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RESEARCH ARTICLE

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Sustainable development goals in the European Union and its regions: Are we moving forward in economic, social, and environmental dimensions?

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Abstract

We build a framework using Markov transition matrices to develop comparative analyses of the dynamics of the United Nations' Sustainable Development Goals across 20 EU Member States and three sustainability dimensions—economic, social, and environmental—over the period of 2011–2019. The results indicate that the European Union has significantly progressed in achieving sustainable development, and that this progress has been achieved in all dimensions of sustainability and all EU regions. Nevertheless, we have detected different dynamics of sustainability across some countries and dimensions. This can help policymakers identify where greater emphasis should be placed on putting global goals back on track.

KEYWORDS
European Union, Markov chains, sustainable development goals, transition matrices

1 | INTRODUCTION

In 2015, the United Nations (UN) approved the 2030 Agenda for Sustainable Development and adopted 17 sustainable development goals (SDGs) as a reference point for inclusive, sustainable growth and development globally for 2015–2030 (Le Blanc, 2015). Since then, the agenda, together with the Paris Climate Agreement (United Nations, 2015), has marked a universal path for a more sustainable growth model in each of its three dimensions: economic (prosperity), social (people), and environmental (planet). In this regard, progress has been made in many parts of the world. More people live better lives compared with 10 years ago; they have access to better healthcare, decent jobs, and education (OECD, 2022; United Nations, 2022). However, as pointed out by earlier references, the speed and scale of the improvements were not sufficient to meet the SDGs. In particular, some issues, such as gender inequality, poverty, global hunger, and climate change, need much more attention.

In September 2019, world leaders called for an ambitious plan (Decade of Action) to mobilize all sectors of society and advance progress at the required rate to meet the SDGs over the decade of 2020–2030 (United Nations, 2019). However, this plan has been severely affected by the COVID-19 pandemic (OECD, 2022). Today, the data show severe shortcomings that urge policy actions to get back on track (United Nations, 2022), although the observed short stagnation of the environmental crisis (OECD, 2022) is a good sign.

Monitoring relevant indicators is essential to assess the progress of this desired multi-faceted sustainable development to ensure the achievement of the set goals and to identify where a country stands and which policies are most effective (Schmidt-Traub et al., 2017). Good-quality data are key inputs for this task (Lafortune et al., 2020).

The attempts found in the previous literature to advance the monitoring of SDGs have mainly been based on the construction of aggregate indicators calculated as the simple average of a set of normalized indicators to measure the progress of all SDGs as a whole or individually. A detailed review of these studies for the European continent (e.g., ASviS, 2021; European Commission, Eurostat, 2021; Lafortune et al., 2021; OECD, 2019, 2022) points out the lack of consensus on how to normalize and aggregate the information and the different results obtained when applying the diverse approaches. Moreover, aggregate indicators face several other weaknesses related to aggregation, the static nature of these indicators, and the difficulty of interpretation and comparison among countries. In general, the previous literature has focused on establishing country rankings and identifying the distance of each SDG (or indicator) from the desired target. However, over time, the indicators' behavior has been underinvestigated, making it challenging to identify the strengths that countries should capitalize on and the weaknesses they should work on. In this regard, as pointed out by the OECD (2008), although aggregated indicators may be useful for ranking the relative performance of a country, individual variables might be more relevant to policy formulation. In addition, monitoring the progress of SDGs in the previous literature also suffers from a lack of consideration of the three dimensions of sustainability and their potential synergies or trade-offs (OECD, 2019, 2022) and the lack of potential regional patterns that may exist among different European regions (Lafortune et al., 2021).

In this article, we aim to identify patterns in sustainable development in 20 European Union (EU) Member States between 2011 and 2019, monitoring the progress of 69 indicators distributed along economic, social, and environmental dimensions. Our objectives are threefold. First, we evaluate the direction and magnitude of sustainable development progress and explore the potential differences among European regions. Second, we investigate the dynamics of SDGs. Finally, we explore the possible differences among the three dimensions of sustainability. To achieve these objectives, we build on previous economic literature that has employed Markov transition matrices to investigate patterns in other fields of economics, such as income distribution (e.g., Quah, 1993, 1996), trade specialization (e.g., Alessandrini et al., 2007; Zaghini, 2005), assessment of ecological indicators (Pennino et al., 2017), and circular bioeconomy (Kardung & Drabik, 2021).

Our research contributes to the related literature by exploring an alternative framework to assess the progress of the SDGs, which allows us to investigate and develop comparative analyses of the dynamics of SDGs across the EU Member States and the sustainability dimensions over time. Our research builds on an approach similar to that of Kardung and Drabik (2021), who analyzed the mobility of 41 circular bioeconomy indicators in 10 EU Member States. Based on the framework proposed by these authors, our research analyzes a large set of SDG indicators and countries, providing a more comprehensive view of the dynamics and trends in the short and medium runs. We also contribute to the literature by exploring the differences across the three dimensions of sustainability and across diverse EU regions.

2 | DATA

The official Eurostat SDG indicator set contains (at the time of writing this article[1]) data for 102 indicators according to the 17 SDGs (European Commission, Eurostat, 2021) with incomplete time and country coverage. This means that, for some indicators, information was not available for some specific countries or years. Therefore, to ensure a balanced panel dataset for our analysis, we selected a consistent sample to cover as many indicators, countries, and years as possible. This allowed us to have data for 69 indicators and 20 EU Member States over the period 2011–2019 while simultaneously enabling a reliable degree of representativeness of the sample.

First, the 69 selected indicators represent 68% of the indicators provided by Eurostat, covering all 17 SDGs as well as ensuring a balance between the three dimensions of sustainability: economic (35 indicators out of 45), social (36 indicators out of 58), and environmental (23 indicators out of 46). The classification of SDGs among the different dimensions is a challenging task since many international organizations offer diverse classifications. Therefore, we reviewed the different classifications proposed by international organizations, summarized by Tremblay et al. (2020). We assigned an SDG to a given dimension if at least 20% of the reviewed classifications assigned this SDG to this dimension. Table 1 lists the selected official indicators, the SDGs, and the dimensions to which they belong according to our approach. The economic dimension includes SDGs 7, 8, 9, 10, 11, and 12; the social dimension covers SDGs 1, 2, 3, 4, 5, 6, and 10; and the environmental dimension includes SDGs 6, 7, 11, 12, 13, 14, and 15. SDGs 16 and 17 do not belong to any of the three dimensions, so they are considered only when all the SDGs are analyzed without distinguishing the different dimensions of sustainability.

