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A Global Assessment of Sustainable Development: Integrating Socioeconomic, Resource and Environmental Dimensions

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Sustainable development and its assessment have increasingly played a key background role in government policymaking across the world. Generally, sustainable development is defined as the coordination of economic, environmental, and social development in order to balance intra-generational welfare and maximize inter-generational overall welfare. Therefore, the purpose of our research is to assess national sustainable development from the perspective of integrating economic, environmental, and social dimensions, and then to better monitor the status of sustainable development. We first adopt and modify the National Sustainable Development Index, which has been proposed as a way to amend the Human Development Index, including 12 indicators (weighted by the Entropy Method) in economic, environmental, and social dimensions. After that, we assess the sustainable development status of 179 countries from 2010 to 2016. The result shows that there is no obvious trend of narrowing the gap in sustainable development levels among countries, or even an expanding trend in this period. We also make a comparison between the original NSDI and our modified NSDI and find that the modified NSDI not only retains the merits but also makes up for the shortcomings of the original one in acceptability, reliability, and continuity.

Keywords: sustainable development, UN indicators, entropy method, environmental assessment, innovation

INTRODUCTION

Governments and researchers have had the tendency to investigate and monitor the progress of sustainability ever since the UN 2030 Agenda and Sustainable Development Goals (SDGs) were adopted by all 193 member states (Hametner and Kostetckaia, 2020). This action turns out to be necessary in terms of constructing a composite index system (Alaimo and Maggino, 2020), which serves as the tool to evaluate national sustainable development, basically because it, on the one hand, unfolds a comprehensive picture of sustainability and, on the other hand, supports governments in putting the public policies into practice (Jin et al., 2020).

As reviewed in the next section, a list of sustainable development indices has been proposed for sustainability assessment, but these indices have limitations in three aspects. First, some indexes contain too many indicators to measure sustainability for most countries due to data restrictions (Jin et al., 2020). For example, Li et al. (2014) (Li et al., 2014) built the Human Green Development Index (HGDI) by including 12 indicators in socioeconomic and resource environment dimensions, which can well represent sustainable development, but the HGDI is unable to measure sustainability for many countries because of the unavailability of data, especially for some developing countries. Second, some indices have simple structures and low data requirements, which can measure sustainability for most countries but cannot effectively represent sustainable development. The Human Development Index (HDI) is widely used as a sustainability assessment index simply because of its concise composition and connotation (Bilbao-Ubillos, 2013). However, it is also criticized for not being "strict" enough as it fails to present indicators in environmental and resource dimensions (Bravo, 2014; Hickel, 2019). Third, the popular weighing methods reported in the literature include "equal weights," "expert weights," and "factor analysis," but these methods have limitations in varying degrees. The first two methods are criticized for their lack of objectivity (Li et al., 2014; Wang et al., 2019), and the third method can only estimate weights if correlation exists between indicators (Khalid et al., 2020).

In order to make a breakthrough or progress on the above issues, the National Sustainable Development Index (NSDI) is proposed as a way to amend the HDI (Jin et al., 2020). The NSDI includes 12 indicators in economic, social, and environmental dimensions, which are built as an improvement index of HDI. Like many other well-known improvement indices of HDI, such as HSDI (Bravo, 2014), HGDI (Li et al., 2014), and SDI (Hickel, 2019), NSDI is built by adding indicators in the environment and resource dimensions to the HDI. But the difference is that NSDI measures the weight of each indicator with the entropy method, which is based on the idea of entropy from basic information theory. This method is objective compared with the traditional equal weight method or expert weight method (Ma et al., 2015). Therefore, NSDI is considered as a scientific and acceptable index that has been used as a dependent variable in empirical research (Jin and Martinez-Vazquez, 2021).

However, there is an obvious demerit to NSDI. The NSDI includes "drinking water" and "sanitation" which are respectively measured by "population using improved drinking water sources (%)" and "population using improved sanitation facilities (%)," but the data for these two indicators are counted every 5 years, such as 2010 and 2015. It means that NSDI can only be measured once every 5 years, which means it could not be used for annual continuous monitoring of national sustainable development.

Therefore, this study not only aims to assess national sustainable development globally but also to modify the NSDI to make up for its demerit and then propose a more continuous and acceptable index, so as to better monitor the status of sustainability. First, this study helps strengthen the public and academic understanding of sustainable development. Admittedly, there are many studies investigating the environmental dimension of sustainable development yet failing to recognize the core of sustainable development, that is, comprehensive and coordinated development involving economic, environmental, and social dimensions (Jin et al., 2020). Second, we propose a modified NSDI to make up for some demerits of the original one and enhance its acceptability, continuity, and reliability, which represents a small step ahead of the other existing indices. The two sub-indicators in the original NSDI can only be measured once every 5 years, which means the original one can only be measured once every 5 years, such as 2005, 2010, and 2015, while the modified one can be measured every year.

The following will be categorized into five sections. **Section 2** is a literature review. **Section 3** describes the NSDI and its modification, as well as the data source and the entropy method. **Section 4** presents the result. **Section 5** compares the NSDI with the modified NSDI. **Section 6** concludes.

LITERATURE REVIEW

The Concept of Sustainable Development

The concept of sustainable development has its origins in ecology; however, it has been justified as a more comprehensive concept involving economics, sociology, and environmental science. Sustainable development has come under the spotlight in academia ever since the Our Common Future reported in Brundtland Commission (World Commission on Environment and Development-WCED, 1987). That report theoretically updated the definition specifically that sustainable development now refers to the development that meets the needs of the present generation without compromising the needs of the future generation. It could be reckoned as the first definition of sustainable development, considering its first emphasis on intergenerational and ecologically oriented aspects (Alaimo and Maggino, 2020). Although the concept of sustainable development derives from ecology, it has brought together many other disciplines such as sociology, economics, and environmental science (Ramos and Caeiro, 2010; Bolcárová and KološTa, 2015). As Guillén-Royo (2016) pointed out, sustainable development requires action in three aspects through development policies that promote economic growth, promote social equality, and reduce negative environmental impacts. Similarly, Kwatra et al. (2020) (Kwatra et al., 2020) put forward that sustainable development is a multi-dimensional concept that highlights the integration and dynamic balance among economic, social, and environmental domains to ensure inter- and intragenerational equity. Overall, the definition of sustainable development varies among researchers, although it has now acknowledged to be the cross-cutting concept with respect to economy, society, and environment (Goodland and Daly, 1996). As Jin et al. (2020) have concluded, sustainable development is to coordinate economic, social, and environmental development, hence to balance the intra-generational welfare and then maximize the total welfare of generations (Jin et al., 2020).

Indices for Sustainable Development Assessment

Sustainable development has stirred a fervent debate worldwide and gained momentum in academia after the updated concept was put forward. Recently, a growing number of researchers have been delving into building a composite index for sustainability assessment. There are such pioneering and classic examples like the Index of Sustainable Economic Welfare (Cobb, 1989; Cobb and Cobb, 1994), ecological footprint (Wackernagel and Rees, 1997), Environmental Sustainability Index (Esty et al., 2005), and Environmental Performance Index (Esty et al., 2006). In addition, many widely cited sustainable development indices are constructed by international organizations, such as the UN's Sustainable Development Goals Index (United Nations (UN), 2019) and the United Nations Development Program's (United Nations Development Programme (UNDP), 2004) Human Development Index (HDI).

The Human Development Index (HDI) is the one of the most widely used and referenced indices (Estoque and Murayama, 2014). It has gained popularity because of its simple composition, representative sub-indicators, and rich connotation (Hickel, 2019). Specifically, it consists of three equal weighted indicators: income, life expectancy, and education. However, it is also criticized for not being "strict" enough as it fails to present indicators in environmental and resource dimensions (Türe, 2013; Bravo, 2014).

