EXTENDED ABSTRACT

Title: Sustainable Development Goals in the European Union. Assessing the dynamics of achieving them through Markov chains

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Abstract:
Since 2015, the Sustainable Development Goals (SDGs) have marked the path for a more sustainable growth model in each of their three dimensions: economic, social and environmental. Monitoring relevant indicators is essential to assess the progress of this sustainable development to ensure the achievement of the set goals. To our knowledge, the attempts found in the relevant literature to advance in the monitoring of SDGs have been mainly based on the construction of aggregate indices at global level or on the level on individual SDGs, which are calculated as the average of a set of normalized indicators (e.g., OECD, 2019; SDSN and IEEP, 2020, among others). However, this methodological approach faces several problems related to aggregation, its static nature and its difficulty of interpretation and comparison among countries. Monitoring the progress of SDGs also suffers from a lack of consideration of the three dimensions of sustainability and their potential synergies or trade-offs.

We develop an alternative approach to the one mentioned earlier and investigate the dynamics of SDGs using Markov transition matrices. We seek inspiration from previous economic literature that investigated patterns in income distribution (e.g., Quah, 1993, 1996), trade specialization (e.g., Zaghini, 2005) or circular bioeconomy (Kardung and Drabik, 2021). The last-mentioned study is closest to ours as it analysed the mobility of 41 circular bioeconomy indicators in 10 European Union Member States over the years 2006-2016.

Following this approach, we aim to find patterns in the evolution of sustainable development in 20 European Union Member States from 2011 to 2019, monitoring the progress of 69 indicators distributed among three dimensions of sustainability:

economic, social and environmental. We pursue three objectives. First, we evaluate the direction and magnitude of the progress of sustainable development; second, we investigate the dynamics of SDGs and quantify their mobility over time; and third, we explore the possible differences among the three dimensions of sustainability.

The Eurostat SDG indicator set contains data for the 102 indicators proposed by Eurostat (2021). However, this database does not offer a homogenous time and country coverage for all indicators. Therefore, we have selected a sample that ensures a balanced panel dataset covering as many indicators, countries and years as possible. This procedure allows us to have data for 69 indicators in 20 EU Member States for the period of 2011-2019 (in total 12,420 observations) while simultaneously enabling a reliable degree of representativeness of the sample. First, the 69 selected indicators cover 68% of the indicators proposed by Eurostat and ensure a balance between the three dimensions of sustainability: economic (36 indicators out of 45), social (35 indicators out of 58) and environmental (23 indicators out of 46). Second, the 20 selected countries (Austria, Belgium, Czech Republic, Denmark, Estonia, Greece, Finland, Germany, Hungary, Ireland, Italy, Latvia, Lithuania, Netherlands, Portugal, Romania, Spain, Sweden, Slovakia, and Slovenia) are also proportioned in terms of geographical dispersion (according to the Eurovoc classification, five countries are from western Europe, four belong to southern Europe, six from the northern Europe, and five are included in central and eastern Europe) and in terms of their sustainable development (according to the SDSN ranking –SDSN and IEEP, 2020-, six of these countries are in the highest part of the ranking, seven in the medium part, and seven in the lowest positions). Finally, a nine-year period is covered (2011-2019), which allows us to investigate both sort-term and medium-term dynamics.

The first step in data management is ensuring consistency in the interpretation of the indicators. For some indicators such as per capita GDP, tertiary education attainment or resource productivity, a higher indicator value means a progression in sustainable development, whereas for other indicators like unemployment rate, people at risk of poverty, or CO2 emissions, a higher value indicates that sustainability is regressing. Therefore, a negative sign is applied to the latter type of indicators with a negative desired direction in order to ensure that a higher indicator value implies a move towards sustainable development.