Second, the sample of the 20 selected Member States comprises Austria, Belgium, Czechia, Denmark, Estonia, Finland, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Netherlands, Portugal, Romania, Slovakia, Slovenia, Spain, and Sweden. This sample is proportional in terms of geographical dispersion according to the Eurovoc classification (European Commission, 2014): five countries are from Western Europe (Austria, Belgium, Germany, Ireland, and Netherlands), four belong to Southern Europe (Greece, Italy, Portugal, and Spain), six are located in Northern Europe (Denmark, Estonia, Finland, Latvia, Lithuania, and Sweden), and five are located in Central and Eastern Europe (Czechia, Hungary, Romania, Slovakia, and Slovenia). Following the Sustainable Development Solutions Network and the Institute for European Environmental Policy ranking (Lafortune et al., 2020), the studied countries are also balanced in their sustainable development since six are within the first third of this classification (Austria, Denmark, Finland, Germany, Slovenia, and

[1]The data used were extracted in May 2022 from Eurostat (Eurostat, 2022).

TABLE 1 Summary of the selected sustainable development goal indicators.

Code	Indicator	Desired direction	SDG	Ec	So	En
sdg_01_20	People at risk of income poverty after social transfers	−	1		X	
sdg_01_30	Severely materially deprived people	−	1		X	
sdg_01_40	People living in households with very low work intensity	−	1		X	
sdg_01_41	In work at-risk-of-poverty rate	−	1,8	X	X	
sdg_01_60	Population living in a dwelling with a leaking roof, damp walls, floors or foundation or rot in window frames of floor by poverty status	−	1,11	X	X	X
sdg_02_20	Agricultural factor income per annual work unit	+	2		X	
sdg_02_30	Government support to agricultural research and development	+	2		X	
sdg_02_40	Area under organic farming	+	2		X	
sdg_02_51	Harmonized risk indicator for pesticides, by groups of active substances	−	2		X	
sdg_02_60	Ammonia emissions from agriculture	−	2		X	
sdg_03_11	Healthy life years at birth by sex	+	3		X	
sdg_03_20	Share of people with good or very good perceived health by sex	+	3		X	
sdg_03_41	Standardized death rate due to tuberculosis, HIV and hepatitis by type of disease	−	3		X	
sdg_03_42	Standardized preventable and treatable mortality	−	3		X	
sdg_03_60	Self-reported unmet need for medical examination and care by sex	−	1,3		X	
sdg_04_10	Early leavers from education and training by sex	−	4		X	
sdg_04_10b	Gender gap for early leavers from education and training by sex	−	4		X	
sdg_04_20	Tertiary educational attainment by sex	+	4,9	X	X	
sdg_04_20a	Gender gap for tertiary educational attainment by sex	−	4		X	
sdg_04_60	Adult participation in learning by sex	+	4		X	
sdg_05_30	Gender employment gap	−	5		X	
sdg_05_40	Gender gap for inactive population due to caring responsibilities by sex	−	5		X	
sdg_05_50	Seats held by women in national parliaments and governments	+	5		X	
sdg_05_60	Positions held by women in senior management positions	+	5		X	
sdg_07_10	Primary energy consumption	−	7	X		X
sdg_07_11	Final energy consumption	−	7	X		X
sdg_07_20	Final energy consumption in households per capita	−	7	X		X
sdg_07_30	Energy productivity	+	7,12	X		X
sdg_07_40	Share of renewable energy in gross final energy consumption by sector	+	7,13	X		X
sdg_07_50	Energy import dependency by products	−	7	X		X
sdg_07_60	Population unable to keep home adequately warm by poverty status	−	1,7	X	X	X
sdg_08_10	Real GDP per capita	+	8	X		
sdg_08_11	Investment share of GDP by institutional sectors	+	8	X		
sdg_08_20	Young people neither in employment nor in education and training by sex	−	8	X		
sdg_08_30	Employment rate	+	8	X		
sdg_08_40	Long-term unemployment rate	−	8	X		
sdg_08_60	People killed in accidents at work, by sex	−	3,8	X	X	
sdg_09_10	Gross domestic expenditure on R&D by sector	+	9	X		

(Continues)

TABLE 1 (Continued)

Code	Indicator	Desired direction	SDG	Ec	So	En
sdg_09_30	R&D personnel by sector	+	9	X		
sdg_09_40	Patent applications to the European Patent Office	+	9	X		
sdg_09_50	Share of busses and trains in total passenger transport	+	9,11	X		X
sdg_09_60	Share of rail and inland waterways in total freight transport	+	9	X		
sdg_09_70	Air emission intensity from industry	−	9	X		
sdg_10_20	Disparities in household income per capita. Adjusted gross disposable income of households per capita	−	10	X	X	
sdg_10_30	Relative median at-risk-of-poverty gap	−	10	X	X	
sdg_10_41	Income quintile share ratio. Income distribution	−	10	X	X	
sdg_10_50	Income share of the bottom 40% of the population	+	10	X	X	
sdg_10_60	Asylum applications by state of procedure	−	10	X	X	
sdg_11_10	Overcrowding rate by poverty status	−	1,11	X	X	X
sdg_11_20	Population living in households considering that they suffer from noise, by poverty status	−	3,11	X	X	X
sdg_11_40	Road traffic deaths, by type of roads	−	3,11	X	X	X
sdg_11_50	Exposure to air pollution by particulate matter	−	3,11	X	X	X
sdg_11_60	Recycling rate of municipal waste	+	11	X		X
sdg_12_20	Resource productivity and domestic material consumption	+	8,12	X		X
sdg_12_30	Average CO_2 emissions per km from new passenger cars	−	9,12,13	X		X
sdg_12_41	Circular material use rate	+	12	X		X
sdg_13_10	Greenhouse gas emissions by source sector	−	13			X
sdg_13_20	Greenhouse gas emissions intensity of energy consumption	−	7,13	X		X
sdg_13_60	Population covered by the Covenant of Mayors for Climate & Energy signatories	+	13			X
sdg_14_40	Bathing sites with excellent water quality by locality	+	6,14		X	X
sdg_15_20	Surface of terrestrial sites designated under Natura 2000	+	15			X
sdg_16_10	Standardized death rate due to homicide by sex	−	16			
sdg_16_20	Population reporting occurrence of crime, violence or vandalism in their area by poverty status	−	11,16	X		X
sdg_16_30	General government total expenditure on law courts	+	16			
sdg_16_60	Population with confidence in EU institutions by institution	+	16			
sdg_17_10	Official development assistance as share of gross national income	+	17			
sdg_17_30	EU imports from developing countries by country income groups	+	17			
sdg_17_40	General government gross debt	−	17			
sdg_17_50	Share of environmental taxes in total tax revenues	+	17			