Some sustainable development indexes were built based on the HDI by adding indicators of resources and the environment, such as the Human Sustainable Development Index (HSDI) constructed by Bravo (2014) (Bravo, 2014), the Human Green Development Index (HGDI) by Li et al. (2014), and the National Sustainable Development Index (NSDI) by Jin et al. (2020) (Jin et al., 2020). HSDI, HGDI, and NSDI are all taken as "modified indices" or improved schemes of the HDI, but they are quite different in composition and connotation. Among these modified indices of HDI, NSDI is considered a relatively comprehensive indicator and more in line with the concept of sustainable development (Jin and Martinez-Vazquez, 2021).

METHODS AND DATA

The Framework and Modification of NSDI

Jin et al. (2020) put forward the NSDI with 12 indicators in economic, social, and environmental dimensions based on the concept of sustainable development. Sustainable development is to coordinate economic, social, and environmental development and to balance intra-generational welfare so as to maximize the total welfare of generations (Guillén-Royo, 2016; Kwatra et al., 2020). So, the government should set a sustainable development goal in a comprehensive way, including the three dimensions (Goodland and Daly, 1996).

However, as Introduction has mentioned, the NSDI has an obvious demerit that makes it impossible to measure sustainability annually. Jin et al. (2020) measure the "drinking water" and "sanitation," respectively, by "population using improved drinking water sources (%)" and "population using improved sanitation facilities (%)." But the data for the two indicators are accounted every 5 years, like 2005 and 2010, which means the NSDI can only be measured once every 5 years. It brings three issues: 1) the NSDI is unable to monitor national sustainable development annually; 2) information loss in the process of sustainability assessment; 3) can not be used for annual panel data analysis, which will restrict the further empirical research.

Therefore, it is necessary to modify and improve the NSDI to better monitor and evaluate sustainability. As Khalid et al. (2020) have pointed out, data shortage is an important reason why many sustainable development indices cannot be effectively measured and compared. So, the data issue of NSDI must be addressed. This study makes the "drinking water" and "sanitation," respectively, measured by "population using at least basic drinking water sources (%)" and "population using at least basic sanitation facilities (%)," as shown in the bottom two rows of **Table 1**. We adopt these two indicators because 1) they are accounted for once a year and the annual measurement of NSDI can be guaranteed; and 2) basic drinking water sources and sanitation facilities can better reflect the basic needs of humans for public health and the environment. Finally, we propose a modified NSDI based on the original one (see **Table 1**).

Normalization

Normalization is a necessary step before the 12 indicators are aggregated into a composite index. There are many kinds of normalization methods, such as "ranking," "distance to target," "Z-Score," and "min-max" (Nardo et al., 2005; Pollesch and Dale, 2016). We adopt the min-max method for normalization because it is simple, mature, and widely used (Bravo, 2014; Khalid et al., 2020). According to the min-max method, we divide the 12 indicators into positive indicators and negative indicators (as shown in the last column of **Table 1**). Positive indicators are those whose increasing values represent better performance in sustainable development, such as income level and forest area, and negative indicators are the ones whose lower values represent better performance, such as CO2 emissions per capita. The min-max normalization formula for positive and negative indexes is shown in **Eqs. 1**, **2**, respectively.

$$\tilde{x}_{ij} = \frac{X_{ij} - minX_{ij}}{maxX_{ij} - minX_{ij}} \text{ and} \tag{1}$$

$$\tilde{x}_{ij} = 1 - \frac{X_{ij} - minX_{ij}}{maxX_{ij} - minX_{ij}}. \tag{2}$$

In the aforementioned equations, X is the raw data value, min (X) is the minimum observed value of the indicator, max (X) is the maximum observed value of the indicator, X_{ij} is the indicator j of country i, and $\tilde{x}_{ij}$ is the result of normalization.

Weighting for 12 Indicators

Weighting is another important step to aggregate all the indicators into a sustainable development index. There are some popular weighting methods presented in the literature, such as equal weights, factor analysis, expert weights, and the

TABLE 1 | Framework of National Sustainable Development Index.

Index	Dimension	Factor	Indicator	Premise
National Sustainable Development Index (NSDI)	Economic dimension	Economic growth	Real GDP growth	+
		Income level	Income index	+
		Economic structure	Employment in services (% of total employment)	+
	Resource and environmental dimension	Climate	CO_2 emissions per capita	-
		Air quality	PM 2.5	-
		Forest	Forest area (% of total land area)	+
		Arable land	Arable land per person	+
		Energy	Renewable energy consumption (% of total final energy consumption)	+
	Social Dimension	Education	Expected years of schooling	+
		Health	Life expectancy index	+
		Drinking water	Population using at least basic drinking-water sources (%)	+
		Sanitation facilities	Population using at least basic sanitation facilities (%)	+

Note: The descriptions and data source of the 12 indicators can be found in ***Supplementary Appendix Table SA1****.*

TABLE 2 | Weights of 12 indicators.

Index	Dimension	Factor	Indicator	Weights (%)
National Sustainable Development Index (NSDI)	Economic dimension	Economic growth	Real GDP growth	5.78
		Income level	Income index	16.02
		Economic structure	Employment in services (% of total employment)	7.46
	Resource and environmental dimension	Climate	CO_2 emissions per capita	5.01
		Air quality	PM2.5	7.56
		Forest	Forest area (% of total land area)	9.03
		Arable land	Arable land per person	4.13
		Energy	Renewable energy consumption (% of total final energy consumption)	9.53
	Social dimension	Education	Expected years of schooling	15.03
		Health	Life expectancy index	13.16
		Drinking water	Population using at least basic drinking-water sources (%)	3.76
		Sanitation facilities	Population using at least basic sanitation facilities (%)	3.53

entropy method (Li et al., 2014; Jin et al., 2020; Khalid et al., 2020). But these methods have limitations in varying degrees. For example, equal weights mean that the weights of all indicators are equal, but the importance of different indicators for sustainable development is obviously different. Similarly, the expert weights method also lacks objectivity (Li et al., 2014). And the factor analysis can only estimate weights if a correlation exists between indicators (Khalid et al., 2020). The entropy method is considered an objective weighting technique in sustainable development studies (Wang et al., 2019).

We use the entropy method to weight each indicator. The entropy method is a weighting technique based on the idea of entropy from the information theory. Specifically, information is a measure of the order degree, and entropy is a measure of the disorder degree in a system; hence, the smaller the entropy of the indicator, the more information provided by the indicator, the greater its role and weight in the comprehensive evaluation (Zhang et al., 2003; Wang et al., 2019). As Zhang et al. (2003) have pointed out, the weight measured by the entropy method represents the relative rate of change of the indicator in a composite index system, while the relative level of each indicator should be figured by the standardized value of its data. Thus, the entropy method is an objective weighting technique that makes weight judgments based on the size of the data information load. It can reduce the influence of human subjectivity on the evaluation result and makes the evaluation results more realistic (Ma et al., 2015; Wang et al., 2019).

According to the principle of the entropy method, we first normalize each index, as shown in **Eqs. 1**, **2**. Thus, the entropy value e_j of indicator j could be obtained, as shown in **Eqs 3**, **4**.

$$k = 1/\ln(n) \tag{3}$$

$$e_j = -k\sum_{i=1}^{n} \tilde{x}_{ij} ln\tilde{x}_{ij}, \tag{4}$$

where n is the number of samples and the constant k depends on n.

TABLE 3 | The mean value of NSDI and its ranking of 179 countries from 2010 to 2016.

