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A Multivariate Approach in Measurement of the Sustainable Development of European Countries

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Due to the rising importance and popularity of the concept of sustainable development, a huge number of various methodologies and concepts for measuring sustainability have evolved in the last few decades. However, there are still challenges and issues that should be solved, suggesting the need for new approaches and sustainability metrics to be developed and proposed. The main goal of this paper is the present possibilities of application of I-distance methodology to measurement of the sustainable development as it could address some of the actual challenges related to subjective nature of usually applied normalization, weighting and aggregation methods.The proposed I-distance methodology was applied on a set of European countries. A twofold approach provided a deeper insight into not only domain dynamics, but also into total score dynamic. It can support policy makers to identify key indicators and focus the policy areas where appropriate policy measures would have the most significant influence on the overall positioning of the country.

Keywords: Sustainable development; Sustainability; Composite indicators; I-distance methodology; I2-distance; twofold I-distance approach.

1. Introduction

The roots of the sustainability concept can be found in sources from many centuries ago, including ones from the sciences of religion, philosophy and economics (Mebratu, 1998). However, the term “sustainable development” was used for the first time in the World Conservation Strategy (IUCN, 1980). Most commonly, sustainable development can be described as “development which satisfies the needs of the existing, without jeopardizing possibilities of the future generations to satisfy their own needs”, as it was defined in the Bruntland report (WCED, 1987). The concept of sustainable development includes numerous ecological, social and economic factors, which are stated as the three pillars or the triple bottom line for providing sustainability, and which do not exclude each other, but can even accent each other (UN, 2005).

A rising interest in sustainable development is a result of the perception of current actual conditions of the global human environment, which is largely unsatisfying and worrying, and demands urgent reaction of all members of the society, focused on long term environment protection and maintenance of biological stability (Petrovic, 2012). Although this topic is primarily considered on the level of national states, an increasing influence of the international institutions which regulate numerous interactions among states is obvious, and especially in the areas of systems and flows of international trade, finance, international property rights etc., which shows the general importance of the institutions in securing sustainable development as institutional capital (Platje, 2008).

Sustainable development is a very important and popular concept which is open to different approaches and interpretations, so naturally a large number of researchers, organizations, institutions and international agencies developed and offered many various methodologies and concepts for measuring sustainability. However, there is still an extensive discussion as to in which directions and how sustainability metrics should further develop (Ciegis et al., 2015; Frugoliet al., 2015; Hák et al., 2016; Stigliz et al., 2009; TFSD, 2013), demonstrating both a significant space and need for new conceptual approaches which would open new perspectives for measuring sustainable development.

The focus of this paper is on investigating the impact of the subjective nature of commonly applied normalization, weighting and aggregation methods on the results of the actual approaches in area of sustainable development indices. The main goals of this paper are to propose an I-distance methodology as alternative that can address those subjectivity-related challenges as well as to compare the results of our study with the results of some of the most recent approaches. Our main research hypothesis claims that a coherent sustainable development composite indicator framework can be developed based on the statistically assessed significances of the variables.

The remainder of the paper is organized as follows. The following section provides a review of the leading existing approaches in measuring sustainable development. In the next section a new approach is presented and applied on a set of European countries, including a comparative analysis of results with one of the most recent approaches. The final section presents conclusions of the paper.

2. Actual Approaches in Measuring Sustainable Development

The main goal of all sustainability metrics is to inform relevant communities included in the process of policy making within the wider process of sustainable development management (Boulanger, 2008) and to provide an appropriate quantitative information base (Ball, 2002). Indicators of sustainability can provide information about any aspect of the process and relationship between life environment and social-economic activities. Due to the rising importance of this topic, the metrics used for measuring sustainability are still being developed and consist of indicators, indices (composite indicators), benchmarks, new revision systems, new accounting concepts etc. which are applied on a wide range of spatial and time scales (Hak et al., 2007; Bell&Morse, 2008). While some of these methods and approaches treat measuring and rating of different aspects of sustainability within business and other organizations (Herzig&Schaltegger, 2006) and local communities (Ball, 2002; EIU, 2009), a whole list of methodological approaches is recognized that are focused on rating and comparing different aspects of sustainability and sustainable development management within national states.

Conceptual approaches in measuring sustainable development could be grouped in two general categories: (1) set of single, unaggregated indicators and (2) composite indicators. Unlike the sets of indicators, composite indicators have the ability to summarize complex and sometimes elusive processes into a single figure to benchmark a country's performance in policy consumption (Giovannini et al., 2008) and such a summary statistic can indeed capture reality and provide meaningful information (Sharpe, 2004). Therefore, the main focus of this paper are the composite indicators of sustainable development, where Table 1 provides a list of the approaches that are widely used and discussed in literature (TFSD, 2013), together with a summary of the approaches regarding the issues of normalization, weighting and aggregation.