Source: Authors based on Eurostat SDG dataset (Eurostat, 2022) and Tremblay et al. (2020). *Note*: Ec, So, and En stand for "Economic," "Social," and "Environmental" dimensions.

Sweden), seven are in the second third of the ranking (Belgium, Czechia, Estonia, Hungary, Ireland, Netherlands, and Slovakia), and seven are in the last third (Greece, Italy, Latvia, Lithuania, Portugal, Romania, and Spain).

Finally, a 9-year period is covered (2011–2019), which allows us to investigate both short-run and medium-run dynamics. This can be very informative about how the implementation and delivery of the 2030 Agenda evolved in the most recent period and act as a benchmark for future comparisons in the design of urgent transformative policies (including adequate financing) to build back better when we are currently less than 10 years away from fulfilling the ambitions of the 2030 Agenda, and the long-term planning is no longer sufficient.

3 | METHODOLOGY

The first step is ensuring consistency in interpreting the indicators. For some indicators, such as per capita gross domestic product, tertiary education attainment, or resource productivity, a higher indicator

TABLE 2 Descriptive statistics of average *z*-scores of sustainable development goal indicators.

All SDGs	2011	2012	2013	2014	2015	2016	2017	2018	2019
Mean	−0.674	−0.418	−0.388	−0.283	−0.221	0.008	0.333	0.604	1.038
Median	−0.946	−0.695	−0.592	−0.411	−0.190	0.091	0.583	0.905	1.425
SD	1.031	0.787	0.648	0.708	0.678	0.665	0.655	0.758	1.054
Range	3.883	2.845	2.374	3.617	3.993	3.828	3.128	3.021	4.671
Economic	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**
Mean	−0.716	−0.405	−0.356	−0.176	−0.175	−0.050	0.266	0.614	1.000
Median	−0.982	−0.825	−0.558	−0.318	−0.178	0.121	0.487	0.761	1.406
SD	1.045	0.824	0.668	0.810	0.627	0.676	0.666	0.706	1.085
Range	3.685	2.637	2.374	3.617	2.630	3.093	2.859	2.860	4.671
Social	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**
Mean	−0.550	−0.303	−0.337	−0.419	−0.399	−0.112	0.390	0.642	1.088
Median	−0.874	−0.605	−0.522	−0.519	−0.286	−0.036	0.653	0.917	1.424
SD	1.183	0.850	0.637	0.559	0.727	0.707	0.646	0.676	0.899
Range	3.883	2.738	2.225	2.315	3.993	3.339	2.636	2.955	3.560
Environmental	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**
Mean	−1.259	−0.649	−0.393	0.036	0.103	0.311	0.362	0.538	0.950
Median	−1.368	−0.962	−0.573	−0.113	0.100	0.240	0.672	0.763	1.288
SD	0.625	0.712	0.686	0.872	0.494	0.330	0.739	0.756	1.004
Range	2.515	2.472	2.374	3.165	1.955	1.309	2.636	2.977	4.297

value means progression in sustainable development, whereas for others, such as the unemployment rate, people at risk of poverty, or carbon dioxide emissions, a higher value indicates that sustainability is regressing. The third column of Table 1 shows the desired direction of each indicator. Therefore, we multiplied the values of the indicators for which smaller values are desired by minus 1 to ensure that a higher indicator value implies a move in the desired direction.

The second step involves normalizing indicators to enable the interpretation and comparison of the performance of a diverse set of indicators with different magnitudes. To do so, one approach in the literature comprises comparing the magnitude of each indicator with its desired target. However, only 12 out of the 69 indicators considered in this study have a target set by the SDGs, hindering the application of this procedure. The alternative approach we used comprises calculating, for each country, the *z*-score of an indicator *i* in year *t* by measuring how many standard deviations (*s*) the value of that indicator (*x*) is away from the indicator's temporal mean ($\overline{x}$).

$$z_{it} = \frac{x_{it} - \overline{x}_i}{s_i}. \tag{1}$$

To assess the direction and magnitude of the indictors' progress, we regressed individual *z*-scores on a time trend and obtained the slope parameters by calculating

$$\widehat{\beta}_i = \frac{Cov[t, z_{it}]}{Var[t]}. \tag{2}$$

A statistically significant positive (negative) slope parameter indicates an improvement (deterioration) in the indicator over time. The slope parameters also enable us to rank the indicators and dimensions of sustainability by the speed of their improvement by analyzing the percentage of progressing (regressing) *z*-scores.

We analyzed the changes in the intra-distribution of indicators over time using Markov transition matrices following Quah (1993, 1996), Zaghini (2005), and Kardung and Drabik (2021). We classified the values of individual indicators into three groups: high, medium, and low. The three thirds are obtained based on the cut-off points in the range defined by the tertiles.

