.0	15.5	17.2	20.3
Slovenia	78.8	80.1	80.9	82.0	84.0	87.0	66.2	64.0	66.0	19.9	19.7	20.5
Spain	81.2	82.4	83.0	51.2	54.0	58.0	58.6	56.0	60.0	23.0	22.8	23.1

(continued)



Table A1. Continued

Country	Life expectancy			Educational attainment			Employment rate			Household disposable income		
	2011	2014	2017	2011	2014	2017	2011	2014	2017	2011	2014	2017
Sweden	81.2	81.9	82.3	85.0	87.0	83.0	72.7	74.0	76.0	26.5	27.5	30.6
Switzerland	82.2	82.8	83.0	86.8	86.0	87.0	78.6	79.0	80.0	27.5	30.7	36.4
U.K.	79.7	81.1	81.0	69.6	77.0	81.0	69.5	71.0	74.0	27.2	25.8	28.4
U.S.	77.9	78.7	78.8	88.7	89.0	90.0	66.7	67.0	69.0	37.7	39.5	44.0
Mean	79.2	80.1	80.7	74.1	76.5	79.2	66.1	66.4	68.5	22.3	23.8	26.2
Std. deviation	2.4	2.3	2.2	15.4	14.6	13.4	6.3	6.9	6.4	6.3	6.5	7.0
Max	82.7	82.8	83.9	90.9	93.0	94.0	78.6	79.0	80.0	37.7	39.5	44.0
Min	73.8	74.4	75.0	28.2	35.0	37.0	55.4	51.0	52.0	8.7	12.9	13.9

Source: Better Life Index (BLI) database developed by the OECD; the repetition of Table 4 of [Mazziotta – Pareto \(2016\)](#) completed by the data from 2017.

