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How Sustainable Development Goals interlinkages influence European Union countries' progress towards the 2030 Agenda

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Abstract

The analysis of interlinkages between the sustainable development goals (SDGs) and the assessment of countries' progress towards the goals are two prominent research areas in the debate around the 2030 Agenda. The central questions are whether countries are progressing towards the goals at sufficient speed, and whether the SDGs can be achieved in their entirety. While it is evident that trade-offs between the 2030 Agenda's objectives might prevent countries from achieving all 17 SDGs simultaneously, the extent to which interactions (synergies and trade-offs) between the goals facilitate or hinder countries' progress towards achieving the 2030 Agenda has so far received little attention. The present study combines the two topics by linking the analysis of synergies and trade-offs between the SDGs in the European Union (EU) member states with a longitudinal assessment of these countries' progress towards the goals. SDG interlinkages are assessed through Spearman's rank order correlation, while progress is calculated according to Eurostat's progress measure. Using regression analysis, we find a significant negative relationship between countries' progress and the shares of trade-offs among SDG indicators and a moderate positive relationship between progress and synergies, suggesting that trade-offs have a bigger influence on the pace of countries' progress towards the goals than synergies. In order to achieve the SDGs by 2030, it is thus crucial to not only exploit synergies between the goals but also to overcome trade-offs.

KEYWORDS
interlinkages, synergies and trade-offs, SDGs, composite index, measuring progress, European Union

1 | INTRODUCTION

The 2030 Agenda, adopted in September 2015 by 193 countries, provided a set of 17 sustainable development goals (SDGs) intended to be both universal and indivisible in nature. The 'universality' principle means that the SDGs should be achieved by 2030 by both the so-called developed and developing countries alike, whereas the 'indivisibility' principle refers to the notion that all 17 goals—be they of economic, environmental or social nature—are equally important and can only be achieved in conjunction. The 2030 Agenda highlights the significance of the interconnectedness between the goals by stating that 'the interlinkages and integrated nature of the Sustainable Development Goals are of crucial importance in ensuring that the purpose of the new Agenda is realised' (UN, 2015).

Since the 2030 Agenda's adoption, multiple attempts have been undertaken to monitor how far the countries are from

achieving the goals and how much progress they have already made (see, e.g., Eurostat, 2021b; Guijarro & Poyatos, 2018; Hametner & Kostetckaia, 2020; Miola & Schiltz, 2019; OECD, 2019; Sachs et al., 2021). However, it has also been questioned whether the 17 SDGs can be achieved in their entirety, due to possible conflicts between the economic and environmental goals (see, e.g., Hickel, 2019; Hickel & Kallis, 2020; Robra & Heikkurinen, 2019; Spangenberg, 2017). In response to this, many researchers have already studied how the 17 goals (and their 169 targets) are interconnected, with the aim to identify positive and negative interlinkages between them (Dalampira & Nastis, 2020; Linnerud et al., 2021; Pham-Truffert et al., 2020; Pradhan et al., 2017; Tremblay et al., 2020; Warchold et al., 2021). Positive interlinkages, that is, when progress towards one goal helps to achieve another goal, are usually referred to as synergies, while negative interlinkages are described as trade-offs, meaning that progress on one goal hinders the achievement of another goal.

While scholars have so far focused on applying a variety of methods for identifying synergies and trade-offs between the 17 SDGs—ranging from qualitative approaches such as expert judgement (e.g., International Council for Science, 2017; Singh et al., 2018; Weitz et al., 2018) to quantitative ones such as system-dynamics models (e.g., Moyer & Bohl, 2019; Pedercini et al., 2019) and to papers that combine several approaches, such as Dawes (2020) or Tremblay et al. (2020)—the extent to which these interlinkages influence the actual progress of countries towards (or away from) the goals has received little attention.

The present study aims to fill this gap, by linking the analysis of SDG interlinkages with a longitudinal assessment of countries' progress towards the goals. By doing so, this study seeks to contribute to better understanding the nature of the relationship between SDG interlinkages and progress towards the goals. The analysis of synergies and trade-offs is based on correlation analysis (Spearman's rho), and the assessment of progress builds on the progress measure developed by Eurostat and modified in a study by Hametner and Kostetckaia (2020). Both approaches are applied to the 27 member states of the European Union (EU) based on data from Eurostat's EU SDG indicator set. Regression and correlation analyses are then carried out to assess the link between SDG interlinkages and SDG progress over time.

The main research question this study consequently attempts to answer is: (1) How are synergies and trade-offs between the SDGs in the EU member states related to the progress these countries have made towards the SDGs? In order to analyse this relationship, the study also addresses the following questions: (2) What is the pattern of synergies and trade-offs between the SDGs in the EU member states? (3) Which regional differences exist between EU member states concerning SDG interlinkages?