Let us assume a state space $S = \{1,2,3\}$ and define the probability of moving from one state to another state in just one step to be $\Pr(n|m) = P_{mn}$, then the 3×3 transition matrix is defined as follows

$$P = \begin{pmatrix} P_{11} & P_{12} & P_{13} \\ P_{21} & P_{22} & P_{23} \\ P_{31} & P_{32} & P_{33} \end{pmatrix}, \tag{3}$$

where $0 \le P_{mn} \le 1, \forall (m,n) \in S^2$, and $\sum_{n \in S} P_{mn} = 1, \forall m \in S$. Note that both short- and medium-run matrices were calculated by looking at the averages of the annual matrices and transitions over the entire period, respectively. In the latter case, to avoid the potential effect of outliers in the starting and ending points, the averages of the first 2 years (2011 and 2012) and the last 2 years (2018 and 2019) were used to evaluate medium-term dynamics.

Finally, we assessed the extent of indicator movement among thirds using the mobility index (M_1) proposed by Shorrocks (1978).

$$M_1 = \frac{n - tr(P)}{n - 1}, \tag{4}$$

TABLE 3 Evolution of indicators' *z*-scores in the period 2011–2019 by country and dimension of sustainability.

	Percentage of progressing indicators			
Country	**All SDGs**	**Economic**	**Social**	**Environmental**
Austria	58	57	53	65
Belgium	59	62	56	65
Czechia	78	65	61	70
Denmark	39	46	25	52
Estonia	46	51	36	61
Finland	45	46	39	61
Germany	71	62	64	74
Greece	57	57	53	65
Hungary	54	43	47	48
Ireland	62	65	61	52
Italy	59	62	56	87
Latvia	51	51	44	65
Lithuania	54	57	44	57
Netherlands	52	49	36	61
Portugal	52	57	50	48
Romania	52	49	50	48
Spain	51	43	42	48
Sweden	48	51	33	48
Slovakia	57	62	50	70
Slovenia	45	51	42	65
	Percentage of regressing indicators			
Country	**All SDGs**	**Economic**	**Social**	**Environmental**
Austria	12	11	14	4
Belgium	12	14	14	9
Czechia	19	11	14	9
Denmark	20	19	25	13
Estonia	14	11	19	0
Finland	16	11	14	4
Germany	10	11	11	9
Greece	9	14	6	13
Hungary	20	24	22	22
Ireland	20	19	17	17
Italy	14	22	22	9
Latvia	13	11	17	9
Lithuania	16	19	19	13
Netherlands	22	24	28	17
Portugal	9	11	8	9
Romania	14	16	14	13
Spain	13	14	17	4
Sweden	20	22	22	22
Slovakia	12	5	17	0
Slovenia	12	8	17	4
	Average slope parameter			
Country	**All SDGs**	**Economic**	**Social**	**Environmental**
Austria	0.20	0.20	0.18	0.26
Belgium	0.21	0.92	0.19	0.22
Czechia	1.24	0.23	0.20	0.26
Denmark	0.10	0.10	0.00	0.17
Estonia	0.17	0.14	0.10	0.31
Finland	0.15	0.19	0.15	0.26
Germany	0.24	0.21	0.23	0.25
Greece	0.21	0.16	0.23	0.20
Hungary	0.15	0.10	0.11	0.13
Ireland	0.15	0.18	0.16	0.16
Italy	0.20	0.12	0.15	0.25
Latvia	0.19	0.17	0.15	0.24
Lithuania	0.18	0.15	0.14	0.19
Netherlands	0.13	0.08	0.05	0.16
Portugal	0.22	0.20	0.22	0.20
Romania	0.19	0.19	0.19	0.20
Spain	0.18	0.16	0.14	0.25
Sweden	0.13	0.16	0.07	0.32
Slovakia	0.21	0.24	0.17	0.32
Slovenia	0.18	0.19	0.14	0.26

Note: The average slope parameter obtained as the mean of the statistically significant slope coefficients of indicators ($\widehat{\beta}$).

where n is the order of matrix P and $tr(P)$ is its trace (the sum of elements on the main diagonal). Therefore, a higher value of M_1 index implies higher mobility from one third to another.

As a complement to M_1, we also calculated an alternative index (M_2) that uses the determinant of the transition matrix and therefore measures all changes in the matrix (Shorrocks, 1978)

$$M_2 = 1 - |\det(P)|. \tag{5}$$

The M_2 index can be thought of as evaluating the degree of concentration of the probability values in the matrix P. If the probability values are concentrated, that is, a few states gather all the movements from other states, M_2 will be lower than if the distribution pattern is less dispersed.

To enhance the understanding of these two indices, let us consider the following transition matrices

$$P_A = \begin{pmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{pmatrix}; P_B = \begin{pmatrix} 0 & 1 & 0 \\ 0 & 0 & 1 \\ 1 & 0 & 0 \end{pmatrix}; P_C = \begin{pmatrix} 0.33 & 0.33 & 0.33 \\ 0.33 & 0.33 & 0.33 \\ 0.33 & 0.33 & 0.33 \end{pmatrix}$$

Matrix P_A, $M_1 = 0$ since there is no mobility among thirds, and $M_2 = 0$ since the probabilities in the matrix are concentrated in a few states. In matrix P_B, movements are also concentrated in a few states ($M_2 = 0$), but in this case, $M_1 = 1.5$ since all the indicators change from

