Harmonic development index: a novel approach to measure environmental, social, and economic development

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Gross domestic product (GDP) is the most commonly used approach to measure a country's economic performance. The shortcomings of GDP in capturing overall well-being, economic development and sustainable growth are among the most debated issues in economic research. This study aimed to develop a method that captures broader aspects of socio-economic prosperity. We compiled a panel dataset of yearly measurements with 32 social and economic indicators from 87 countries between 2005 and 2019 from publicly available sources. Linear interpolation, extrapolation, and random forest imputation methods were used to substitute missing values. Logarithmic transformation of some selected variables, followed by the standardisation of all variables, was applied to ease the usability and comparability of the variables. Exploratory factor analysis with maximum likelihood estimation was used to construct six domain-specific subindices, or domains in general (variance explained by factors > 50%). Variances explained by the factors were used as weights to create the composite indicator.
Interpolation, extrapolation, and imputation procedures were used to complete 20.7% of the dataset. Six domains were generated by factor analysis. Two domains were found to have one dominant factor each (variance explained by the factor > 50%, $p < 0.05$). Three domains showed two dominant factors each (cumulative variance explained by the factors > 50%, $p < 0.05$). One domain had a single dominant factor that did not reach the

Regional Statistics, Vol. 15. No. 1. 2025
Online first: György–Purczeld–Mazzag–Bató–Vékás 1–16; DOI: 10.15196/RS150102

variance explained cut-off value (36.8%), although the second factor was not significant (p = 0.554); therefore, the first factor was considered the only dominant factor. We found that domains including variables related to the real economy (25.7%) and social equality and sustainability (19.0%) had the highest weights in the composite indicator.

This study developed a novel method to capture important aspects of social and economic prosperity in 87 countries. The harmonic development index allows intercountry and intertemporal comparisons across six domains related to economic development, work- and knowledge-based society, and financial, environmental, social, and demographic sustainability. The composite indicator serves as a tool to rank countries and track changes in the rankings, providing useful information for policymakers and researchers.

Keywords:
sustainable development,
GDP,
factor analysis,
composite indicator

Online first publication date: 14 December 2024

Introduction

Several studies argued that gross domestic product (GDP) is an imperfect measure of countries' economic progress and does not consider important aspects of our lives (Jones–Klenow 2016, [8]). The areas not captured by GDP are grouped around three well-defined domains: well-being, economic welfare, and sustainability (Bleys 2012). The shortcomings of GDP are well known, and several indices have been developed to address its limitations. However, quantifying the unrepresented areas of GDP does not have a straightforward approach. The concept of well-being inherently encompasses various dimensions including financial and economic aspects (Wilmarth 2021). Economic welfare of a country does not necessarily increase well-being of its people; thus, GDP is not sufficient to indicate economic welfare. In this context, sustainability refers to the future sustainability of current levels of well-being and economic welfare and the physical limits to growth (Bleys 2012, Terzi et al. 2021). Over the past decades, the number of articles on composite indicators (CI) used in various research has increased exponentially (Greco et al. 2019, Mazziotta–Pareto 2020, Müller-Frączek 2019). In general, CIs are often used to evaluate and compare

the performance of countries in different dimensions over a longer period of time, including Central and Eastern Europe (Hudrlíková et al. 2013, Kocziszky–Szendi 2023). CIs simplify large, multidimensional datasets while retaining the majority of the underlying information base (Joint Research Centre-European Commission 2008). The development of CIs usually involves three steps: normalisation, weighting, and aggregation (El Gibari et al. 2019). Weighting methods are typically classified into three categories: equal weighting, data-based methods, and participatory based methods (El Gibari et al. 2019). Aggregation methods are commonly divided into compensatory and non-compensatory methods (Asadzadeh et al. 2017). Although the methodological framework for the development of CIs is widely accepted, it also allows for the inclusion of so-called craftsmanship to achieve the intended purpose (El Gibari et al. 2019, Joint Research Centre-European Commission 2008, Treviño-Cantú 2024). The current study is aimed at developing a composite indicator that captures important aspects of environmental, social, and economic prosperity and allows intercountry and intertemporal comparisons.