The article is structured into six sections. Section 2 reviews the existing literature on monitoring SDG progress and on assessing the interlinkages between the goals. In Section 3, we discuss the data sources and methods used in the study. Section 4 describes the main results of the correlation and regression analyses and Section 5 discusses the results. Section 6 provides conclusions.

2 | LITERATURE REVIEW

The analysis of SDG interlinkages and the assessment of countries' progress towards the goals are two of the most prominent research areas in the current debate around the 2030 Agenda (Bennich et al., 2020; Hametner & Kostetckaia, 2020; Lafortune et al., 2020; Miola & Schiltz, 2019). Although both research streams vaguely refer to each other when discussing the implications of their findings, they have to date remained largely separated. Notable exceptions are the studies by Campagnolo et al. (2018) and by Biggeri et al. (2019), who explicitly take into account interlinkages between the goals for constructing their composite SDG indices. Campagnolo et al. (2018) extrapolate SDG indicators' trends to 2030 in order to assess future sustainability of countries, while their modelling framework allows to also see trade-offs and synergies between sustainability pillars. Biggeri et al. (2019), on the other hand, attempt to improve measuring progress towards the goals by considering interlinkages in a modified SDG progress index. Other studies, however, limit themselves to take note that SDG interlinkages might explain differences found between countries in terms of SDG achievement (Hametner & Kostetckaia, 2020; Miola & Schiltz, 2019), or that a better understanding of the nature of SDG interlinkages would help to achieve the 2030 Agenda (Bennich et al., 2020; Pradhan et al., 2017; Singh et al., 2018; Warchold et al., 2021).

The present study attempts to take the next logical step in this debate by combining the two research areas. However, unlike Biggeri et al. (2019) and Campagnolo et al. (2018), we do not just account for interlinkages in measuring progress towards the SDGs, but aim to shed light on the extent to which synergies and trade-offs facilitate or hinder countries in moving towards the 2030 Agenda's objectives. To this end, we seek to use synergies and trade-offs as explanatory variables for a measurement of countries' SDG progress. Such a research setting requires quantitative data at country level for both SDG interlinkages (synergies and trade-offs) and SDG progress over time (i.e., longitudinal data). Therefore, in the following subsections, we review the relevant literature and explain the choice of methods for the present study.

2.1 | Monitoring countries' progress towards the SDGs

Since the adoption of the 2030 Agenda and the SDGs, many studies and reports have attempted to measure sustainability levels of countries based on the SDG indicators (see, e.g., Campagnolo et al., 2018; Diaz-Sarachaga et al., 2018; Guijarro & Poyatos, 2018; Lafortune et al., 2020; Miola & Schiltz, 2019; Muff et al., 2017; OECD, 2019; Sachs et al., 2021). Most of these studies developed a composite index that aggregates available data into one number, which enables

the benchmarking of countries based on their SDG performance. Since indicators in a dataset often have different measurement units, normalisation of data is required before aggregation (OECD, 2008). Normalisation against a target value has widely been used in the literature (Çolak & Ege, 2013; OECD, 2008, 2019; Pasimeni, 2012). However, only few SDG targets are quantitative and provide a clear threshold against which countries' performance could be measured; thus, some studies defined 'ideal' target values based on scientifically defined thresholds or on average values of the top performing countries (OECD, 2019; Sachs et al., 2017, 2020, 2021, 2018, 2019). This results in an index that measures the performance of countries in relation to each other (Hametner & Kostetckaia, 2020; Miola & Schiltz, 2019), rather than the absolute progress the countries have achieved.

The results of such country rankings are quite homogeneous over time, with countries from Northern Europe usually topping the rankings and countries from Southern and Eastern Europe on the bottom (among the EU member states; Bolcárová & Kološta, 2015; Campagnolo et al., 2018; Diaz-Sarachaga et al., 2018; Hametner & Kostetckaia, 2020; Pasimeni, 2013). Even studies that publish annual updates like the SDG Index report (Sachs et al., 2016, 2017, 2020, 2021, 2018, 2019) show a remarkable consistency in the position of EU countries in the ranking. As Hametner and Kostetckaia (2020) demonstrated, this consistency leaves room for several—contradicting—interpretations regarding whether the countries have actually achieved any progress towards the goals. To address the issue, Hametner and Kostetckaia (2020) suggested an *absolute* measure of countries' progress towards the SDGs that is not dependent on the progress other countries have achieved and that can also be applied in the absence of quantified targets. The measure is based on calculating the compound annual growth rate (CAGR) of an indicator trend between two points in time—a method first developed by Eurostat (2014) and applied in their annual SDG monitoring reports (Eurostat, 2017, 2018, 2019a, 2019b, 2020b, 2021b). The method was further modified by Hametner and Kostetckaia (2020) and applied to the analysis of progress of the EU member states towards the goals. This method was used for the present study because it offers quantitative absolute aggregated longitudinal data on countries' progress towards the SDGs. Applying this method to the EU SDG indicators' time series allows calculating the absolute (i.e., not relative to other countries) progress the EU countries have achieved over time. As this method relies on assessing whether indicators are evolving in a desirable (e.g., increase in employment rate) or undesirable (e.g., increase in CO_2 emissions) direction, it allows calculating countries' progress towards (or movement away from) the SDGs even in the absence of quantified targets.