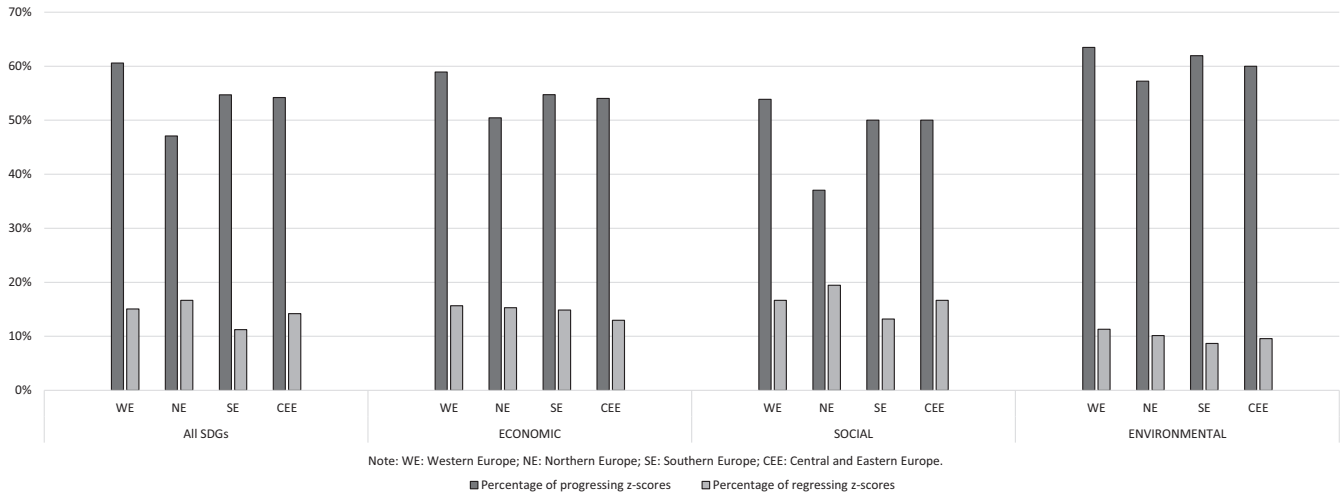

FIGURE 1 Percentage of progressing and regressing indicators by region and dimension of sustainability.

TABLE 4 ANOVA tests for progressing and regressing indicators by dimension.

	Progressing indicators	
Dimensions	***F* statistic (*p*-value)**	**Bartlett's test**
All SDGs	4.87 (0.014)	1.24 (0.742)
Social	4.63 (0.016)	1.36 (0.715)
Economic	1.34 (0.296)	2.71 (0.439)
Environmental	0.77 (0.528)	2.45 (0.485)
	Regressing indicators	
Dimension	***F* statistic (*p*-value)**	**Bartlett's test**
All SDGs	1.59 (0.231)	1.95 (0.583)
Social	1.07 (0.389)	3.04 (0.386)
Economic	0.21 (0.887)	0.95 (0.814)
Environmental	1.00 (0.418)	4.32 (0.229)

Note: Bartlett's test is used to test whether the variances are homogenous, and the statistic is distributed as a χ^2 with 3 degrees of freedom in this case (Bartlett, 1937).

one third to a different third. Finally, matrix P_C shows lower concentration of probabilities—$M_1 = M_2 = 1$ in this case.

4 | RESULTS

4.1 | Direction and magnitude of the indictors' progress

Table 2 presents the main descriptive statistics of the average *z*-scores for all analyzed SDG indicators and for their economic, social, and environmental dimensions. Significant progress in sustainable development is observed over the sample period, with an average *z*-score increasing from −0.67 to 1.04. This progress is more pronounced for the environmental dimension (with an average *z*-score increasing from −1.26 to 0.95) than for the economic (from −0.72 to 1.00) and social areas (from −0.55 to 1.09). Average *z*-scores tend to increase from 1 year to another, except in 2013 and 2014 for the social dimension.

To analyze the direction and magnitude of indicators' progress, Table 3 shows the percentage of progressing (regressing) indicators, that is, the percentage of indicators that exhibit a statistically significant positive (negative) slope coefficient when regressed on a time trend. It also provides the average slope parameter obtained as the mean of the statistically significant slope coefficients of indicators ($\hat{\beta}$). This information is presented for each country and dimension of sustainability. The results indicate that the environmental dimension presents the highest percentage of significantly positive coefficients and the lowest percentage of significantly negative coefficients. The differences between the economic and social dimensions are less pronounced, although the economic dimension tends to outperform the social area. Similar results can be found in an OECD (2019) report for the OECD countries using the average number of countries progressing toward SDG targets for all SDG dimensions.

The countries with the highest percentage of progressing indicators in the three dimensions of sustainability are Czechia, Germany, and Ireland. On the contrary, Denmark, Hungary, the Netherlands, and Sweden are the countries with the highest percentage of regressing indicators in most dimensions.

4.2 | Regional analysis of the indictors' progress

To take a closer look at the potential regional disparities in the evolution of the indicators, Figure 1 illustrates the percentage of progressing and regressing indicators by dimensions and four subregions according to the geographical classification defined by EuroVoc (European Commission, 2014).

We have tested for any significant differences among the four sub-regions by conducting a one-way analysis of variance (ANOVA);

TABLE 5 Multiple comparison tests by dimension and subregions for progressing and regressing indicators.

	Progressing indicators			Regressing indicators		
All SDGs	**CEE**	**NE**	**SE**	**CEE**	**NE**	**SE**
NE	−0.071 (0.378)			0.025 (1.000)		
SE	−0.005 (1.000)	0.076 (0.370)		−0.030 (1.000)	−0.054 (0.280)	
WE	0.064 (0.630)	**0.135** (0.010)	0.059 (0.932)	0.009 (1.000)	−0.016 (1.000)	0.038 (0.973)
Social						
NE	−0.130 (0.107)			0.028 (1.000)		
SE	0.000 (1.000)	0.130 (0.149)		−0.035 (1.000)	−0.063 (0.556)	
WE	0.039 (1.000)	**0.168** (0.021)	0.039 (1.000)	0.000 (1.000)	−0.028 (1.000)	0.035 (1.000)
Economic						
NE	−0.036 (1.000)			0.023 (1.000)		
SE	0.007 (1.000)	0.043 (1.000)		0.019 (1.000)	−0.005 (1.000)	
WE	0.049 (1.000)	0.085 (0.375)	0.042 (1.000)	0.027 (1.000)	−0.004 (1.000)	−0.008 (1.000)
Environmental						
NE	−0.051 (1.000)			0.044 (1.000)		
SE	0.023 (1.000)	0.074 (1.000)		−0.004 (1.000)	−0.048 (0.975)	
WE	0.029 (1.000)	0.080 (1.000)	0.005 (1.000)	0.021 (1.000)	−0.023 (1.000)	0.025 (1.000)

Note: For each group of indicators and sustainability dimensions, the first entry of the table shows the difference between the means of the percentage of progressing (regressing) indicators between the region in the row and the region in the column. The second entry underneath is the Bonferroni-adjusted significance of that difference, which is reported in parentheses.
Abbreviations: CEE, Central and Eastern Europe; NE, Northern Europe; SE, Southern Europe; WE, Western Europe.

that is, we compared the means for each dimension of the percentage of progressing (regressing) indicators among the four regional groups. Table 4 presents the results. The *F* test rejects the null hypothesis that all group means are the same for the percentage of progressing indicators for "All SDGs" and for the "Social" dimension. For the other two dimensions of progressing indicators and for all dimensions of regressing indicators, we cannot reject the null hypothesis.