Literature review

Nordhaus–Tobin (1971) made one of the earliest attempts to better represent economic welfare with the development of the measure of economic welfare. In 2007, the European Commission held a conference on 'beyond GDP' that focused on the most appropriate indices to measure progress (Bleys 2012). Thus far, several indices have been developed, including the human development index (HDI), first published in 1990 by Anand–Sen (1994), the inclusive development index (IDI) by the World Economic Forum (Corrigan 2017), and the better life index (BLI) developed by the Organisation for Economic Co-operation and Development (Durand 2015). The limitations of HDI are related to the choice of variables, weighting, and aggregation methods, while the shortcomings of the IDI are related to data availability (Dörffel–Schuhmann 2022, [5]). The BLI indicator is characterised by the flexible weighting and aggregation approach (Koronakos et al. 2020). Several other indices have been developed such as the SDG index (Schmidt-Traub et al. 2017), the inequality-adjusted HDI (UNDP 2024), and the social progress index (2024).

Methods

The following areas were considered important for developing the composite indicator: *economic development*, *financial sustainability*, *environmental sustainability*, *work- and knowledge-based society*, *social sustainability*, and *demographic sustainability*.

Statistical analysis

We compiled a panel dataset containing annual measurements of 32 social and economic indicators across 87 countries between 2005 and 2019 from publicly available databases (see Appendix Tables A1 and A2). First, we applied linear interpolations and extrapolations to substitute the missing values. Second, we used random forest-based imputations where missing values were still detected after the interpolation and extrapolation step. We used logarithmic transformation for the following variables because of their skewness and/or monetary nature: real wage, median income, GDP per capita, CO_2 emissions, air pollution, fertility rate (adjusted), P90P10, R&D expenditure, unemployment ratio, labour productivity, and water stress (see Appendix Table A1). Similar to previous studies, all the 32 variables were standardised through calculation of the mean and standard deviation over the period examined (Corrigan 2017, Wendling et al. 2020). We decided to use the data-based weighting method and a compensatory aggregation technique (El Gibari et al. 2019). Kolmogorov-Smirnov test was used to test normality.

The domains were constructed using six separate exploratory factor analyses with maximum likelihood estimation and varimax rotation. Although various benchmark values are acceptable for the variance explained, we considered > 50% as the cut-off value (Hair 2009, Williams et al. 2010). For *financial sustainability*, *social sustainability*, and *work- and knowledge-based society* domains, we multiplied the factors by minus one to improve their interpretation. Factor scores were generated for all factors in the six domains for 87 countries from 2005 to 2019. In domains with more than one dominant factor, we used the variances explained by the factors as weights to compute a single weighted average factor for each domain. In the aggregation phase, the variance explained by each factor as a proportion of the total variance was used as a weight. The composite indicator was calculated as the weighted sum of all domains. In the last step, the composite indicator and the domains were rescaled between 0 and 100. We performed the analysis using R statistical software (v4.1.2 Vienna, Austria). The *tidyverse* package was applied for interpolations and extrapolations, the *mice* package for imputation and the *stats* package for exploratory factor analysis ([6], van Buuren–Groothuis-Oudshoorn 2011, Wickham et al. 2019).

Results

Descriptive statistics

Data for 32 variables from 87 countries between 2005 and 2019 were compiled, with 20.7% missing values. Based on the database with no missing values (i.e. after linear interpolation, extrapolation, and random forest imputation), the descriptive statistics of the 32 variables were calculated and are presented in Table 1.