Most papers measuring progress towards the SDGs do not investigate the reasons behind good or bad performance of countries. Some studies mention that governments' commitment to achieve the SDGs might have an influence on countries' progress towards the goals (Sachs et al., 2018), while others question the integrity and compatibility of the SDGs, indicating that achievement of the goals in their entirety and within planetary boundaries might not be possible (Hickel, 2019; Hickel & Kallis, 2020; Jain & Jain, 2020; Randers et al., 2019; Robra & Heikkurinen, 2019). The present study aims to investigate interlinkages between the goals as a possible explanation of countries' progress (or lack thereof) towards the SDGs.

2.2 | Assessing interlinkages between the SDGs

As for assessing interlinkages between the SDGs, scholars have employed various techniques, varying from linguistic approaches, based on the wording of the targets (Le Blanc, 2015; Miola et al., 2019), to modelling complex systems interactions (Laspidou et al., 2020; Pedercini et al., 2019).

Since the purpose of our study is to find a quantifiable relationship between countries' progress towards the SDGs and the interlinkages between the goals, we rely on quantitative methods for identifying the interlinkages. Most studies using a quantitative approach applied Spearman's rank correlation analysis to the SDG indicators in order to identify synergies, which in that context are defined as strong positive correlations, and trade-offs (strong negative correlations). For example, Pradhan et al. (2017) identified the most frequent SDG interactions based on data for 227 countries. Kroll et al. (2019) analysed how synergies and trade-offs have changed over time and also provided an analysis of expected future interactions between the SDGs. Ronzon and Sanjuan (2019) applied correlation analysis to the bioeconomy-related SDGs and identified hotspots of synergies (SDGs 7 and 11) and trade-offs (SDGs 2 and 9). Warchold et al. (2021) applied several correlation methods, including Spearman's rank correlation, to identify interlinkages and analyse them considering population, location, income, and regional groups. The rationale behind the application of several correlation methods was to overcome the problem of undetected relationships and to distinguish between monotone linear, monotone non-linear, and non-monotone non-linear relationships. However, the authors came to the conclusion that while most interactions cannot be classified, the majority of identified synergies and trade-offs are monotone linear relationships that can be found with Spearman's rank correlation. For the purpose of our paper, there is consequently no need to distinguish between linear and non-linear monotone relationships in the identified synergies or trade-offs, and using Spearman's rank correlation thus appears sufficient due to its ability to capture monotone relationships (both linear and non-linear) between two variables, unlike Pearson's correlation analysis (Hauke & Kossowski, 2011).

The papers that relied on correlation analysis for identifying interlinkages explicitly recognised that correlation does not imply causality (i.e., a significant correlation between two variables does not imply that these two variables are causally linked, in the sense that one drives the other or that both are driven by the same third variable), but still considered it to be a useful method of measuring interlinkages because it helps to quantitatively assess whether improvements in one SDG coincide with improvements in other SDGs (Kroll et al., 2019; Pradhan et al., 2017). Moreover, as the authors of these papers claim, applying correlation analysis to many countries means that when a specific synergy or trade-off is found repeatedly it is likely that it does not appear by chance.

In line with current literature, we consequently apply a quantitative approach for assessing SDG interlinkages based on Spearman's rank correlation analysis. The results of the correlation analysis are then used to assess whether there is a relationship between the synergies and trade-offs found in the EU member states and these countries' progress towards the SDGs. Similar to other papers (e.g., Kroll et al., 2019; Warchold et al., 2021), we also look into the regional patterns of synergies and trade-offs within Europe as a potential explanatory factor for the differences in SDG interlinkages across countries.