Due to the vague interpretation of sustainability, examination of spatial, time and theme dimensions of measured phenomena is necessary to define a context for a clear understanding not only of exact topic of measurement, but also of the process of reaching sustainability (Bell & Morse, 2008). Looking at the spatial dimension of the above mentioned metrics, there is a noticeable dominance of the "national sustainability" approach that considers the national state as a basic analytical unit. Considering the time horizon, most approaches consider integral approach which tends to singularly perceive interests and needs of both present and future generations. Regarding the thematic perspective, only the SSI approach tends to integrally consider all factors and parameters of all three dimensions of sustainable development – economic, environmental and social dimensions. Others are rather focused on one dimension – economic (ISEW, GPI, GS/ANS), environmental (ESI, EPI, EF), social (HDI) – or have a combined social-environmental focus (WI).

Having in mind that all natural-ecological and social-economic processes and systems are interconnected and in constant interaction on a global level, there are a number of opinions which consider the sustainability of civilization in modern terms possible to maintain only by looking at the big picture of global perspective of its functioning and interaction with the environment (Gidens, 2009; Stern, 2009; Moldan et al., 2012), which requires new research efforts that target a global perspective of measuring sustainable development.

Table 1. Actual approaches in measuring sustainable development and applied methods of normalization, weighting and aggregation

Index	Normalization	Weighting	Aggregation
Index for SustainableEconomicWelfare - ISEW (Daly&Cobb, 1989)	Monetarized	Equal	Arithmetic mean
GenuineProgressIndicator – GPI (Cobb et al., 1995)	Monetarized	Equal	Arithmetic mean
GenuineSavings/Adjusted Net Savings - GS/ANS (Hamilton et al., 1997; WB, 2011)	Monetarized	Equal	Arithmetic mean
EnvironmentalSustainabilityIndex - ESI (Esty et al., 2005)	Standard deviation	equal/experts	Arithmetic mean
Environmental Performance Index – EPI (Hsu et al., 2014)	Best = 100, Worst = 0	PCA and Experts	Arithmetic mean
EcologicalFootprint – EF (Wackernagel&Rees, 1997).	Transformation in km^2	Equal	Arithmetic mean
Well-beingIndex – WI (Prescott-Allen, 2001)	Best = 100, Worst = 0	Subjective	Arithmetic mean
Human DevelopmentIndex – HDI (UNDP, 2014)	Min-max (0-1)	Equal	Arithmetic mean
SustainableSocietyIndex– SSI (van de Kerk&Maunel, 2014)	Min-max (1-10)	Equal	Geometric mean

Integral perspective implies a tendency to cover all aspects of human welfare, which can lead it to lose focus and become a "theory of everything", at the same time risking minimizing the relative importance of long term perspective, due to a "number of urgent problems that need attention here and now" (TFSD, 2013). The integral approach, with its focus on both wellbeing of present and future generations, is criticized because of its underestimating possible catastrophic consequences of the past and present socio-economic processes for future generations (Bernstein, 2008), which makes compromises focused on welfare of the present generation improvement at the price of jeopardizing future ones unacceptable. Increasing consideration of sustainable development from the perspective of human welfare is placing rising attention on economic and social dimensions, with no apparent connection to the environmental sustainability, defined by its biogeophysical aspects and focus on maintaining and improving the integrity of the Earth's life supporting systems (Moldan et al., 2012).

It is noticed that composite indicators in newly emerging policy areas such as sustainable development might be very subjective due to the lack of a transparent and solid underpinning theoretical and statistical framework (Giovannini et al., 2008), where identification of the selection criteria for the underlying indicators is of specific importance, as they are the basis for deciding whether an indicator should be or should not be included in the overall index. Their strong communicative power then can be disproportionate in comparison to their reliability, which could be generally considered as low because indices are strongly influenced by the methods chosen to build them (Luzzati&Gucciardi, 2015).

Regarding commonly applied methodologies and techniques, it is noted (Böhringer&Jochem, 2006) that current approaches, in general, fail to meet fundamental scientific requirements with respect to the three key areas: normalization, weighting and aggregation, as these topics are associated with subjective judgements which reveal a high degree of arbitrariness without mentioning or systematically assessing critical assumptions. Normalization of data implies a value judgment, as different scales cannot not be harmonized in a meaningful manner (Nardo et al., 2005). At the same time, normalization of data before aggregation does not provide a solution to the non-comparability of the data and the ensuing ambiguity of orderings (Ebert &Welsch, 2004). However, the composite indicators examined in this article use different normalization methods, proceeding either by transforming variables' values into a new unique scale (e.g. 0 to 1) by translation and expansion (ESI, EPI, WI, HDI, SSI) or converting all the variables into another area or monetary units by expansion (ISEW, GPI, GS/ANS, EF).

Similarly to normalization, weights are essentially value judgements (Giovannini et al., 2008). It is noted that weighting poses a genuine problem as it ostensibly aims at the comparability of variables even though these are obviously not comparable and since this involves potentially normative 'quotas of substitution' (Ebert&Welsch, 2004). Regarding approaches discussed in this paper, most of them use equal weighting (ISEW, GPI, GS/ANS, EF, HDI, SSI), some of them use subjective, expert-based participatory methods (ESI, EPI, WI) and only one at least partially uses PCA as statistically-based method, combined with experts opinions.