Since the above test cannot detect which regional group means show differences compared to the other regional groups, we performed post hoc multiple comparison tests between every possible pair of regional groups. To avoid the possibility of false rejection, we implemented the Bonferroni adjustment, which is commonly used in the empirical literature attempting to maintain a balance between the statistical power of the test and the type I error rate (Miller, 1981; Van Belle et al., 2004).[2] Table 5 shows the results for each dimension and for the percentage of progressing and regressing indicators. The first entry of the table shows the difference between the means of the percentage of progressing (regressing) indicators between the region in the row and the region in the columns. The second entry underneath is the Bonferroni-adjusted significance of such difference, shown in parentheses. The results indicate that, in general, the four regions are similar. Regarding the "All SDGs" dimension, if the percentage of progressing *z*-score is considered, there is a limited difference in favor of the Western Member States compared to the Northern ones. As for the "Social" dimension, the null is rejected at the 5% level for the pair Western Europe–Northern Europe for progressing *z*-scores.

This result shows no significant differences in the SDGs' performance among European regions, except for some differences in favor of the Western Member States vis-à-vis the Northern ones. This is consistent with the evidence obtained by Lafortune et al. (2021), who showed that Northern European countries have the lowest growth rate of the SDG index for the period 2010–2019.

4.3 | Dynamics of indicators

To analyze the dynamics of the indicators over time, we estimated Markov transition matrices. The short- and medium-run matrices obtained for each country and for all SDGs are presented in the Appendix.[3] The right part of Table A1 shows the medium-run transition matrices that summarize transitions among thirds of the distribution between 2011–2012 and 2018–2019, while the left part of Table A1 presents the short-run transition matrices obtained as the average of all one-year transition matrices for the period 2011–2019. In both cases, the diagonal values represent the probability that indicators will remain in the same third from one period to another, while

[2]We performed alternative correction methods such as *scheffe*, *sidak* in Stata 17 as a robustness check and obtained similar results (available from authors upon request).

[3]Matrices for each dimension of sustainability are not presented for brevity but are available from authors under request.

TABLE 6 Mobility indices.

	All SDGs					Economic			
	One-year		Nine-year			One-year		Nine-year	
	M1	M2	M1	M2		M1	M2	M1	M2
Austria	0.77	0.97	1.24	0.85	Austria	0.84	0.99	1.28	0.90
Belgium	0.76	0.96	1.22	0.86	Belgium	0.77	0.98	1.20	0.78
Czechia	0.73	0.94	1.20	0.87	Czechia	0.75	0.95	1.03	0.99
Denmark	0.74	0.94	1.28	0.99	Denmark	0.73	0.96	1.32	0.96
Estonia	0.75	0.96	1.22	0.93	Estonia	0.73	0.95	1.23	0.97
Greece	0.70	0.93	1.17	0.88	Greece	0.67	0.94	1.33	0.89
Germany	0.71	0.93	1.15	0.90	Germany	0.66	0.90	1.23	1.00
Finland	0.73	0.96	1.26	0.98	Finland	0.73	0.96	1.11	0.93
Hungary	0.68	0.93	1.39	0.67	Hungary	0.68	0.94	1.41	0.83
Ireland	0.73	0.95	1.15	0.92	Ireland	0.75	0.95	1.16	0.85
Italy	0.71	0.95	1.22	0.86	Italy	0.61	0.89	1.41	0.70
Latvia	0.77	0.97	1.30	0.93	Latvia	0.73	0.95	1.28	0.95
Lithuania	0.73	0.95	1.33	0.90	Lithuania	0.65	0.91	1.36	0.87
Netherlands	0.67	0.91	1.20	0.98	Netherlands	0.66	0.91	1.32	0.83
Portugal	0.72	0.95	1.11	0.97	Portugal	0.70	0.95	1.20	0.92
Romania	0.74	0.95	1.35	0.76	Romania	0.71	0.94	1.37	0.88
Spain	0.71	0.94	1.33	0.84	Spain	0.72	0.96	1.33	0.89
Sweden	0.77	0.97	1.37	0.89	Sweden	0.77	0.96	1.32	1.00
Slovakia	0.80	1.00	1.33	0.87	Slovakia	0.81	1.00	1.19	0.90
Slovenia	0.75	0.97	1.09	0.90	Slovenia	0.72	0.96	1.08	0.87
	Social					**Environmental**			
	One-year		Nine-year			One-year		Nine-year	
	M1	M2	M1	M2		M1	M2	M1	M2
Austria	0.83	0.99	1.13	0.92	Austria	0.86	0.99	1.24	0.84
Belgium	0.78	0.98	1.33	0.73	Belgium	0.84	0.98	1.16	0.91
Czechia	0.77	0.96	1.29	0.79	Czechia	0.74	0.94	1.44	0.62
Denmark	0.81	0.98	1.38	0.88	Denmark	0.85	1.00	1.30	0.71
Estonia	0.76	0.98	1.25	0.90	Estonia	0.79	0.96	1.23	0.98
Greece	0.74	0.95	1.29	0.88	Greece	0.72	0.94	1.05	0.82
Finland	0.80	0.99	1.17	0.96	Finland	0.81	0.98	1.29	0.95
Germany	0.70	0.92	1.33	0.75	Germany	0.81	0.98	1.24	0.63
Hungary	0.76	1.00	1.25	0.92	Hungary	0.70	0.99	1.38	0.59
Ireland	0.77	0.97	1.17	0.92	Ireland	0.64	0.90	1.17	0.95
Italy	0.69	0.95	1.29	0.81	Italy	0.80	0.97	0.86	0.94
Latvia	0.83	0.99	1.29	0.96	Latvia	0.78	0.95	1.10	0.96
Lithuania	0.70	0.94	1.29	0.92	Lithuania	0.70	0.92	1.29	0.79
Netherlands	0.76	0.99	1.29	1.00	Netherlands	0.68	0.92	1.29	0.79
Portugal	0.73	0.97	1.17	1.00	Portugal	0.77	0.96	1.18	0.82
Romania	0.70	0.93	1.29	0.75	Romania	0.79	0.97	1.50	0.43
Spain	0.74	0.95	1.38	0.88	Spain	0.81	0.98	1.29	1.00
Sweden	0.83	1.00	1.25	1.00	Sweden	0.74	0.95	1.08	0.56
Slovakia	0.84	0.98	1.42	0.77	Slovakia	0.77	0.95	1.10	0.96
Slovenia	0.74	0.96	1.21	0.92	Slovenia	0.78	0.96	1.25	0.96