	Country	NSDI	Rank	C	Country	NSDI	Rank	C
High-NSDI country	The Netherlands	0.7892	1	EU	Slovakia	0.6599	31	EU
	Finland	0.7824	2	EU	Croatia	0.6578	32	EU
	Iceland	0.7677	3	EU	Panama	0.6557	33	NA
	Denmark	0.7642	4	EU	North Macedonia	0.6549	34	EU
	Sweden	0.7575	5	EU	Korea (Rep)	0.6536	35	AS
	Singapore	0.7575	6	AS	Andorra	0.6494	36	EU
	Austria	0.7361	7	EU	Cyprus	0.6483	37	EU
	Norway	0.7356	8	EU	Latvia	0.6478	38	EU
	Switzerland	0.7305	9	EU	Argentina	0.6466	39	SA
	Belgium	0.7288	10	EU	Malaysia	0.6454	40	AS
	Australia	0.7221	11	OC	Estonia	0.6433	41	EU
	Germany	0.7194	12	EU	Lithuania	0.6427	42	EU
	New Zealand	0.7185	13	OC	Peru	0.6414	43	SA
	Japan	0.7156	14	AS	Costa Rica	0.6342	44	NA
	France	0.7120	15	EU	Romania	0.6327	45	EU
	Canada	0.7048	16	NA	Malta	0.6304	46	EU
	Italy	0.7047	17	EU	Uruguay	0.6288	47	SA
	The United States	0.6984	18	NA	Bulgaria	0.6277	48	EU
	Ireland	0.6972	19	EU	Bahamas	0.6244	49	NA
	The United Kingdom	0.6965	20	EU	Paraguay	0.6236	50	SA
	Luxembourg	0.6961	21	EU	Russian Federation	0.6236	51	EU
	Spain	0.6877	22	EU	Belarus	0.6212	52	EU
	Greece	0.6851	23	EU	Montenegro	0.6169	53	EU
	Portugal	0.6847	24	EU	Barbados	0.6168	54	NA
	Brunei Darussalam	0.6829	25	AS	Albania	0.6167	55	EU
	Czechia	0.6800	26	EU	Brazil	0.6149	56	SA
	Slovenia	0.6738	27	EU	Dominican (Rep)	0.6134	57	NA
	Poland	0.6682	28	EU	Mauritius	0.6128	58	AF
	Israel	0.6652	29	AS	Bosnia and Herzegovina	0.6078	59	EU
	Hungary	0.6609	30	EU	Suriname	0.6066	60	SA
Medium-NSDI country	Turkey	0.6040	61	AS	Trinidad and Tobago	0.5447	91	NA
	Oman	0.6030	62	AS	Bahrain	0.5435	92	AS
	Chile	0.6018	63	SA	Tunisia	0.5414	93	AF
	Fiji	0.6000	64	OC	Morocco	0.5414	94	AF
	Mexico	0.5964	65	NA	Bolivia	0.5393	95	SA
	Seychelles	0.5963	66	AF	Armenia	0.5373	96	AS
	Georgia	0.5874	67	AS	Qatar	0.5356	97	AS
	Lebanon	0.5834	68	AS	Iran	0.5327	98	AS
	Ukraine	0.5809	69	EU	Botswana	0.5307	99	AF
	Jamaica	0.5800	70	NA	Venezuela	0.5299	100	SA
	Serbia	0.5797	71	EU	Colombia	0.5285	101	SA
	Maldives	0.5753	72	AS	Cabo Verde	0.5280	102	AF
	Grenada	0.5748	73	NA	Nicaragua	0.5280	103	NA
	Kuwait	0.5743	74	AS	Algeria	0.5279	104	AF
	Indonesia	0.5738	75	AS	Gabon	0.5276	105	AF
	The United Arab Emirates	0.5665	76	AS	Guyana	0.5269	106	SA
	China	0.5656	77	AS	Namibia	0.5256	107	AF
	Guatemala	0.5611	78	NA	Jordan	0.5249	108	AS
	Libya	0.5584	79	AF	Azerbaijan	0.5247	109	AS
	Dominica	0.5568	80	NA	Moldova	0.5236	110	EU
	Saudi Arabia	0.5558	81	AS	South AF	0.5187	111	AF
	Ecuador	0.5554	82	SA	Cuba	0.5125	112	NA
	El Salvador	0.5535	83	NA	Kyrgyzstan	0.5100	113	AS
	Lao	0.5502	84	AS	India	0.5072	114	AS
	Kazakhstan	0.5499	85	AS	Viet Nam	0.5055	115	AS
	Thailand	0.5487	86	AS	Bhutan	0.5050	116	AS
	Timor-Leste	0.5486	87	AS	Samoa	0.4962	117	OC
	Sri Lanka	0.5479	88	AS	Sao Tome and Principe	0.4959	118	AF
	Honduras	0.5478	89	NA	Turkmenistan	0.4958	119	AS
	Philippines	0.5464	90	AS	Belize	0.4952	120	NA

(Continued on following page)

TABLE 3 | (*Continued*) The mean value of NSDI and its ranking of 179 countries from 2010 to 2016.

	Country	NSDI	Rank	C	Country	NSDI	Rank	C
Low-NSDI country	Mongolia	0.4912	121	AS	Tanzania	0.4224	151	AF
	Zambia	0.4912	122	AF	Equatorial Guinea	0.4224	152	AF
	Eswatini	0.4910	123	AF	Nigeria	0.4186	153	AF
	Senegal	0.4909	124	AF	Pakistan	0.4109	154	AS
	Tonga	0.4818	125	OC	Gambia	0.4108	155	AF
	Vanuatu	0.4791	126	OC	Uganda	0.4104	156	AF
	Uzbekistan	0.4781	127	AS	Guinea	0.4074	157	AF
	Myanmar	0.4715	128	AS	Congo (Dem)	0.4006	158	AF
	Ghana	0.4691	129	AF	Burundi	0.3988	159	AF
	Micronesia	0.4686	130	OC	Madagascar	0.3971	160	AF
	Cambodia	0.4652	131	AS	Mozambique	0.3953	161	AF
	Tajikistan	0.4640	132	AS	Rwanda	0.3866	162	AF
	Bangladesh	0.4627	133	AS	Ethiopia	0.3862	163	AF
	Egypt	0.4609	134	AF	Mauritania	0.3808	164	AF
	Comoros	0.4589	135	AF	Burkina Faso	0.3802	165	AF
	Congo	0.4576	136	AF	Liberia	0.3733	166	AF
	Sudan	0.4543	137	AF	Djibouti	0.3678	167	AF
	Angola	0.4519	138	AF	Nepal	0.3676	168	AS
	Iraq	0.4515	139	AS	Togo	0.3634	169	AF
	Kenya	0.4512	140	AF	Mali	0.3598	170	AF
	Guinea-Bissau	0.4483	141	AF	Eritrea	0.3571	171	AF
	Syrian Arab Republic	0.4483	142	AS	Yemen	0.3449	172	AS
	Haiti	0.4481	143	NA	Sierra Leone	0.3432	173	AF
	Benin	0.4479	144	AF	Afghanistan	0.3278	174	AS
	Zimbabwe	0.4420	145	AF	Malawi	0.3058	175	AF
	Kiribati	0.4412	146	OC	Chad	0.2958	176	AF
	Lesotho	0.4379	147	AF	South Sudan	0.2926	177	AF
	The Solomon Islands	0.4367	148	OC	Central Africa	0.2831	178	AF
	Papua New Guinea	0.4335	149	OC	Niger	0.2445	179	AF
	Cameroon	0.4334	150	AF				

Note: C refers to the continent, so AS, is Asia; AF, is Africa; EU, is Europe, NA is North America; SA is South America; OC, is Oceania.