Regarding the issue of aggregation, it is argued (Ebert &Welsch, 2004) that aggregation procedures for variables should depend on the measurement scales, where distinction between interval scales and ratio scales was made. They pointed out that aggregation based on an arithmetic mean is not an appropriate method for ratio-scaled variables. However, all indices listed in this paper have ratio-scaled variables that are aggregated based on arithmetic mean, with the exception of SSI which uses geometric mean for aggregation of its variables.

3. The Analysis

In this paper, a new approach based on the statistical I-distance methodology is proposed with the purpose of creating a new metrics of sustainable development which has the potential to solve some of the above mentioned issues and challenges related to the subjective and arbitrative nature of different methods applied in the area of normalization, weighting and aggregation. The proposed I-distance methodology was originally developed by Ivanovic (Ivanović, 1973, 1977) and has been recently significantly advanced (Dobrota et al., 2015a,b, 2016; Isljamovic et al., 2015; Jeremić et al., 2011, 2013, 2014; Jovanović-Milenković et al., 2015; Maričić& Kostić-Stanković, 2016; Marković et al., 2015; Radojičić et al., 2012; Savić et al., 2016).

In order to illustrate the applicability of the I-distance methodology and to propose a potential measurement framework for constructing a single synthesized composite indicator of sustainable development, the proposed methodology was applied on a set of all European countries (excluding microstates) listed in Table 2. The set of indicators from Table 3 was selected from the World Bank list of World Development Indicators (WDI) (WB, 2015), based on two key selection criteria: (1) relevancy for any specific dimension of sustainable development (economic, environmental and social) and (2) availability of requested data for the selected European countries.

The raw data for all variables for the year 2010 were obtained from the WDI database (WB, 2015). The year 2010 was selected as the most recent year for which the share of missing data was not higher than 5% for all countries and variables. Values for missing data in the analyzed dataset were calculated and imputed based on a multiple imputation statistical method which was applied by the use of SPSS software with a linear regression model for scale variables. The SPSS multiple imputation program uses a Markov Chain Monte Carlo (MCMC) algorithm, known also as fully conditional specification (FCS) or chained equations imputation.

In order to avoid the problem of a negative coefficient of partial correlation which can occur in cases where is not possible to achieve the same direction of all variables in all sets, the measure of the square I-distance (I^2-distance) was used instead of regular I-distance measure. The I^2-distance ranking method was first applied separately for each of the three groups of basic indicators (economic, environmental and social indicators) with the intention to define the separate ranking of countries in terms of economic, environmental and social sustainability dimensions. Then the I^2-distance ranking method was applied again on the previously calculated I^2-distance values per dimensions in order to define the final ranking of countries referred to comprehensive understanding of sustainable development. The achieved results and ranks in four categories are given in Table 2.This data set was further examined by use of the Pearson correlation test in order to determine a correlation coefficient of each indicator with the I^2-distance values of its economic (I2_Eco), environmental (I2_Env) and social dimensions (I2_Soc) and with the final I^2-distance value for all three dimensions together (I2_SD). The obtained results are incorporated into the graphical presentation given in Figure 1, which provides a better insight into the inner dynamics of compounding dimensions and its most significant indicators, while detailed results for all indicators are provided in Table 3.

Table 2. List of European countries with I²-distance values and ranking per dimensions and for overall sustainable development

Country	I2_SD		I2_Eco		I2_Env		I2_Soc	
	Value	Rank	Value	Rank	Value	Rank	Value	Rank
Iceland	29.40	1	7.90	36	58.45	1	40.74	3
Norway	22.09	2	25.07	8	9.08	17	53.78	1
Switzerland	21.31	3	30.58	7	34.04	4	38.46	5
Sweden	17.75	4	35.85	5	17.41	7	35.75	6
Germany	17.47	5	39.77	2	16.11	8	30.01	10
Luxembourg	17.11	6	31.51	6	11.98	10	40.88	2
Moldova	17.09	7	36.40	4	34.61	3	13.31	30
Belarus	14.71	8	41.72	1	1.47	39	20.89	19
Cyprus	13.40	9	9.15	34	42.05	2	25.32	14
Turkey	12.26	10	38.27	3	5.52	30	18.82	21
Austria	11.65	11	19.24	14	9.11	15	40.17	4
The Netherlands	8.36	12	17.89	19	8.21	20	34.15	7
Finland	8.05	13	20.58	13	4.36	33	32.06	8
Denmark	7.79	14	18.35	18	10.79	11	31.80	9
France	7.46	15	24.49	10	15.97	9	21.92	16
Russian Federation	7.08	16	24.35	11	5.40	31	25.33	13
Albania	6.91	17	17.81	20	27.65	5	14.19	28
The United Kingdom	5.27	18	24.53	9	8.86	18	15.15	25
Italy	4.97	19	18.41	17	8.73	19	23.79	15
Spain	4.76	20	11.87	28	10.36	12	27.51	11
Belgium	4.35	21	19.00	15	7.39	23	20.97	18
Slovenia	4.20	22	12.19	26	17.61	6	21.09	17
The Czech Republic	4.16	23	12.00	27	3.63	34	27.00	12
Ukraine	3.60	24	22.23	12	2.16	38	9.09	37
Poland	2.80	25	18.74	16	7.01	24	10.74	32
Portugal	2.45	26	10.96	30	7.62	22	20.38	20
Macedonia, FYR	2.31	27	14.28	21	2.80	36	17.64	23
Ireland	2.15	28	13.02	24	9.17	13	15.89	24
Montenegro	1.88	29	13.01	25	9.09	16	13.75	29
The Slovak Republic	1.81	30	14.02	22	9.16	14	10.51	33
Bulgaria	1.46	31	10.05	32	8.05	21	15.13	26
Estonia	1.26	32	13.27	23	2.87	35	9.90	35
Lithuania	1.21	33	9.74	33	5.59	29	14.81	27
Bosnia and Herzegovina	1.17	34	5.73	38	2.75	37	18.06	22
Latvia	0.96	35	10.99	29	6.85	25	6.74	40
Hungary	0.92	36	10.27	31	6.34	28	10.39	34
Greece	0.46	37	1.16	40	6.48	27	12.91	31
Serbia	0.45	38	8.12	35	1.32	40	9.49	36
Romania	0.41	39	6.44	37	6.71	26	7.52	38
Croatia	0.18	40	4.83	39	4.79	32	7.34	39