the off-diagonal values indicate the probability that indicators will move to other thirds of the distribution.

For illustration, we compare the short-run transition matrices in the Netherlands and Slovakia. For the Netherlands, 59% of indicators in the first third in 1 year remained in the same third in the next year, while 31% improved by moving to the second third and 10% to the highest third. In addition, 45% of indicators in the second third stayed unaltered the next year, just like 61% of indicators with a *z*-score above the highest tertile.

Slovakia exhibits greater dynamics since the values on the main diagonal are significantly lower: 54%, 33%, and 53%. Consequently, the highest value of the short-run M_1 mobility index calculated as per Equation (4) and depicted in Table 6 is obtained for Slovakia (0.80), while the Netherlands exhibits the lowest value of M_1 (0.67).

A comparison of the M_1 index for the 1-year period and the 9-year period indicates that all countries exhibit greater dynamics in the medium run than in the short run. This result is intuitive since one would expect that the probability of an indicator shifting its relative position in the *z*-score distribution is greater over a longer period. Moreover, a comparison between the three dimensions of sustainability reveals that, in the short term, the economic area exhibits the lowest dynamics. In contrast, the environmental dimension is the most dynamic for nine countries and the social area for nine countries. However, in the medium run, the mobility of the three areas is more balanced.

As a complement to the M_1 index, Table 6 also presents M_2 indices obtained from Equation (5). The M_2 index measures whether the movements represented by the probabilities in the transition matrix are concentrated. Therefore, greater values of M_2 are found in the medium run than in the short run. This result is intuitive since one would expect that movements of indicators are less concentrated throughout the transition matrix over the whole period than over 1 year. Moreover, as was the case for the M_1 index, a lower M_2 index is obtained in the economic dimension in the short term, while the three dimensions are more balanced in the medium term.

An analysis of the values in Table 6 also reveals a positive relationship between M_1 and M_2 indices in the short term. In particular, when M_2 is regressed on M_1, we obtain a slope parameter $\widehat{\beta} = 0.55$ ($p-\text{value} = 0.01$) for all SDGs, and similar results are obtained for the three dimensions. However, in the medium term, the relationship is negative $\left(\widehat{\beta} = -0.43;\ p-\text{value} = 0.03\right)$, although the slope parameter is not statistically significant for the economic and environmental dimensions. This means that as indicators become more mobile (i.e., depart from their initial thirds), they tend to distribute themselves to other thirds more evenly in the short run than in the medium run.

5 | CONCLUSIONS

The purpose of this paper has been to provide a comprehensive view of the dynamics and trends in the short and medium runs of the SDG indicators for a large set of EU Member States across the three dimensions of sustainability: people (social), planet (environmental), and prosperity (economy). Our aim has been to identify patterns in the evolution of sustainable development and study its dynamics and trends. We have contributed to the relevant literature by exploring an alternative framework based on Markov transition matrices to investigate the mobility of the official Eurostat SDG set of indicators.

The results provide valuable information to enhance the understanding of the different dynamics of sustainability across countries and dimensions; they are relevant to public policy in that they identify the regions and dimensions where greater emphasis needs to be placed on putting global goals back on track.

We have observed that the EU has significantly progressed in achieving sustainable development, as evidenced by the evolution of the average *z*-scores of SDG indicators and by the percentage of progressing indicators. This progress has been seen in all dimensions of sustainability and all EU regions. In this regard, no significant differences in the average SDGs' performance among European regions are observed, except for some differences in favor of the Western Member States vis-à-vis the Northern ones. As pointed out by Lafortune et al. (2021), some of these Northern countries, such as Denmark, Finland, and Sweden, started from a socioeconomic situation closer to the objectives set by the SDGs, so it is likely that less effort was required during the analyzed period in these countries in the socioeconomic dimension. In this sense, future studies based on a longer period will be necessary analyze if a convergence process is taking place within EU countries and regions.

Another interesting avenue for future research would be to explore the impacts of the coronavirus pandemic to see whether it has truncated the path of progress toward sustainable development. As pointed out by Lafortune et al. (2021), for the first time since the adoption of SDGs in 2015, the average SDG index score for the EU in 2020 declined slightly. Thus, the crisis and the current uncertainties arising at the economic level for the EU may imperil the fulfillment of the SDG targets when we are less than 10 years away from fulfilling the ambitions of the 2030 Agenda. This will require advancing the analysis of the most affected areas, which will demand more mobilization of resources, foster implementations at the national, regional, and local levels, and encourage institutions to meet the goals by 2030, leaving no one behind.

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APPENDIX: Markov transition matrices

TABLE A1 Markov transition matrices for all the sustainable development goals indicators.