Table 1

Descriptive statistics of the 32 variables

Variables	Mean	Standard deviation	Median	Minimum value	Maximum value	Skewness	Normality test*
Absolute poverty rate	4.56	9.99	0.90	0.00	69.10	3.77	$p < 0.001$
Account balance	−0.82	7.22	−1.30	−43.77	38.79	0.16	$p < 0.001$
Air pollution	1,735.19	1,676.97	1,221.90	67.71	8,698.88	1.50	$p < 0.001$
CO_2 emissions	0.25	0.15	0.22	0.04	0.90	1.40	$p < 0.001$
Domestic net migration	0.0011	0.0028	0.0001	−0.01	0.02	1.89	$p < 0.001$
Economic dependency ratio	1.68	0.53	1.56	0.82	3.98	1.68	$p < 0.001$
Employment	55.84	9.36	56.50	32.01	84.01	0.02	$p < 0.001$
Fertility rate (adjusted)	1.98	0.62	1.82	0.92	4.43	1.33	$p < 0.001$
Fossil fuel[a)]	0.82	0.17	0.85	0.17	1.00	−1.59	$p < 0.001$
GDP per capita	18,609.33	20,994.30	9,459.09	456.59	112,372.68	1.74	$p < 0.001$
GNI SD	0.03	0.01	0.02	0.01	0.07	0.60	$p < 0.001$
HALE	66.85	4.58	66.36	46.72	74.09	−1.16	$p < 0.001$
Income Gini	36.71	7.64	35.20	23.70	64.80	0.79	$p < 0.001$
Interest payments	8.35	7.25	6.48	0.01	47.47	1.93	$p < 0.001$
Internet usage	51.44	28.33	54.90	0.07	99.01	−0.22	$p < 0.001$
ISCED 3	56.16	23.16	60.55	6.76	93.45	−0.25	$p < 0.001$
Labour productivity	329.31	354.81	168.67	5.44	2,097.01	1.75	$p < 0.001$
Labour tax	20.29	12.11	18.60	0.00	54.00	0.51	$p < 0.001$
LPI score	2.97	0.68	2.86	1.53	4.44	0.36	$p < 0.001$
Median income	21.85	16.4	15.35	1.68	63.02	0.81	$p < 0.001$
Net savings	10.07	7.78	9.18	−14.78	38.66	0.30	$p < 0.001$
Nuclear energy[a)]	0.05	0.08	0.00	0.00	0.41	1.98	$p < 0.001$
Old-age dependency ratio	17.15	8.71	16.45	3.76	47.12	0.34	$p < 0.001$
P90P10	13.36	9.33	10.31	4.58	90.60	2.69	$p < 0.001$
Public debt	53.68	34.32	46.13	4.73	234.856	2.02	$p < 0.001$
R&D expenditure	1.04	1.01	0.67	0.03	4.94	1.31	$p < 0.001$
Real wage	35.47	23.11	31.79	1.82	129.03	0.89	$p < 0.001$
Renewables[a)]	0.13	0.15	0.08	0.001	0.83	2.28	$p < 0.001$
Unemployment ratio	8.26	5.20	7.19	0.65	37.25	2.20	$p < 0.001$
Water stress	27.14	30.31	15.56	0.20	137.92	1.53	$p < 0.001$
Wealth Gini	71.34	7.81	70.35	31.00	95.50	0.02	$p < 0.001$
Youth dependency ratio	35.68	15.87	30.00	17.66	102.71	1.67	$p < 0.001$

* Kolmogorov-Smirnov test, $p < 0.05$ was considered statistically significant.

a) Transformed for better interpretation.

Note: GDP = gross domestic product; GNI = gross national income; HALE = healthy life expectancy; ISCED = International Standard Classification of Education; LPI = logistics performance index; R&D = research and development; SD = standard deviation.

Factor analysis

From the exploratory factor analysis, we found that *economic development* and *demographic sustainability* domains each have one dominant factor (variance explained by the factor

> 50%, $p < 0.05$). *Financial sustainability*, *work- and knowledge-based society*, and *social sustainability* domains have two dominant factors (cumulative variance explained by the factors > 50%, $p < 0.05$). *Environmental sustainability* has one dominant factor that did not reach the variance explained cut-off value (36.8%), although the second factor was not significant ($p = 0.554$); therefore, the first factor was considered the only dominant factor (Table 2). Each variable was assigned to one of the domains (see Appendix Table A3).

Table 2

Results of exploratory factor analysis

Domain	Factor	p-value	Cumulative variance explained, %
Economic development	1	<0.001	84.6
Economic development	2	<0.05	89.3
Financial sustainability	1	<0.001	16.5
Financial sustainability	2	<0.001	29.9
Environmental sustainability	1	<0.001	36.8
Environmental sustainability	2	0.554	48.7
Work- and knowledge-based society	1	<0.001	30.5
Work- and knowledge-based society	2	<0.001	57.3
Social sustainability	1	<0.001	39.6
Social sustainability	2	<0.001	62.6
Demographic sustainability	1	<0.05	58.0

Note: $p < 0.05$ was considered statistically significant.