The information utility value of indicator j, g_j, is calculated in **Eq. 5**.

$$g_j = 1 - e_j. \tag{5}$$

Finally, we can get the weight of indicator j, ω_j, as shown in **Eq. 6**.

$$\omega_j = g_j \Big/ \sum_{j=1}^{p} g_j, \tag{6}$$

where the p is the number of indicators.

Threshold Establishment: Rating for Sustainability

It is also necessary to establish a threshold and distinguish these countries accordingly (Rama et al., 2020). After weighting and aggregation, we can get the National Sustainable Development Index of each country with a range from 0 to 1. First, we rank the NSDI of each country from high value to low value. The higher the NSDI, the better will be performance in sustainable development. Second, according to the ranking of the NSDI, these countries are divided into three parts. Countries whose ranking of the NSDI in is the first part, signed as a High-NSDI country. Countries with ranking of NSDI between the first and third parts signed as a medium-NSDI country. Finally, countries with ranking in the third part signed as a low-NSDI country. Many recent studies attempt to define a sustainable country through a similar rating method (Li et al., 2014; Rama et al., 2020).

Data Source and Imputation

We chose to measure the NSDI for 179 countries from 2010 to 2016 (the list of countries is shown in **Table 3**). These countries were selected by two criteria: 1) all countries had published the data of all 12 indicators (see **Supplementary Appendix Table SA1**) and 2) internationally recognized non-sovereign entities were not selected, such as Hong Kong, China. In general, the 179 selected samples include most countries and cover more than 90% of the population and land in the world.

Due to the missing data of some indicators in this period for some countries, this study adopts a different imputation method to fill in the missing data. The current studies prefer to adopt the imputation method to fill in missing data, rather than missing out information. This notion is also in tune with works by Campagnolo et al. (2018). This study adopts different imputation methods according to the actual situation. First is the mean value interpolation method. For example, if the data of 2010 and 2012 are available but the data of 2011 are missing, we use the average value of 2010 and 2012 to replace the value of 2011. This method is used to the imputation of these data: 1) the data of economic structure of Sudan in 2013, 2) the data of health of Yemen in 2013, and 3) the data of education of Afghanistan in

TABLE 4 | The rankings of High-NSDI countries.

R	Country	2010	2013	2016	R	Country	2010	2013	2016
1	The Netherlands	1	1	2	31	Slovakia	28	32	37
2	Finland	3	2	1	32	Croatia	37	31	29
3	Iceland	5	3	3	33	Panama	35	33	30
4	Denmark	6	4	4	34	North Macedonia	34	34	33
5	Sweden	4	5	5	35	Korea (Rep)	31	35	39
6	Singapore	2	6	6	36	Andorra	44	37	36
7	Austria	7	8	8	37	Cyprus	36	42	32
8	Norway	8	7	7	38	Latvia	43	36	38
9	Switzerland	9	9	10	39	Argentina	30	38	46
10	Belgium	10	10	11	40	Malaysia	40	41	35
11	Australia	14	11	9	41	Estonia	38	43	41
12	Germany	12	13	12	42	Lithuania	42	40	43
13	New Zealand	11	12	15	43	Peru	39	39	40
14	Japan	13	14	13	44	Costa Rica	50	44	44
15	France	15	15	14	45	Romania	52	45	42
16	Canada	17	16	19	46	Malta	41	49	48
17	Italy	16	18	17	47	Uruguay	47	47	47
18	The United States	18	19	21	48	Bulgaria	55	46	45
19	Ireland	23	21	18	49	Bahamas	48	54	52
20	The United Kingdom	20	17	20	50	Paraguay	45	48	51
21	Luxembourg	19	20	16	51	Russian Federation	54	50	53
22	Spain	22	22	24	52	Belarus	46	51	58
23	Greece	26	23	22	53	Montenegro	51	55	56
24	Portugal	24	25	23	54	Barbados	49	57	57
25	Brunei Darussalam	21	24	27	55	Albania	61	52	50
26	Czechia	25	26	26	56	Brazil	53	53	61
27	Slovenia	29	27	25	57	Dominican (Rep)	58	60	49
28	Poland	32	28	28	58	Mauritius	59	56	55
29	Israel	27	30	31	59	Bosnia and Herzegovina	68	64	54
30	Hungary	33	29	34	60	Suriname	57	58	66

*Note: 1) R is the ranking of mean value of NSDI, from 2010 to 2016 (see **Table 3**). 2) We only report the NSDI, rankings in 2010, 2013 and 2016 because of the space constraints. The measurement results of High-NSDI, countries from 2010 to 2016 are shown in **Supplementary Appendix Table SB1**.*

2012. Second is the nearest neighbor interpolation method. This method is used to deal with missing data for the variables that are very stable over time, like the arable land. This method is to the imputation of these data: the data of arable land of the United Arab Emirates, Pakistan, Sudan, Iraq, Yemen, and Central Africa in 2016. These imputations in instances can distort the results, but losing out data might prove costlier to some countries (Khalid et al., 2020).

RESULTS

NSDI Measurement and Ranking of Each Country

This study measures the weight of 12 indicators using the entropy method (see the last column of **Table 2**). As a result, the weights of the economic dimension, resource–environmental dimension, and social dimension are, respectively, accounted for at 29.26, 35.26, and 35.48%. The weights of the three dimensions are very close, and the weights of the resource–environmental and social dimensions are slightly higher than those of the economic dimension. And the highest weighed factors are income level, energy and education, respectively, in each dimension. On the one hand, it means that these three factors are the most important factors for national sustainable development. On the other hand, the NSDI is a derivative index or improvement scheme of HDI, so the three indexes with the highest weight are corresponding to the HDI, which reflects that income, education, and health are the basic needs of human development (Bravo, 2014; Jin et al., 2020).

According to the weights in **Table 2**, we aggregate the 12 indicators into the NSDI and measure the sustainability of 179 countries from 2010 to 2016 (see **Table 3** and **Supplementary Appendix Tables SB1, B2, and B3**). As a result, countries are rated between 0 and 1. And these countries are rated as three levels, namely, high-NSDI country, medium-NSDI country, and low-NSDI country, according to their average NSDI values and rankings in this period. As the average NSDI value of each country is shown in **Table 3**, the top ten countries are the Netherlands (0.7892), Finland (0.7824), Iceland (0.7677), Denmark (0.7642), Sweden (0.7575), Singapore (0.7575), Austria (0.7361), Norway (0.7356), Switzerland (0.7305), and Belgium (0.7288), while the bottom ten countries are Mali (0.3598), Eritrea (0.3571), Yemen (0.3449), Sierra Leone (0.3432), Afghanistan (0.3278), Malawi (0.3058), Chad (0.2958), South Sudan (0.2926), Central Africa (0.2831), and Niger (0.2445).

The ranking and rating of each country show distinct characteristics. Most of the high-NSDI countries are in Europe and North America, of which there are 38 in Europe and 7 in North America, respectively. The countries with low NSDI are mainly in Africa (39) and Asia (13). And the countries rated as

TABLE 5 | Rankings of medium-NSDI countries.