From the perspective of the economic dimension of sustainability, there are 10 indicators that are statistically significant, out of which 7 indicators of correlations are significant at the 0.01 level (Table 3). As expected, the most significant indicators come from the economic area: GNI growth ($r = 0.828$, $p < 0.01$), GDP growth ($r = 0.795$, $p < 0.01$), HFCE per capita growth ($r = 0.687$, $p < 0.01$), ANS excluding ($r = 0.651$, $p < 0.01$) and including particulate emission damage ($r = 0.644$, $p < 0.01$), GNI ($r = 0.389$, $p < 0.05$) and GDP ($r = 0.386$, $p < 0.05$). There are also 3 social indicators with significant correlations: Poverty headcount ratio ($r = 0.533$, $p < 0.01$), Public spending on education ($r = 0.500$, $p < 0.01$) and Unemployment ($r = 0.388$, $p < 0.05$).

Table 3. Selected indicators per dimensions, incl. correlations between indicators and I^2-distance values for the related dimension and overall sustainable development

Dimension	Indicators	I2_SD	I2_Eco	I2_Env	I2_Soc
Economic	GDP (Gross domestic product) (constant 2005 US$)	0.143	0.386*	-0.011	0.17
	GDP growth (annual %)	0.234	0.795**	-0.116	0.032
	GDP per capita (constant 2005 US$)	0.611**	0.281	0.311	0.810**
	GNI (Gross National Income) (constant 2005 US$)	0.148	0.389*	-0.006	0.171
	GNI growth (annual %)	0.442**	0.828**	0.105	0.243
	GNI per capita (constant 2005 US$)	0.604**	0.292	0.302	0.822**
	ANS (Adjusted net savings), excluding particulate emission damage (% of GNI)	0.328*	0.651**	-0.077	0.31
	ANS (Adjusted net savings), including particulate emission damage (% of GNI)	0.357*	0.644**	-0.042	0.352*
	HFCE (Household final consumption expenditure) per capita (constant 2005 US$)	0.595**	0.242	0.364*	0.781**
	HFCE (Household final consumption expenditure) per capita growth (annual %)	0.341*	0.687**	0.032	0.075
Enviro-nmental	CO_2 emissions (kg per 2005 US$ of GDP)	0.610**	0.228	0.521**	0.665**
	CO_2 intensity (kg per kg of oil equivalent energy use)	0.603**	0.006	0.696**	0.363*
	CO_2 emissions (metric tons per capita)	0.059	0.123	0.366*	-0.323*
	Alternative and nuclear energy (% of total energy use)	0.480**	-0.009	0.582**	0.376*
	Fossil fuel energy consumption (% of total)	0.559**	-0.036	0.641**	0.390*
	GDP per unit of energy use (constant 2011 PPP $ per kg of oil equivalent)	-0.025	0.008	0.041	0.139
	Terrestrial and marine protected areas (% of total territorial area)	0.006	0.027	0.05	0.177
	Total natural resources rents (% of GDP)	0.187	-0.084	0.453**	0.116
	Population density (people per sq. km of land area)	0.498**	-0.095	0.525**	0.337*
	Fertilizer consumption (kilograms per hectare of arable land)	-0.034	0.106	0.055	-0.228
Social	Unemployment, total (% of total labour force) (modelled ILO estimate)	0.638**	0.388*	0.286	0.751**
	Intentional homicides (per 100,000 people)	0.451**	-0.069	0.423**	0.649**
	Poverty headcount ratio at national poverty line (% of population)	0.633**	0.533**	0.201	0.775**
	Proportion of seats held by women in national parliaments (%)	0.484**	0.225	0.159	0.649**
	Primary completion rate, total (% of relevant age group)	-0.189	-0.138	-0.165	-0.073
	Research and development expenditure (% of GDP)	0.461**	0.262	0.229	0.649**
	Public spending on education, total (% of GDP)	0.600**	0.500**	0.355*	0.476**
	Life expectancy at birth, total (years)	0.318*	-0.041	0.292	0.601**
	Mortality rate, under-5 (per 1,000 live births)	0.497**	0.054	0.314*	0.712**
	Health expenditure per capita, PPP (constant 2005 international $)	0.515**	0.271	0.199	0.796**