The second step involves the normalization of indicators in order to enable the interpretation and comparison of diverse indicators with different magnitudes. To do so, for each country and for the average EU-20 countries, the z-score of each indicator in each year is calculated by measuring how many standard deviations the value of the indicator is away from the indicator's mean. Therefore, a positive z-score implies a value above the mean, and a negative z-score corresponds to a value below the mean over the whole period.

In order to assess the direction and magnitude of indictors' progress, z-scores are linearly regressed against a time trend. By doing so, if the estimated slope parameter of a given indicator is statistically significant, this indicates improvement (or deterioration) of the indicator over time while at the same time enabling us to rank the contribution of each indicator to sustainable development.

Then, the intra-distribution of indicators over time is analysed using Markov transition matrices in order to evaluate the SDG dynamics. To do so, indicators' values are classified into high, medium and low groups according to the tertile they belong to.

Then, the Markov matrices are constructed by calculating a square matrix in which each cell represents the corresponding transition probability, that is, the probability that an indicator from one tertile moves to another tertile in the next period. Both short and long-term matrices are obtained by looking at the average annual transitions or at the transitions over the whole period. In the latter case, to avoid the potential effect of outliers in the starting and ending points, the average of the first two years and the average of the last two years of the sample are used to evaluate long-term dynamics.

Finally, Shorrocks (1978) mobility indices (M1 and M2) are calculated to assess the extent of indicators movement among tertiles. A higher value of both indices implies higher mobility, although they measure different types of mobility. The calculation of the M1 index is based on the trace of the transition matrix, thus measuring the ratio between diagonal and off-diagonal transition probabilities, while the M2 index uses the determinant of the transition matrix and therefore measures all changes in the matrix.

Preliminary results show significant progress in sustainable development over the sample period (with an average z-score going from -0.67 to 1.04), which is more pronounced for the environmental dimension (with an average z-score from -1.26 to 0.95) than for the economics and social areas (with an average z-score from -0.49 to 0.98 and from -0.56 to 1.09, respectively). Moreover, if we look at the slope coefficient obtained by regressing the z-scores against a time trend, the environmental dimension presents the highest percentage of positive and significant coefficients, the lowest percentage of negative and significant coefficients and the highest value of coefficients. Differences between the economic and social dimensions are less pronounced, although the economic dimension seems to outperform the social area.

The comparison of the slope coefficients among indicators reveals that some of the most progressing indicators are the area under organic farming (SDG 2), standardised preventable and treatable mortality (SDG 3), tertiary educational attainment (SDG 4), real GDP per capita (SDG 8), employment rate (SDG 8), and population covered by the Covenant of Mayors for Climate and Energy signatories (SDG 17). On the contrary, the most regressing indicators are ammonia emissions from agriculture (SDG 2), share of buses and trains in total passenger transport (SDG 9), share of rail and inland waterways in total freight transport (SDG 9), disparities in household income per capita (SDG 10), overcrowding rate (SDG 11), and share of environmental taxes in total tax revenues (SDG 17).

Regarding the dynamics and mobility of the indicators over time, a greater M2 index is found in comparison with the M1 index, which is consistent with the definition of those two indices. Moreover, M1 index shows a higher dispersion, so it is used to compare mobility in the short- and long-run and between different dimensions of sustainability. On the one hand, all countries exhibit higher mobility in the long term than in the short term. This result is intuitive since one would expect that the probability of an indicator shifting from one tertile to another is more likely over the whole period than over a one-year period. On the other hand, results indicate that countries with higher mobility (and progress) in one dimension of sustainability tend to also have higher mobility (and progress) in the other two dimensions. This points out that countries tend to move as a block in all dimensions of sustainability, something that is particularly pronounced in the social-economic pair.

In sum, this research focuses on the dynamics and trends of sustainable development and contributes to the relevant literature by proposing an alternative approach to investigate the mobility of the official SDG indicators adopted in the European Union among the three dimensions of sustainability (economic, social and environmental). The results provide valuable information to enhance the understanding of the different dynamics of sustainability across countries and dimensions, thus having relevant implications in public policy.

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