R	Country	2010	2013	2016	R	Country	2010	2013	2016
61	Turkey	67	59	60	91	Trinidad and Tobago	85	95	98
62	Oman	64	63	59	92	Bahrain	91	98	83
63	Chile	65	62	62	93	Tunisia	89	89	97
64	Fiji	66	61	65	94	Morocco	103	85	91
65	Mexico	62	66	64	95	Bolivia	96	92	92
66	Seychelles	60	65	63	96	Armenia	102	97	94
67	Georgia	69	67	68	97	Qatar	75	107	105
68	Lebanon	63	68	77	98	Iran	104	101	87
69	Ukraine	70	69	71	99	Botswana	111	96	93
70	Jamaica	71	71	75	100	Venezuela	101	91	125
71	Serbia	72	70	69	101	Colombia	106	104	99
72	Maldives	73	72	72	102	Cabo Verde	112	102	96
73	Grenada	76	74	74	103	Nicaragua	110	108	95
74	Kuwait	78	75	73	104	Algeria	98	110	104
75	Indonesia	77	73	70	105	Gabon	100	99	100
76	The United Arab Emirates	80	80	76	106	Guyana	105	105	102
77	China	82	79	67	107	Namibia	95	103	117
78	Guatemala	81	78	81	108	Jordan	97	109	111
79	Libya	56	76	115	109	Azerbaijan	107	106	101
80	Dominica	79	83	89	110	Moldova	99	100	108
81	Saudi Arabia	86	82	85	111	South AF	109	111	112
82	Ecuador	88	77	90	112	Cuba	108	113	118
83	El Salvador	84	81	88	113	Kyrgyzstan	116	112	110
84	Lao	93	88	78	114	India	117	115	103
85	Kazakhstan	92	84	84	115	Viet Nam	118	114	107
86	Thailand	87	94	79	116	Bhutan	113	116	109
87	Timor-Leste	74	86	106	117	Samoa	114	123	119
88	Sri Lanka	90	90	80	118	Sao Tome and Principe	120	120	114
89	Honduras	83	93	86	119	Turkmenistan	123	119	113
90	Philippines	94	87	82	120	Belize	121	117	121

*Note: 1) R is the ranking of mean value of NSDI from 2010 to 2016 (see **Table 3**). 2) We only report the NSDI, rankings in 2010, 2013, and 2016 because of the space constraints. The measurement results of medium-NSDI countries from 2010 to 2016 are shown in **Supplementary Appendix Table SB2**.*

medium NSDI are mainly in Asia (27), Africa (11), and North America (11). In addition, we find that all the developed countries[1] are high-NSDI countries, and most of them are ranked in the top 30, while all the medium-NSDI and low-NSDI countries are developing countries.

There are three main reasons for the poor performance of sustainability in developing countries. First, the level of the economy and residents' income is relatively low. Second, the supply of public goods and services is insufficient and inefficient, like education, public health, and environmental protection, due to poor governments or inadequate fiscal revenue (Jin and Qian, 2020). Last, some developing countries, such as China, are bombarded with such problems as inadequate management and technology of pollution control and resource utilization while still promoting economic growth at all costs, which damages national sustainable development (Jin et al., 2020).

Variations of NSDI Value and Ranking From 2010 to 2016

The variations in NSDI values and rankings reflect variations in the sustainability of these countries in 2010–2016. As the results in **Table 4** and **Supplementary Appendix Table SB1** show, the sustainability of 20 countries increased from 2010 to 2016, 11 countries decreased, and the rest of 19 countries remained unchanged, in these high-NSDI countries. The five countries with the highest growth rates of NSDI were Denmark (0.0302), Bosnia and Herzegovina (0.0267), Iceland (0.0266), Albania (0.0227), and Finland (0.0224), while the five countries with the largest decline in NSDI were Barbados (−0.0180), New Zealand (−0.0212), Suriname (−0.0226), Belarus (−0.0228), and Argentina (−0.0335).

Table 5 and **Supplementary Appendix Table SB2** report the NSDI ranking and values for medium-NSDI countries in the same period. As a result, the sustainability of 17 countries increased from 2010 to 2016, 15 countries decreased, and the rest of 18 countries remained unchanged, in these medium-NSDI countries. Among them, the five countries with the highest growth rates of NSDI were China (0.0317), Vietnam (0.024), Laos (0.0238), India (0.0225), and Iran (0.0208), while the five countries with the largest decline in NSDI were Namibia (−0.0354), Venezuela (−0.0479), Qatar (−0.0518), Timor-Leste (−0.0542), and Libya (−0.112).

The NSDI ranking and values of low-NSDI countries are presented in **Table 6** and **Supplementary Appendix Table SB3**. As a result, the sustainability of 17 low-NSDI countries increased from 2010 to 2016, 12 ones decreased, and the rest of 20

[1]According to the standards of CIA's the World Fact Book and IMF

TABLE 6 | Rankings of low-NSDI countries.

R	Country	2010	2013	2016	R	Country	2010	2013	2016
121	Mongolia	124	122	127	151	Tanzania	153	153	150
122	Zambia	119	121	122	152	Equatorial Guinea	155	151	157
123	Eswatini	127	118	116	153	Nigeria	152	149	159
124	Senegal	122	124	120	154	Pakistan	158	155	151
125	Tonga	129	126	123	155	Gambia	149	154	154
126	Vanuatu	125	125	130	156	Uganda	154	157	155
127	Uzbekistan	128	127	126	157	Guinea	157	156	152
128	Myanmar	132	129	124	158	Congo (Dem)	156	159	160
129	Ghana	130	128	133	159	Burundi	159	158	163
130	Micronesia	131	132	132	160	Madagascar	161	161	153
131	Cambodia	138	131	128	161	Mozambique	160	160	158
132	Tajikistan	126	130	135	162	Rwanda	165	162	162
133	Bangladesh	137	133	129	163	Ethiopia	162	163	161
134	Egypt	133	135	137	164	Mauritania	167	165	164
135	Comoros	134	136	138	165	Burkina Faso	163	164	165
136	Congo	136	140	139	166	Liberia	166	166	170
137	Sudan	142	137	134	167	Djibouti	169	168	166
138	Angola	144	138	141	168	Nepal	168	167	168
139	Iraq	141	142	131	169	Togo	171	169	169
140	Kenya	140	141	136	170	Mali	170	172	167
141	Guinea-Bissau	139	143	142	171	Eritrea	172	173	171
142	Syrian Arab Republic	115	152	156	172	Yemen	164	171	174
143	Haiti	148	139	140	173	Sierra Leone	173	170	172
144	Benin	146	134	145	174	Afghanistan	174	174	173
145	Zimbabwe	135	148	147	175	Malawi	176	176	175
146	Kiribati	150	144	143	176	Chad	175	177	178
147	Lesotho	147	147	144	177	South Sudan	178	175	176
148	The Solomon Islands	145	145	146	178	Central Africa	177	179	177
149	Papua New Guinea	143	150	148	179	Niger	179	178	179
150	Cameroon	151	146	149					

*Note: 1) R is the ranking of mean value of NSDI, from 2010 to 2016 (see **Table 3**). 2) We only report the NSDI, rankings in 2010, 2013, and 2016 because of the space constraints. The measurement results of low-NSDI countries from 2010 to 2016 are shown in **Supplementary Appendix Table SB3**.*

ones remained unchanged. Among these countries, the five countries with the highest growth rates of NSDI were Cambodia (0.0288), Bangladesh (0.0276), Eswatini (0.0265), Pakistan (0.0255), and Iraq (0.0215), while the five countries with the largest decline in NSDI were Gambia (−0.0249), Nigeria (−0.0282), Chad (-0.0548), Yemen (−0.0685), and the Syrian Arab Republic (−0.0959).