** Correlation is significant at the 0.05 level (2-tailed), $p < 0.05$*
*** Correlation is significant at the 0.01 level (2-tailed), $p < 0.01$*

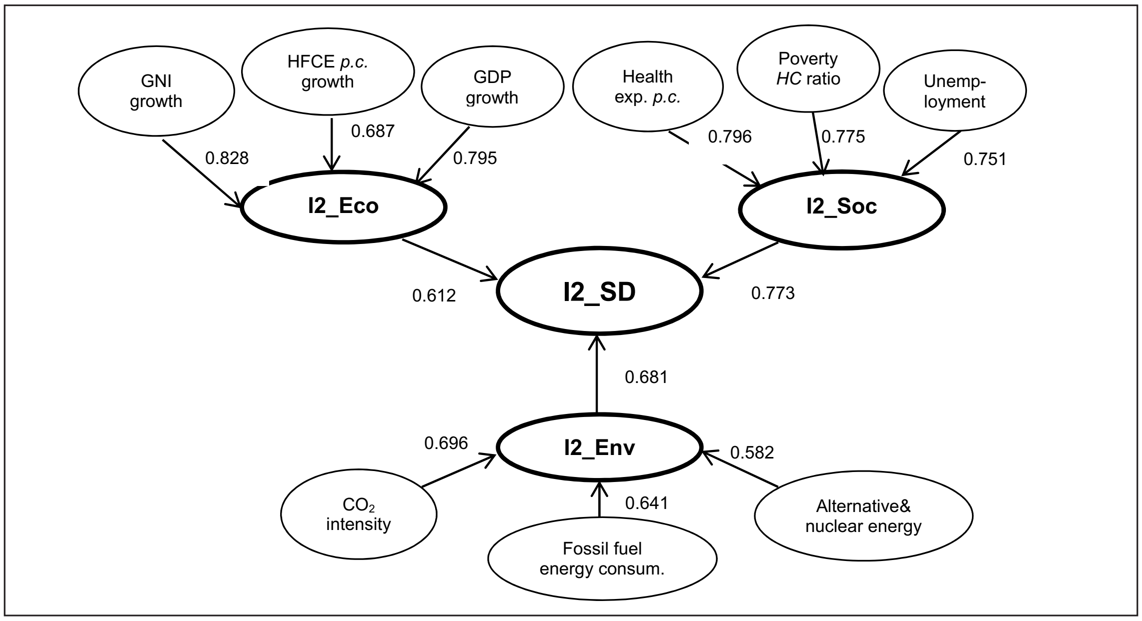

Figure 1. Inner dynamics of compounding dimensions and its most significant indicators

These results indicate that the most important factors of the economic dimension of sustainability are rates of growth (GNI, GDP and HFCE) and rates of savings (ANS indicators), rather than absolute total and per capita economic values. Consequently, the highest ranked countries in terms of economic dimension in Table 2 are Belarus, Germany and Turkey, which had some of the highest values of those indicators in 2010, as opposed to the lowest ranked countries like Greece, Croatia and Bosnia and Herzegovina, which had among the lowest values.

Regarding the environmental dimension of sustainability, there are 11 statistically significant indicators, including 7 indicators with significance at the 0.01 level (Table 3). The most important environmental indicators are: CO_2 intensity ($r = 0.696$, $p < 0.01$), Fossil fuel energy consumption ($r = 0.641$, $p < 0.01$), Alternative and nuclear energy ($r = 0.582$, $p < 0.01$), Population density ($r = 0.525$, $p < 0.01$), CO_2 emissions per unit of GDP ($r = 0.521$, $p < 0.01$), Total natural resources rents ($r = 0.453$, $p < 0.01$) and CO_2 emissions per capita ($r = 0.366$, $p < 0.05$). Interestingly, a statistically significant correlation exists with only one economic indicator – HFCE per capita ($r = 0.364$, $p < 0.05$), and three social indicators: Intentional homicides ($r = 0.423$, $p < 0.01$), Public spending on education ($r = 0.355$, $p < 0.05$) and Mortality rate ($r = 0.314$, $p < 0.05$), implying that secured basic economic and social qualities could be an important factor of effective focus on achieving environmental sustainability. Detection of the fact that as many as five indicators are related to greenhouse gases (GHG) emissions supports numerous opinions about the importance of solving GHG and climate change challenges in securing environmental sustainability (Bernstein, 2008; Stern, 2009). It also explains why the highest ranked countries in terms of the environmental dimension are Iceland, Cyprus, Moldova and Switzerland, as they have highest values on these indicators, in contrast to Serbia, Belarus and Ukraine at the bottom of the rank list (Table 2).