Considering that *economic development* and *demographic sustainability* domains each have one dominant factor, and the second factor of *environmental sustainability* was not statistically significant, factor weights were only generated for the first factors. For *financial sustainability, work- and knowledge-based society,* and *social sustainability* domains, factor weights were generated for both the first and second factors (Table 3).

Table 3

Factor weights of the domains

Domain	Factor	Factor weight
Economic development	1	1.00
Financial sustainability	1	0.50
Financial sustainability	2	0.50
Environmental sustainability	1	1.00
Work- and knowledge-based society	1	0.51
Work- and knowledge-based society	2	0.49
Social sustainability	1	0.55
Social sustainability	2	0.45
Demographic sustainability	1	1.00

We calculated the variance explained by each of the six factors as a proportion of the total variance to generate the weights of the domains to the composite indicator (Table 4). Figure 1 displays the result of the aggregation.

Table 4

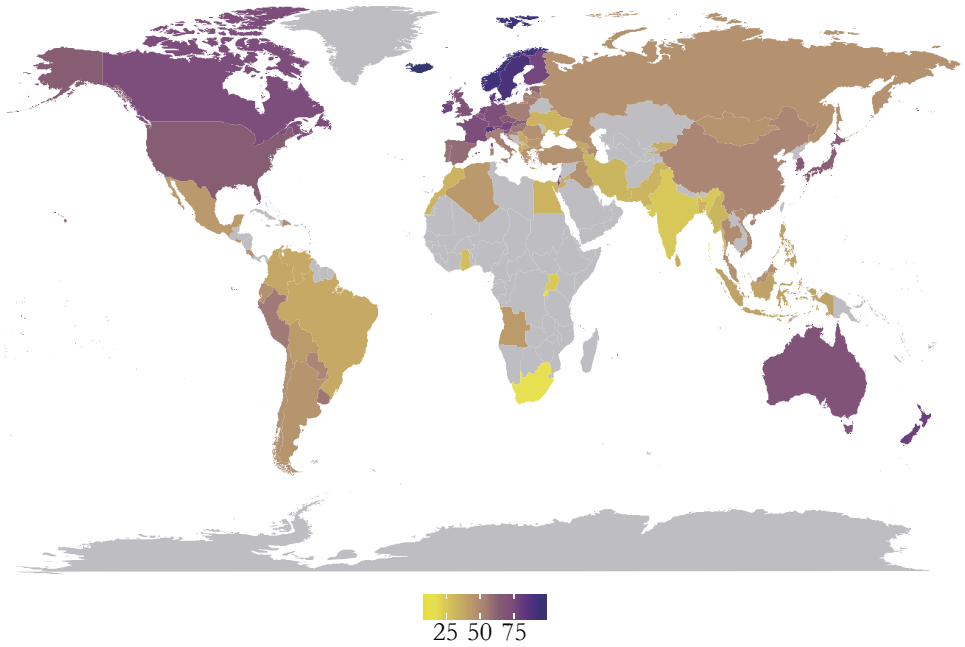
Weights of the domains in the composite indicator

Name	Weight in the composite indicator, %
Economic development	25.7
Social sustainability[a)]	19.0
Demographic sustainability	17.6
Work- and knowledge-based society[a)]	17.4
Environmental sustainability	11.2
Financial sustainability[a)]	9.1

a) Factors multiplied by minus one.

Figure 1

Harmonic development index values, 2019



Note: grey areas: data not available.