In sum, the variations of NSDI value and ranking in each country show distinct characteristics. First, the 30 countries with the largest increase in NSDI were mainly Asian countries (12) and European countries (9). On the one hand, many European developed countries still maintain a high growth rate of the NSDI. Exemplary is the case of upper-middle income Serbia—the country representing a historical statehood core of both Yugoslavia countries. It owns its fluctuating dynamics in the NSDI list due to the partial lack of sustainable investment in health care (Jakovljevic, 2013) and social insurance coverage (Jakovljevic et al., 2011). Issues affecting fiscal sustainability were largely driven by the prohibitively expensive budget impact of blockbuster pharmaceuticals (Jakovljevic et al., 2015), population aging (Ogura and Jakovljevic, 2014), and migration (Jakovljevic et al., 2018). On the other hand, many Asian countries have performed better and better in sustainable development in recent years. For example, the NSDI of China has increased the most in 2010–2016, thanks to rapid economic growth and environmental protection. Second, the 30 countries with the largest decline in the NSDI were mainly in Africa (9) and Asia (9). Third, most African and South American countries experienced a decline in sustainability from 2010 to 2016. The average NSDI of South American and African countries decreased by 0.102 and 0.038, respectively. Last, the sustainability of most European countries showed an increasing trend, with an average increase of 0.0053 in the NSDI. It means that the global sustainable development level may have a trend of divergence in 2010–2016.

Geographical Distribution of NSDI

The geographical distribution of the NSDI is shown in **Figure 1**. As the figure shows, the darker the blue, the higher will be the NSDI of the country and the better will be its performance in sustainable development, while the white indicates the data vacancy. The subfigures (a), (b), and (c), respectively, show the geographical distribution of the NSDI in 2010, 2013, and 2016. Overall, the blue color of countries in Western Europe, North America, and Oceania is the deepest, while that in Africa and West Asia is the shallowest, especially in sub-Saharan Africa. And, the blue color of Central Asia, East Asia, and South America is in the middle. In addition, countries in the northern hemisphere are darker in blue than those in the southern hemisphere. And, we find that the "north–south gap" in the development level still exists and has not narrowed in this period,

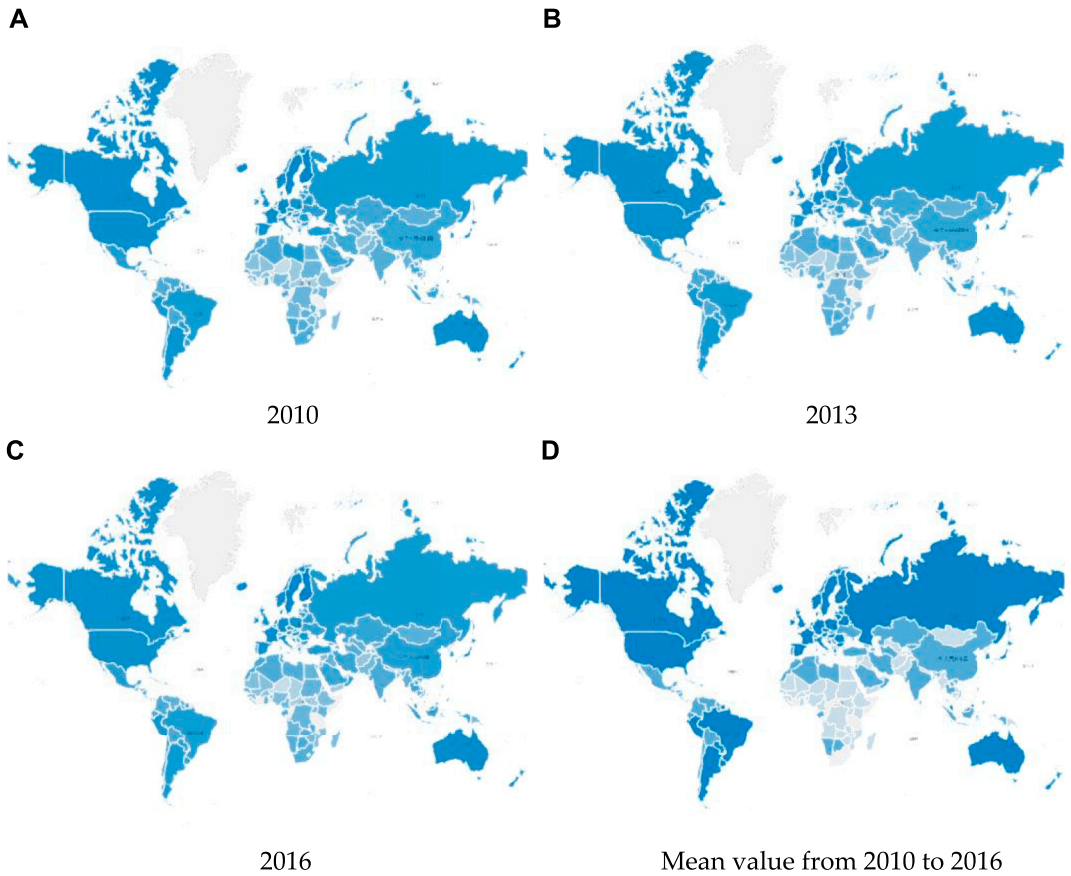

FIGURE 1 | Geographical distribution of NSDI. Note: **(A)** is the geographical distribution of NSDI in 2010; **(B)** is the geographical distribution of NSDI in 2013; Subfigure **(C)** is the geographical distribution of t NSDI in 2016; **(D)** is the geographical distribution of the mean value of NSDI from 2010 to 2016, and high-NSDI countries are dark blue, medium-NSDI countries are light blue, and low-NSDI countries are gray.

TABLE 7 | Rankings of low-NSDI countries.

Factor	Modified NSDI		NSDI	
	Indicator	Weights (%)	Indicator	Weights (%)
Economic growth	Real GDP growth	5.78	Real GDP growth	6.09
Income level	Income index	16.02	Income index	9.20
Economic structure	Employment in services (% of total employment)	7.46	Employment in services (% of total employment)	9.31
Climate	CO_2 emissions per capita	5.01	CO_2 emissions per capita	12.30
Air quality	PM2.5	7.56	$PM_{2.5}$	7.55
Forest	Forest area (% of total land area)	9.03	Forest area (% of total land area)	8.74
Arable land	Arable land per person	4.13	Arable land per person	14.49
Energy	Renewable energy consumption (% of total final energy consumption)	9.53	Renewable energy consumption (% of total final energy consumption)	8.38
Education	Expected years of schooling	15.03	Expected years of schooling	7.14
Health	Life expectancy index	13.16	Life expectancy index	7.39
Drinking water	Population using at least basic drinking-water sources (%)	3.76	Population using improved drinking water sources (%)	4.95
Sanitation facilities	Population using at least basic sanitation facilities (%)	3.53	Population using improved sanitation facilities (%)	4.45

by comparing the NSDI in 2010, 2013, and 2016. Furthermore, there is no obvious trend of convergence in the level of sustainable development globally.

There is an important reason why the geographical distribution of NSDI shows the aforementioned characteristics. On the one hand, the countries with higher economic levels always maintain a good

performance in sustainable development because of their mature and sound systems in economics, social security, environmental protection, and so on. On the other hand, those backward countries not only have poor economic foundation but also do not have the aforementioned conditions, so it is always difficult to improve their sustainable development level. Even some countries have always been mired in war and extreme poverty, so sustainable development is out of the question. Therefore, the development of various countries presents a similar phenomenon to the "Matthew effect."

Fortunately, we can be optimistic from the cases of the rapid increase in the NSDI in some developing countries. For example, the NSDI of China has greatly improved, from 0.5517 to 0.5834, with an increase of 0.0317, during 2010–2016. In another case, the NSDI of India increased from 0.4943 to 0.5168, with an increase of 0.0225. Both countries used to be very backward and poor countries in the world, but they have achieved great development in recent decades and still maintain a strong momentum of economic growth. It may provide important reference for other developing countries, through studying the laws of the rapid development of these two countries. Furthermore, it is essential to emphasize that China is the classic case of overachiever among the large nations in terms of Sustainable Development Goals (Jakovljevic et al., 2019). This is clearly visible in its struggle to lift 800 million citizens out of poverty line (Liu et al., 2017). Another well documented evidence are Chinese historical trends and future long-run forecasts on health spending up to 2025 (Jakovljevic et al., 2017) and 2030. These underlying hidden patterns clearly point out to Chinese leadership among the most rapidly developing emerging BRIC nations.