The social dimension has the highest number of 19 statistically significant indicators, including 13 indicators with significance at the 0.01 level (Table 3). Among these 13 indicators, only 3 of them are economic indicators. However, they are on the 1st, 2nd and 4th places by statistical significance: GNI per capita ($r = 0.822$, $p < 0.01$), GDP per capita ($r = 0.810$, $p < 0.01$) and HFCE per capita ($r = 0.781$, $p < 0.01$). This demonstrates the importance of the average level of national wealth per capita as a basis for achieving higher levels of social sustainability. Regarding social indicators, only one is not statistically significant (Primary completion rate) and all 9 others are at 0.01 level of statistical significance, which illustrates the importance of various social aspects (healthcare, education, politics, poverty and crime) on social sustainability. However, as the most significant social indicators are Health expenditure per capita ($r = 0.796$, $p < 0.01$), Unemployment ($r = 0.751$, $p < 0.01$), Poverty headcount ratio ($r = 0.775$, $p < 0.01$) and Mortality rate ($r = 0.712$, $p < 0.01$), healthcare and basic economic existence could be considered as more important areas of social policy. There are also 6 environmental indicators that are statistically significant, out of which 5 are related to GHG emissions, pointing out that those countries that are striving to reduce their GHG emissions are also most advanced in terms of the social dimension of sustainability. As a result, the top ranked countries as to social sustainability are Norway, Luxemburg and Iceland, which all have higher values for the mentioned indicators, as opposed to Latvia, Croatia and Romania, which are at the bottom of the list (Table 2).

Finally, considering the comprehensive perspective of sustainable development, 21 statistically significant indicators are noted (out of which 17 are with significance at the 0.01 level), including 7 economical, 5 environmental and 9 social indicators (Table 3). Interestingly, almost all social indicators are statistically significant (except Primary completion rate), including the 1st and 2nd ranked Unemployment ($r = 0.638$, $p < 0.01$) and Poverty headcount ratio ($r = 0.633$, $p < 0.01$) as well as Public spending on education (7th, $r = 0.600$, $p < 0.01$), which is the only indicator assessed as statistically significant for all 3 dimensions of sustainable development. This could indicate the crucial importance of various social aspects for understanding and the perception of overall sustainable development, especially for those related to the level of satisfaction of basic socio-economic needs. Among economic indicators, GDP per capita (3rd, $r = 0.611$, $p < 0.01$), GNI per capita (5th, $r = 0.604$, $p < 0.01$) and HFCE per capita (8th, $r = 0.595$, $p < 0.01$) can be identified as most important, denoting a significant correlation of average wealth of citizens to overall result. Environmental indicators with the highest level of statistical significance are CO_2 emissions per unit of GDP (4th, $r = 0.610$, $p < 0.01$), CO_2 intensity (6th, $r = 0.603$, $p < 0.01$) and Fossil fuel energy consumption (9th, $r = 0.559$, $p < 0.01$), which reveals the fundamental importance of GHG emissions for the achieved level of sustainable development.

Considering all 3 dimensions of sustainable development together (Table 2), the highest ranked countries are Iceland, Norway, Switzerland, Sweden and Germany, which all have very low levels of unemployment and poverty, significant spending on education, high levels of national wealth per capita and obvious national focus on the reduction of GHG emissions. The main contributors to Iceland's first position are outstanding environmental performances and very low levels of GHG emissions. On the other hand, the lowest ranked countries such as Croatia, Romania, Serbia, and Greece are characterized by struggling with poverty and unemployment issues, relatively low public expenditure for education, low rates of economic growth and weak average wealth measures, followed by poor environmental performances. As all these bottom-ranked countries come from South East Europe, this can be considered as a warning signal that this region requires special attention and support in order to overcome actual issues and challenges.

The Pearson correlation test was also applied to determine a correlation coefficient between all four calculated I^2-distance values, with the results given in Table 4 that show correlation coefficients between all four calculated I^2-distance values, demonstrating that a statistically significant correlation at the 0.01 level exists between the values for overall sustainable development, on the one hand, and values for each of 3 dimensions, on the other hand. It shows that there is no statistically significant correlation between economic and environmental dimension I^2-distance values, implying that the level of economic development and performances in principle do not determine the level of environmental sustainability and vice versa.

Table 4. The correlation between different calculated I^2-distance values

	I2_SD	I2_Eco	I2_Env	I2_Soc
I2_SD	*	0.612**	0.681**	0.773**
I2_Eco		*	0.091	0.381*
I2_Env			*	0.349*
I2_Soc				*

** Correlation is significant at the 0.05 level (2-tailed), $p < 0.05$*
*** Correlation is significant at the 0.01 level (2-tailed), $p < 0.01$*

The relatively low statistically significant correlation at the 0.05 level between I^2-distance values of social and economic as well as social and environmental dimensions prove the validity of the proposed measurement concept as it confirms that the measured dimensions represent statistically separated entities, but also discovers the specific influence of different social qualities for the achievement of higher levels of both economic and environmental performances.