Conclusions

This study presented a new approach to create a composite indicator that factors in important components of sustainable economic development and addresses the shortcomings of GDP as a measure of countries' economic performance. We used

exploratory factor analysis to construct the domains. The weights for each domain were determined based on the factor analysis results to build the harmonic development index. Beyond comparisons of index values and overall rankings, the domain-specific subindices can help identify strengths and weaknesses, and potential areas of improvement for specific countries, such as demographic and environmental sustainability for the majority of developed countries. Moreover, examining average rates of change over longer periods can provide further insights into long-term dynamics. This analysis can highlight countries that consistently demonstrate overall or domain-specific improvement, in addition to pinpointing countries with the highest and lowest values. This study has a few limitations, including the narrow time span as the data of harmonic development index is available from 2005. Additionally, compared to the HDI (191 countries) and IDI (103 countries), the harmonic development index allows for comparisons of fewer (87) countries (Corrigan 2017, UNDP 2022). Furthermore, the constrained availability of data for the 32 variables limits the accuracy of the results.

In conclusion, the composite indicator is formulated to consider important aspects of economic development and it allows cross-country and intertemporal comparisons. The methodology enables the harmonic development index to be updated annually, fostering future studies on its application and testing.

Appendix

Table A1

List of 32 variables (in alphabetical order by short names)

Short name of the variable	Full name of the variable	Source
Absolute poverty rate	Poverty headcount ratio at $1.90 a day (2011 PPP) (% of population).	[9]
Account balance	Current account balance (% of GDP).	[9]
Air pollution*	Number of age-standardised disability-adjusted life-years lost per 100,000 persons (DALY rate) due to exposure to air pollution.	[3]
CO_2 emissions*	CO_2 emissions (kg per PPP $ of GDP).	[9]
Domestic net migration	Net migration to population ratio.	[9]
Economic dependency ratio	Employed to inactive and unemployed population ratio.	[9]
Employment	Employment to population ratio, 15+, total (%) (modelled ILO estimate).	([9]
Fertility rate (adjusted)*	Child poverty-adjusted fertility rate.	[9]
Fossil fuel	Per capita energy from fossil fuels.	[7]
GDP per capita*	GDP per capita (constant 2015 US$).	[9]
GNI SD	Standard deviation of GNI per capita by region (NUTS 2).	Smits–Permanyer 2019
HALE	Healthy life expectancy at birth (years).	[10]
Income Gini	Gini index measures the extent to which the distribution of income (or, in some cases, consumption expenditure) among individuals or households within an economy deviates from a perfectly equal distribution.	[9]
Interest payments	Interest payments (% of expense).	[9]
Internet usage	Individuals using the internet (% of population).	[9]
ISCED 3	Educational attainment, at least completed upper secondary, population 25+, total (%) (cumulative).	[9]
Labour productivity*	GDP per capita to employment ratio.	[9]
Labour tax	Labour tax and contributions (% of commercial profits).	[9]
LPI Score	The LPI is an interactive benchmarking tool created to help countries identify the challenges and opportunities they face in their performance on trade logistics and what they can do to improve their performance.	[9]
Median income*	Median daily per capita income or consumption expenditure (2011 PPP).	[9]
Net savings	Adjusted net savings, including particulate emission damage (% of GNI).	[9]
Nuclear energy	Per capita energy from nuclear energy.	[7]

(Table continues on the next page.)

(Continued.)

Short name of the variable	Full name of the variable	Source
Old-age dependency ratio	Age dependency ratio, old (% of working-age population).	[9]
P90P10*	The decile dispersion ratio presents the ratio of the average income of the richest 10% by that of the poorest 10%.	[9]
Public debt	Public debt as a share of GDP.	[4]
R&D expenditure*	Research and development expenditure (% of GDP).	[9]
Real wage*	Real GDP / Average annual hours worked by persons engaged.	Feenstra et al. 2015
Renewables	Per capita energy from renewable energy.	[7]
Unemployment ratio*	Unemployment, total (% of total labour force) (modelled ILO estimate).	[9]
Water stress*	Level of water stress: freshwater withdrawal as a proportion of available freshwater resources.	[2]
Wealth Gini	Gini index measures the extent to which the distribution of wealth among individuals or households within an economy deviates from a perfectly equal distribution.	[1]
Youth dependency ratio	Age dependency ratio, young (% of working-age population).	[9]

*Logarithmic transformed variables.