DISCUSSION: A COMPARISON BETWEEN ORIGINAL NSDI AND MODIFIED NSDI

Table 7 shows the comparison between our modified NSDI and the NSDI constructed by Jin et al. (2020). There are two main differences between the two indices: 1) the factors "drinking water" and "sanitation" are measured by "population using at least basic drinking water sources (%)" and "population using at least basic sanitation facilities (%)" in the modified NSDI; 2) the weight of each indicator is recalculated with new data through the entropy method. Comparing with the original NSDI, the weights of "income level," "energy," "education," and "health" are significantly increased in our modified NSDI, while the weights of economic structure," "climate," and "arable land" are decreased.

From the measurement results of sustainable development, we find that the modified NSDI retains some merits of the original NSDI. First, NSDI is an improved scheme of HDI, which has many characteristics of HDI, while the modified NSDI retains the characteristics of HDI that focus on human development and welfare. Second, it is clear that the modified NSDI still puts a stop to the "celebration" of "gas-guzzling developed countries" (Togtokh, 2011; Bravo, 2014). Those Middle Eastern countries that are rich but energy-intensive perform poorly in NSDI rankings, for example, Qatar and the United Arab Emirates are, respectively, ranked at 97 and 76 in **Table 3**.

Furthermore, the modified NSDI has more merits than the original one. First, the modified NSDI can measure the level of sustainable development globally and annually, but the original one can only measure it once every 5 years, such as in 2010 and 2015. Second, the modified NSDI can be used for further empirical research on annual panel data. For example, Jin and Martinez-Vazquez (Jin and Martinez-Vazquez, 2021) have studied the relationship between fiscal decentralization and sustainable development by using NSDI as a dependent variable. Third, the modified NSDI is more applicable and acceptable than the original one and can be used to measure for more countries. The modified NSDI could be used to measure sustainable development for 179 countries in this study, while the original one could be used to measure it for 163 countries (Jin et al., 2020). Last, the measurement result of the modified NSDI is more reliable than that of the original one. The measurement results of the original NSDI lack of accuracy, that is, the measurement results of the sustainable development level in some countries, are higher than the actual level, such as Lithuania and Kazakhstan, which are ranked at 15 and 18, respectively (Jin et al., 2020). This is because the original NSDI overemphasizes the proportion of the environment and resources.

CONCLUSION

This study is intended to assess sustainability globally based on the modified NSDI, hence to help policymakers better monitor the status of sustainable development and formulate development policies. So, we first modify the NSDI with some alternative indicators and adopt it for sustainable development assessment, and then compare the modified NSDI with the original one. The result shows that the modified NSDI not only retains the merits but also makes up for the shortcomings of the original NSDI in acceptability, reliability, and continuity. In addition, we also find that there is no obvious trend toward narrowing the gap in sustainable development levels among countries, or even an expanding trend.

As mentioned earlier, the HSDI, HGDI, and NSDI are all regarded as "derivative indices" or modification schemes of the HDI, but they vary from each other in composition and connotation. The HDI stresses on the ability and sustainability of human beings (Pata et al., 2021). But no matter whether they are poor, rich, or even developing or developed countries, they must act under the constraints of the earth's environment. Living in this interrelated ecosystem, humans are believed to be tied to nature; hence, the local actions of each country are subject to the natural conditions of the world. Bravo (Bravo, 2014) reckons that the environment is an integral part of human sustainable development and builds the HSDI by adding an indicator (per capita CO2 emissions) to the present environmental dimension based on the HDI. Besides, the resource crisis has been increasingly exposed to such noticeable issues as excessive energy consumption and land pollution. Hence, it is safe to say that the sustainability of human beings, to a great extent, is susceptible to the resources on the earth. The HGDI is constructed by adding some indicators both in resource and environmental dimensions from those considerations. In terms of the previously defined concept of sustainable development,

we ought to promote the realization of economic growth while raising awareness of protecting the ecological environment and making rational use of natural resources to ensure the welfare of future generations. Conceivably, protecting the environment at the cost of hindering economic development is not a sustainable development mode. Thus, the NSDI is set with economic, social, and resource-environmental dimensions and 12 indicators (see **Table 1**) (Jin et al., 2020). The NSDI is seen as a reliable and relatively complete SD index, but still with shortcomings. Therefore, we amend and upgrade the NSDI in this study to make up for the shortcomings of the original one in acceptability, reliability, and continuity.

Based on the aforementioned results, we derived the following policy implication. Governments should be committed to promoting coordinated development in the dimensions of the economy, society, and environment, without "care for this and lose that." Specifically, governments should first accommodate the business climate to help economic growth, then strengthen environmental protection and resource utilization supervision, and finally improve government spending on livelihood projects, especially education, medical care, and social security.

DATA AVAILABILITY STATEMENT

The original contributions presented in the study are included in the article/**Supplementary Materials**, further inquiries can be directed to the corresponding authors.

AUTHOR CONTRIBUTIONS

JS conceived and designed the research and provided guidance throughout the entire research process; JS wrote and supplemented the English paper, and MJ participated in data analysis. HJ and F-ST review and edited and paper and is responsible for all R and R works.

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SUPPLEMENTARY MATERIAL

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REFERENCES

Alaimo, L. S., and Maggino, F. (2020). Sustainable Development Goals Indicators at Territorial Level: Conceptual and Methodological Issues-The Italian Perspective. *Soc. Indic Res.* 2, 383–419. doi:10.1007/s11205-019-02162-4

Bilbao-Ubillos, J. (2013). The Limits of Human Development Index : The Complementary Role of Economic and Social Cohesion, Development Strategies and Sustainability. *Sust. Dev.* 21, 400–412. doi:10.1002/sd.525

Bolcárová, P., and KološTa, S. (2015). Assessment of Sustainable Development in the EU 27 Using Aggregated SD index. *Ecol. Indic* 48, 699–705. doi:10.1016/j.ecolind.2014.09.001

Bravo, G. (2014). The Human Sustainable Development Index: New Calculations and a First Critical Analysis. *Ecol. Indicators* 37, 145–150. doi:10.1016/j.ecolind.2013.10.020

Campagnolo, L., Eboli, F., Farnia, L., and Carraro, C. (2018). Supporting the UN SDGs Transition: Methodology for Sustainability Assessment and Current Worldwide Ranking. *Economics* 12, 1–31. doi:10.5018/economics-ejournal.ja.2018-10

Cobb, C. W., and Cobb, J. B. (1994). *The Green National Product: A Proposed Index of Sustainable Economic Welfare*. Lanham, MD, USA: University Press of America.

Cobb, C. W. (1989). *The Index for Sustainable Economic Welfare*. Boston, USA: Beacon Press.

Estoque, R. C., and Murayama, Y. (2014). Social-ecological Status index: A Preliminary Study of its Structural Composition and Application. *Ecol. Indicators* 43, 183–194. doi:10.1016/j.ecolind.2014.02.031

Esty, D. C., Levy, M. A., Srebotnjak, T., and de Sherbinin, A. (2005). *Environmental Sustainability Index: Benchmarking National Environmental Stewardship*. New Haven, CT, USA: Yale Center for Environmental Law & Policy.

Esty, D. C., Levy, M. A., Srebotnjak, T., de Sherbinin, A., Kim, C. H., and Anderson, B. (2006). *Pilot2006 Environmental Performance Index*. New Haven, CT, USA: Yale Center for Environmental Law & Policy.