For the purpose of comparison of the proposed I^2-distance-based ranking with some of the actual approaches, Sustainable Society Index (SSI) is chosen as it is the only one among discussed approaches that attempts to integrally comprehend all three dimensions of sustainable development. In general, SSI aims to describe societal progress along three dimensions of well-being (human, environmental and economic), based on the assessment of 8 policy categories and 21 indicators, that is calculated for 151 countries accounting for 99% of the world population (van de Kerk&Manuel, 2012). The SSI ranking results for year 2012 are considered to be most relevant, as they are based on data sources mostly from the year 2010, although general data source range is 2005-2011. Global ranking is transformed to ranking of European countries by simple excluding non-European countries from the list. The variables considered in the SSI are normalized using the min-max method in 1-10 scale (10 = most sustainable score) and aggregated into categories by simple geometric mean, with equal weights assigned to all indicators. Three SSI Wellbeing dimensions are calculated as the geometric mean of the related underlying categories. The overall SSI index is calculated as the geometric mean of all eight categories.

The comparison of ranking results of these two approaches for European countries is given in Table 5. The examination was based on the Spearman's rank correlation coefficient method and the obtained results showed that there is no correlation between the two ranking lists (Rho=0.193; p=0.234). Although there is one country with the same position in both rankings (the United Kingdom) and some of the higest ranked countries (Switzerland, Sweden, Norway) have similar positions in terms of both approaches, a large numbers of countries show huge inconsistencies between their ranks. Clearly, more attention needs to be focused on the most drastic inconsistencies between the sustainability ranks obtained by employing the I^2-distance method and the SSI approach. Generally, there are 18 countries whose rankings fluctuate by more than ten places. In particular, the greatest ranking difference is noted for Iceland (1st position on I^2-distance list vs. 34th on SSI list) and Latvia (35th vs. 4th position).

In the I^2-distance-based assessment (Table 2), Iceland demonstrated superior performances in environmental (1st place) and social (3rd place) dimensions, but quite a poor rank in economical dimension (36th place), which can be seen as in contrast with the 1st position on the overall SD ranking. However, it should be pointed out that different economic indicators showed to be statistically significant for the calculation of I^2-distance values for the economical dimension only (I2_Eco) and of I^2-distance values for the overall sustainable development (I2_SD). For the ranking on the level of economical dimension alone, the most influencing indicators appeared to be GNI growth, GDP growth, HFCE per capita growth, ANS excluding and ANS including particulate emission damage, where the values of Iceland were not impressive (39th, 34th, 26th , 38th and 38th position per indicator respectively). On the other hand, in terms of per capita values of GDP, GNI and HFCE, Iceland is among the top ranked countries (4th, 6th and 4th positions per indicator, respectively). As these indicators of average wealth of citizens are denoted as statistically most significant economic indicators for overall I2_SD results, and having in mind that Iceland has very low levels of unemployment and poverty, significant spending on education, outstanding environmental performances and very low levels of GHG emissions, this can be considered as a valid explanation of its 1st position on the overall SD ranking list.

Regarding the SSI ranking, Iceland is the 1st positioned country in terms of Human Wellbeing, mid-positioned (16th) regarding Environmental Wellbeing, but with the lowest, 40th ranking position in terms of Economic Wellbeing, resulting with the low overall SSI ranking of Iceland at the 34th place. Here it should be pointed out that the SSI method uses a small number of indicators for each category, all with equal weights within category and therefore with significant influence on the related results. It implies concerns about the selection of indicators and their appropriateness to represent a valid measure for given categories, as well as the usage of predefined equal weights which do not provide for the ability for any correction of their influence based on its statistical significance. This is contrary to the I^2-distance approach, which attempts to utilize statistical significances of indicators as a tool for objective statistically-based weighting of indicators, which also allows inclusion of a larger number of indicators without data normalization, where their weights would implicitly make their selection. So in the case of Iceland, low performances in Organic Farming, Genuine Savings and Public Debt indicators outweigh good results of GDP and Employment indicators, despite potential doubts if these indicators could be considered as equally relevant for the assessment of economical dimension.