DALY = disability-adjusted life year; GDP = gross domestic product; GNI = gross national income; HALE = healthy life expectancy; ILO = International Labour Organization; ISCED = International Standard Classification of Education; LPI = logistics performance index; NUTS = Nomenclature of Territorial Units for Statistics; PPP = purchasing power parity; R&D = research and development; SD = standard deviation; US = United States.

Table A2

List of countries (in alphabetical order by country)

Country	Development level (based on IMF [2018])
Albania	Emerging and developing
Algeria	Emerging and developing
Angola	Emerging and developing
Argentina	Emerging and developing
Armenia	Emerging and developing
Australia	Advanced economies
Austria	Advanced economies
Azerbaijan	Emerging and developing
Bangladesh	Emerging and developing
Belgium	Advanced economies
Bolivia	Emerging and developing
Brazil	Emerging and developing
Bulgaria	Emerging and developing
Canada	Advanced economies
Chile	Emerging and developing
China	Emerging and developing
Columbia	Emerging and developing
Costa Rica	Emerging and developing
Croatia	Emerging and developing
Cyprus	Advanced economies
Czech Republic	Advanced economies
Denmark	Advanced economies
Dominican Republic	Emerging and developing
Ecuador	Emerging and developing
Egypt	Emerging and developing
Estonia	Advanced economies
Finland	Advanced economies
France	Advanced economies
Georgia	Emerging and developing
Germany	Advanced economies
Ghana	Emerging and developing
Greece	Advanced economies
Hungary	Emerging and developing
Iceland	Advanced economies
India	Emerging and developing
Indonesia	Emerging and developing
Iran	Emerging and developing
Iraq	Emerging and developing
Ireland	Advanced economies
Israel	Advanced economies
Italy	Advanced economies
Japan	Advanced economies

(Table continues on the next page.)

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Country	Development level (based on IMF [2018])
Jordan	Emerging and developing
Kyrgyzstan	Emerging and developing
Latvia	Advanced economies
Lithuania	Advanced economies
Luxembourg	Advanced economies
Malaysia	Emerging and developing
Malta	Advanced economies
Mauritius	Emerging and developing
Mexico	Emerging and developing
Mongolia	Emerging and developing
Morocco	Emerging and developing
Myanmar	Emerging and developing
New Zealand	Advanced economies
North Macedonia	Emerging and developing
Norway	Advanced economies
Pakistan	Emerging and developing
Paraguay	Emerging and developing
Peru	Emerging and developing
Philippines	Emerging and developing
Poland	Emerging and developing
Portugal	Advanced economies
Romania	Emerging and developing
Russia	Emerging and developing
Rwanda	Emerging and developing
Salvador	Emerging and developing
Serbia	Advanced economies
Slovakia	Advanced economies
Slovenia	Emerging and developing
South African Republic	Emerging and developing
South Korea	Advanced economies
Spain	Advanced economies
Sri Lanka	Emerging and developing
Sweden	Advanced economies
Switzerland	Advanced economies
Thailand	Emerging and developing
Netherlands	Advanced economies
United States of America	Advanced economies
Trinidad and Tobago	Emerging and developing
Turkey	Emerging and developing
Uganda	Emerging and developing
Ukraine	Emerging and developing
United Kingdom	Advanced economies
Uruguay	Emerging and developing
Venezuela	Emerging and developing
Vietnam	Emerging and developing

Table A3

Domain variables

Economic development	Financial sustainability	Environmental sustainability	Work- and knowledge-based society	Social sustainability	Demographic sustainability
GDP per capita	Net savings	Air pollution	Employment	HALE	Old-age dependency ratio
LPI Score	Account balance	Fossil fuel	Labour productivity	Income Gini	Domestic net migration
Internet usage	Economic dependency ratio	Nuclear energy	Labour tax	P90P10	Youth dependency ratio
Median income	Interest payments	Renewables	Unemployment ratio	Wealth Gini	Fertility rate (adjusted)
Real wage	R&D expenditure	CO_2 emissions	ISCED 3	Absolute poverty rate	
	Public debt	Water stress		GNI SD	

Note: GDP = gross domestic product; GNI = gross national income; HALE = healthy life expectancy; ISCED = International Standard Classification of Education; LPI = logistics performance index; R&D = research and development; SD = standard deviation.

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