Goodland, R., and Daly, H. (1996). Environmental Sustainability: Universal and Non-negotiable. *Ecol. App* 6 (4), 1002–1017. doi:10.2307/2269583

Guillén-Royo, M. (2016). *Sustainability and Wellbeing: Human-Scale Development in Practice*. London, UK: Routledge.

Hametner, M., and Kostetckaia, M. (2020). Frontrunners and Laggards: How Fast Are the EU Member States Progressing towards the Sustainable Development Goals. *Ecol. Econ.* 177, 745623. doi:10.1016/j.ecolecon.2020.106775

Hickel, J. (2019). The Sustainable Development index: Measuring the Ecological Efficiency of Human Development in the Anthropocene. *Ecol. Econ.* 167, 423517. doi:10.1016/j.ecolecon.2019.05.011

Jakovljevic, M. B., Djordjevic, N., Jurisevic, M., and Jankovic, S. (2015). Evolution of the Serbian Pharmaceutical Market Alongside Socioeconomic Transition. *Expert Rev. Pharmacoeconomics Outcomes Res.* 15 (3), 521–530. doi:10.1586/14737167.2015.1003044

Jakovljevic, M. B. (2013). Resource Allocation Strategies in Southeastern European Health Policy. *Eur. J. Health Econ.* 14 (2), 153–159. doi:10.1007/s10198-012-0439-y

Jakovljevic, M., Jakab, M., Gerdtham, U., McDaid, D., Ogura, S., Varavikova, E., et al. (2019). Comparative Financing Analysis and Political Economy of Noncommunicable Diseases. *J. Med. Econ.* 22 (8), 722–727. doi:10.1080/13696998.2019.1600523

Jakovljevic, M., Jovanovic, M., Lazic, Z., Jakovljevic, V., Djukic, A., Velickovic, R., et al. (2011). Current Efforts and Proposals to Reduce Healthcare Costs in Serbia. *Ser. J. Exp. Clin. Res.* 12 (4), 161–163. doi:10.5937/sjecr1104161j

Jakovljevic, M. M., Netz, Y., Buttigieg, S. C., Adany, R., Laaser, U., and Varjacic, M. (2018). Population Aging and Migration - History and UN Forecasts in the EU-28 and its East and South Near Neighborhood - One century Perspective 1950-2050. *Glob. Health* 14 (1), 30–36. doi:10.1186/s12992-018-0348-7

Jakovljevic, M., Potapchik, E., Popovich, L., Barik, D., and Getzen, T. E. (2017). Evolving Health Expenditure Landscape of the BRICS Nations and Projections to 2025. *Health Econ.* 26 (7), 844–852. doi:10.1002/hec.3406

Jin, H., and Martinez-Vazquez, J. (2021). *Sustainable Development and the Optimal Level of Fiscal Expenditure DecentralizationICePP Working Paper Series, #2103, Andrew Young School of Policy Studies*. Georgia, USA: Georgia State University.

Jin, H., Qian, X., Chin, T., and Zhang, H. (2020). Global Assessment of Sustainable Development: Based on the Modification of Human Development Index with Entropy Method. *Sustainability* 12 (8), 1–20. doi:10.3390/su12083251

Jin, H., and Qian, X. (2020). How the Chinese Government Has Done with Public Health from the Perspective of the Evaluation and Comparison about Public-Health Expenditure. *Int. J. Environ. Res. Public Health* 17 (12), 3466. doi:10.3390/ijerph17249272

Khalid, A. M., Sharma, S., and Dubey, A. K. (2020). Data Gap Analysis, Indicator Selection and Index Development: A Case for Developing Economies. *Soc. Indic Res.*, 148. doi:10.1007/s11205-019-02225-6

Kwatra, S., Sharma, P., and Kumar, A. (2020). A Critical Review of Studies Related to Construction and Computation of Sustainable Development Indices. *Ecol. Indic* 112 (112), 106061. doi:10.1016/j.ecolind.2019.106061

Li, X. X., Liu, Y. M., and Song, T. (2014). Calculation of the Green Development Index. *Soc. Sci. China* 6, 69–95.

Liu, Y., Liu, J., and Zhou, Y. (2017). Spatio-temporal Patterns of Rural Poverty in China and Targeted Poverty Alleviation Strategies. *J. Rural Stud.* 52, 66–75. doi:10.1016/j.jrurstud.2017.04.002

Ma, Y. M., Wu, Y. M., and Wu, B. J. (2015). Comprehensive Evaluation of Sustainable Urban Development of Yangtze River Delta Based on Entropy Method and Quadrant Method. *Econ. Geogr.* 6, 47–53.

Nardo, M., Saisana, M., Saltelli, A., Tarantola, S., Hoffman, A., and Giovannini, E. (2005). *Handbook on Constructing Composite Indicators: Methodology and User Guide*.

Ogura, S., and Jakovljevic, M. (2014). Health Financing Constrained by Population Aging - an Opportunity to Learn from Japanese Experience/Finansiranje Zdravstvene Zaštite U Uslovima Starenja Popualcije - Prilika Da Učimo Na Japanskom Iskustvu. *Serbian J. Exp. Clin. Res.* 15 (4), 175–181. doi:10.2478/sjecr-2014-0022

Pata, U. K., Aydin, M., and Haouas, I. (2021). Are Natural Resources Abundance and Human Development a Solution for Environmental Pressure? Evidence from Top Ten Countries with the Largest Ecological Footprint. *Resour. Pol.* 70, 101923. doi:10.1016/j.resourpol.2020.101923

Pollesch, N. L., and Dale, V. H. (2016). Normalization in Sustainability Assessment: Methods and Implications. *Ecol. Econ.* 130, 195–208. doi:10.1016/j.ecolecon.2016.06.018

Rama, M., González-García, S., Andrade, E., Moreira, M. T., and Feijoo, G. (2020). Assessing the Sustainability Dimension at Local Scale: Case Study of Spanish Cities. *Ecol. Indicators* 117, 106687. doi:10.1016/j.ecolind.2020.106687

Ramos, T. B., and Caeiro, S. (2010). Meta-performance Evaluation of Sustainability Indicators. *Ecol. Indicators* 10, 157–166. doi:10.1016/j.ecolind.2009.04.008

Togtokh, C. (2011). Time to Stop Celebrating the Polluters. *Nature* 479, 269. doi:10.1038/479269a

Türe, C. (2013). A Methodology to Analyse the Relations of Ecological Footprint Corresponding with Human Development index: Eco-Sustainable Human Development index. *Int. J. Sustain. Dev. World Ecol.* 20, 9–19. doi:10.1080/13504509.2012.751562

United Nations Development Programme (Undp) (2004). *Note on Statistics in the Human Development Report*. New York, NY, USA: UNDP.

United Nations (Un) (2019). *Sustainable Development Report 2019*. New York, NY, USA: UN.

Wackernagel, M., and Rees, W. (1997). *Our Ecological Footprint*. Basel, Switzerland: Birkhouse Publishing.

Wang, M., Zhao, X., Gong, Q., and Ji, Z. (2019). Measurement of Regional Green Economy Sustainable Development Ability Based on Entropy Weight-Topsis-Coupling Coordination Degree-A Case Study in Shandong Province, China. *Sustainability* 11, 280–295. doi:10.3390/su11010280

World Commission on Environment and Development-Wced (1987). *Our Common Future*. Oxford, UK: University Press.

Zhang, W. M., An, J. W., and Han, C. (2003). The Application of Entropy Method in the Evaluation of Urban Sustainable Development. *J. Quant Tech. Econ.* 6, 115–118.

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