Average one-year transition matrix				Nine-year transition matrix			
Austria	**T1**	**T2**	**T3**	**Austria**	**T1**	**T2**	**T3**
T1	0.52	0.33	0.15	T1	0.17	0.52	0.30
T2	0.32	0.38	0.30	T2	0.13	0.26	0.61
T3	0.16	0.29	0.55	T3	0.70	0.22	0.09
Belgium	T1	T2	T3	Belgium	T1	T2	T3
T1	0.53	0.30	0.17	T1	0.17	0.57	0.26
T2	0.30	0.41	0.29	T2	0.22	0.22	0.57
T3	0.17	0.29	0.54	T3	0.61	0.22	0.17
Czechia	T1	T2	T3	Czechia	T1	T2	T3
T1	0.54	0.29	0.17	T1	0.17	0.52	0.30
T2	0.29	0.44	0.27	T2	0.13	0.30	0.57
T3	0.17	0.27	0.56	T3	0.70	0.17	0.13
Denmark	T1	T2	T3	Denmark	T1	T2	T3
T1	0.54	0.33	0.13	T1	0.00	0.43	0.57
T2	0.27	0.42	0.31	T2	0.39	0.30	0.30
T3	0.20	0.24	0.56	T3	0.61	0.26	0.13
Estonia	T1	T2	T3	Estonia	T1	T2	T3
T1	0.55	0.28	0.16	T1	0.04	0.39	0.57
T2	0.30	0.40	0.29	T2	0.22	0.43	0.35
T3	0.14	0.32	0.54	T3	0.74	0.17	0.09
Finland	T1	T2	T3	Finland	T1	T2	T3
T1	0.57	0.30	0.13	T1	0.04	0.43	0.52
T2	0.31	0.39	0.30	T2	0.35	0.30	0.35
T3	0.12	0.31	0.57	T3	0.61	0.26	0.13
Germany	T1	T2	T3	Germany	T1	T2	T3
T1	0.54	0.29	0.17	T1	0.13	0.57	0.30
T2	0.28	0.46	0.26	T2	0.17	0.35	0.48
T3	0.18	0.25	0.57	T3	0.70	0.09	0.22
Greece	T1	T2	T3	Greece	T1	T2	T3
T1	0.57	0.31	0.13	T1	0.26	0.52	0.22
T2	0.27	0.45	0.28	T2	0.17	0.22	0.61
T3	0.16	0.24	0.59	T3	0.57	0.26	0.17
Hungary	T1	T2	T3	Hungary	T1	T2	T3
T1	0.61	0.30	0.09	T1	0.04	0.65	0.30
T2	0.27	0.42	0.31	T2	0.13	0.17	0.70
T3	0.13	0.28	0.60	T3	0.83	0.17	0.00
Ireland	T1	T2	T3	Ireland	T1	T2	T3
T1	0.56	0.30	0.14	T1	0.17	0.48	0.35
T2	0.30	0.41	0.29	T2	0.09	0.39	0.52
T3	0.14	0.29	0.57	T3	0.74	0.13	0.13
Italy	T1	T2	T3	Italy	T1	T2	T3

TABLE A1 (Continued)

Average one-year transition matrix				Nine-year transition matrix			
Austria	**T1**	**T2**	**T3**	**Austria**	**T1**	**T2**	**T3**
T1	0.60	0.30	0.10	T1	0.17	0.61	0.22
T2	0.28	0.40	0.32	T2	0.26	0.17	0.57
T3	0.13	0.30	0.58	T3	0.57	0.22	0.22
Latvia	T1	T2	T3	Latvia	T1	T2	T3
T1	0.55	0.29	0.15	T1	0.09	0.43	0.48
T2	0.28	0.39	0.33	T2	0.17	0.30	0.52
T3	0.16	0.32	0.52	T3	0.74	0.26	0.00
Lithuania	T1	T2	T3	Lithuania	T1	T2	T3
T1	0.57	0.33	0.11	T1	0.00	0.52	0.48
T2	0.27	0.41	0.32	T2	0.13	0.35	0.52
T3	0.17	0.26	0.57	T3	0.87	0.13	0.00
Netherlands	T1	T2	T3	Netherlands	T1	T2	T3
T1	0.59	0.31	0.10	T1	0.13	0.39	0.48
T2	0.26	0.45	0.29	T2	0.09	0.43	0.48
T3	0.15	0.24	0.61	T3	0.78	0.17	0.04
Portugal	T1	T2	T3	Portugal	T1	T2	T3
T1	0.57	0.32	0.11	T1	0.39	0.30	0.30
T2	0.31	0.40	0.29	T2	0.09	0.30	0.61
T3	0.13	0.28	0.60	T3	0.52	0.39	0.09
Romania	T1	T2	T3	Romania	T1	T2	T3
T1	0.54	0.34	0.13	T1	0.13	0.57	0.30
T2	0.28	0.41	0.30	T2	0.13	0.17	0.70
T3	0.18	0.25	0.57	T3	0.74	0.26	0.00
Slovakia	T1	T2	T3	Slovakia	T1	T2	T3
T1	0.54	0.34	0.13	T1	0.04	0.52	0.43
T2	0.33	0.33	0.35	T2	0.22	0.26	0.52
T3	0.14	0.34	0.53	T3	0.74	0.22	0.04
Slovenia	T1	T2	T3	Slovenia	T1	T2	T3
T1	0.58	0.29	0.13	T1	0.26	0.52	0.22
T2	0.30	0.38	0.32	T2	0.17	0.30	0.52
T3	0.13	0.33	0.55	T3	0.57	0.17	0.26
Spain	T1	T2	T3	Spain	T1	T2	T3
T1	0.57	0.30	0.13	T1	0.17	0.52	0.30
T2	0.28	0.42	0.30	T2	0.22	0.13	0.65
T3	0.15	0.27	0.58	T3	0.61	0.35	0.04
Sweden	T1	T2	T3	Sweden	T1	T2	T3
T1	0.52	0.33	0.16	T1	0.04	0.43	0.52
T2	0.31	0.40	0.29	T2	0.30	0.22	0.48
T3	0.17	0.28	0.55	T3	0.65	0.35	0.00