Table 5. A comparison of the I^2-distance and SSI ranking of European countries

Country	I2_rank	SSI rank	Difference	Country	I2_Rank	SSI rank	Difference
Iceland	1	34	33	Belgium	21	31	10
Norway	2	5	3	Slovenia	22	6	16
Switzerland	3	1	2	The Czech Republic	23	13	10
Sweden	4	2	2	Ukraine	24	36	12
Germany	5	14	9	Poland	25	16	9
Luxembourg	6	17	11	Portugal	26	24	2
Moldova	7	30	23	Macedonia FYR	27	28	1
Belarus	8	29	21	Ireland	28	39	11
Cyprus	9	33	24	Montenegro	29	12	17
Turkey	10	32	22	The Slovak Republic	30	8	22
Austria	11	3	8	Bulgaria	31	25	6
The Netherlands	12	23	11	Estonia	32	27	5
Finland	13	7	6	Lithuania	33	11	22
Denmark	14	20	6	Bosnia and Herz.	34	40	6
France	15	21	6	Latvia	35	4	31
The Russian Fed.	16	37	21	Hungary	36	22	14
Albania	17	9	8	Greece	37	38	1
The United Kingdom	18	18	0	Serbia	38	35	3
Italy	19	10	9	Romania	39	19	20
Spain	20	26	6	Croatia	40	15	25

Similarities can be noted in the case of Latvia, which has quite a low, 35th position in I^2-distance based ranking (followed by not a very impressive positioning in terms of all dimensions: economic 29th, environmental 25th and social 40th), which can be explained with Latvian poor performances for statistically significant indicators of national wealth (GDP and GNI) per capita, unemployment, poverty, spending on education, CO_2 emissions per unit of GDP and CO_2 intensity. At the same time, in terms of the SSI approach, Latvia is highly ranked with 4th overall position, complemented with appropriate positions for environmental (2nd), economic (12th) and human (32nd) wellbeing dimensions, as it has better results for equally weighted basic indicators relevant for the SSI calculation.

The obvious discrepancy between results can be explained with essentially different approach to weighting and aggregation of indicators into related composites. After a normalization of data based on min-max method, the SSI approach considers that a small number of equally weighted indicators determine results for each category, then a small number of equally weighted categories determine results for each dimension, which are then finally aggregated as equally weighted to the overall SSI rank. On the contrary, the I^2-distance approach tends to use raw data for extensive range of indicators for direct calculation without intermediate steps, with weighting based on the assessed statistical significance of each considered indicator.

Conclusion

Sustainable development is one of the most important concerns of modern societies. Hence a comprehensive assessment of sustainability has become crucial to measure progress, identify areas to be addressed and evaluate policy implications. Due to the rising importance and popularity of sustainable development, a large number of researchers and institutions developed various concepts and methodologies for sustainability measuring. However, many sustainability indicators still lack a consistent definition of sustainability, have perspectives that are too short-termed, and are unable to model the complex dynamics of sustainability phenomena (Somogyi, 2016). At the same time, composite sustainability indicators shape world views and embody broader visions of society through not only intended use but also a multiple unanticipated influence (Lehtonen et al., 2016).

In this paper, the I-distance methodology has been proposed as a framework and foundation for assessing sustainable development which is providing a new perspective on the measurement of sustainable development and addressing actual challenges related to the subjective and arbitrative nature of usually applied methods for normalization, weighting and aggregation. The I-distance methodology is able to synthesize many different indicators into a single numerical value which represents the basis for ranking observed entities. An applied twofold I-distance approach provided a deeper insight into not only domain dynamics, but also to total score dynamic (Maričić& Kostić-Stanković, 2016). It can support policymakers to identify key indicators and focus the policy areas where appropriate policy measures would have the most efficient influence on the overall positioning of the country (Savić et al., 2016).

The initial hypothesis was tested and proven by the application of the proposed methodological framework on the set of statistical data from the World Development Indicator database (WB, 2015) for a set of all European countries (excluding microstates). A comparative analysis with the SSI approach showed the obvious discrepancy between results that could be explained with essentially different approach to normalization, weighting and aggregation of indicators into related composites. Contrary to the SSI approach, the proposed I^2-distance approach used raw data for an extensive range of indicators for direct calculation without intermediate steps, with weighting based on the assessed statistical significance of each considered indicator. In this way, the objectiveness, reliability and accuracy of sustainability metrics has been improved.

As sustainability metrics are used as a quantitative information foundation for appropriate policy making processes, this proposal has important policy implications related to the improvement of objectiveness, reliability and accuracy of sustainability metrics used on all policy levels. The proposed approach is able to identify priority areas specific for each country so that policymakers can focus their attention on the areas where attention and action would have the most significant impact on the overall relative position of the country. It may be noted that countries from South Eastern Europe are predominantly among the lower ranked countries, including Serbia on the unenviable 38^{th} position. This is due to a very poor performance recorded in the indicators that were rated the most important. At the same time, it points out the areas in which there is the greatest potential for improvement and development that can have a most significant impact on the overall performances and relative position of Serbia compared to other countries. These findings direct a special policy attention towards empowerment of economic growth (measured by GNI, GDP and HFCE), focus on poverty, unemployment and education policies and reductions in CO_2 intensity and fossil fuel energy consumption.

The proposed approach provides a solid basis for a deeper understanding of differences between countries as well as insight into a relative statistical importance of the selected indicators, which may represent an effective and transparent means of identification of their respective significance in the overall aggregation calculation. Therefore, it is concluded that the proposed approach could provide a new perspective and useful contribution to overall scientific efforts invested in this area, as well as a complement to numerous emerging approaches and studies related to the advancement of methodology and practice of sustainable development measurement.

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