3 | DATA SOURCES AND METHODS

3.1 | Data sources

The paper is based on the official EU SDG indicator set that was adopted by the European Statistical System Committee in 2017, which is also used by Eurostat for its annual SDG monitoring reports (Eurostat, 2021a). The indicators in the set have been selected based on their relevance for monitoring the SDGs in the EU context and can therefore be considered the most appropriate data source for assessing progress towards the goals across EU countries (Miola & Schiltz, 2019). The indicators fulfil numerous data quality requirements, such as sound methodology and procedure, compliance with EU and international standards and sustainability of statistical production (Eurostat, 2021a). The EU SDG indicator set comprises 100 indicators structured according to the 17 SDGs (Eurostat, 2020a). Thirty-six indicators are so called multi-purpose indicators and are used to monitor more than one goal. As a result, the number of indicators differs from goal to goal, ranging from a minimum of 5 to a maximum of 11 indicators. To avoid double-counting, multi-purpose indicators were only included once in all calculations. The data used in this study were extracted in September 2020 from the Eurostat website (Eurostat, 2019b).

3.2 | Methods

Our study applied four calculation methods to the EU SDG indicator set: (1) Spearman's rank-order correlation for investigating the interlinkages between the SDGs, (2) analysis of variance (ANOVA) for assessing regional differences across EU countries, (3) the progress measure developed by Hametner and Kostetckaia (2020) for calculating countries' development over time towards (or away from) the SDGs, and (4) regression analysis for studying the relationship between SDG interlinkages and progress.

3.2.1 | Spearman's rank-order correlation

Spearman's rank-order correlation coefficient evaluates the strength of an association between two variables (Spearman, 1904) and has been used for assessing interlinkages between the SDGs in several studies (Kroll et al., 2019; Miola et al., 2019; Pradhan et al., 2017; Ronzon & Sanjuan, 2019; Warchold et al., 2021). In this study, we carried out Spearman's rank correlation analysis across all pairs of indicator time-series with more than three data pairs in order to capture the correlations among and between the SDGs for the EU member states. In order to avoid the potentially disruptive effects of the economic crisis of 2008 and of the COVID-19 pandemic starting in 2020, we based the correlation analysis on the indicators' time series data from 2009 to 2019. However, depending on the data availability for a specific indicator and country, many time series were shorter.

Spearman's rank correlation was chosen due to its suitability for monotone non-linear relationships and low sensitivity to outliers (Hauke & Kossowski, 2011). In order to avoid false associations, prior to the correlation analysis we assigned a positive sign to indicators with values that would need to increase to achieve the SDGs (e.g., employment rate) and a negative sign to indicators with values that would need to decrease (e.g., greenhouse gas emissions). Positive correlation coefficients consequently represent synergies, and negative ones trade-offs.

In this study, a correlation between an indicator pair is considered significant if its p-value is below .1. Similarly to other studies (Kroll et al., 2019; Warchold et al., 2021), we use a threshold of ±0.5 for the correlation coefficient to define a synergy or a trade-off between an indicator pair because a relation is considered to be strong or moderate if it is above or below this threshold (Smarandache, 2016). Thus, a correlation is considered to be a synergy if the correlation coefficient (Spearman's rho) is above 0.5 and it is considered to be a trade-off if it is below −0.5. Indicator pairs with a correlation coefficient between −0.5 and 0.5 are labelled as non-correlations. The correlation results for each country are then aggregated by calculating the overall percentage of synergies, trade-offs and non-correlations for each country.

In line with (Warchold et al., 2021), we have also included non-significant correlations in our results. This was done in order to present a clearer picture of the nature of interlinkages within and between the SDGs, as earlier studies that used Spearman's rank correlation to calculate interlinkages gave the impression that the SDGs are highly correlated with each other, with most correlations being either strong synergies or trade-offs (Kroll et al., 2019; Miola et al., 2019; Pradhan et al., 2017; Ronzon & Sanjuan, 2019). As shown in this study and by Warchold et al. (2021), including non-correlations in the calculations yields a more accurate picture, as the majority of indicator pairs actually do not show a significant correlation or do not cross the synergy and trade-off thresholds.

3.2.2 | Analysis of variance

ANOVA was applied to investigate differences in the patterns of synergies and trade-offs across EU countries. Drawing on previous studies that utilised the concept of different socio-economic (or welfare-state) models to analyse intra-European differences of sustainable development (Hametner & Kostetckaia, 2020; Steurer & Hametner, 2013), we

TABLE 1 Socio-geographic grouping of EU member states for ANOVA calculations (loosely based on Hametner & Kostetckaia, 2020; Steurer & Hametner, 2013)

Socio-geographic group	Western Europe	Southern Europe	Northern Europe	Eastern Europe
Countries	Austria	Bulgaria	Denmark	Czechia
	Belgium	Croatia	Finland	Estonia
	Germany	Cyprus	Ireland	Hungary
	France	Greece	Netherlands	Latvia
	Italy	Malta	Sweden	Lithuania
	Luxembourg	Portugal		Poland
		Spain		Romania
		Slovenia		Slovakia

Abbreviations: ANOVA, analysis of variance; EU, European Union.

categorised the EU countries into four socio-geographic groups (see Table 1). ANOVA was then applied to analyse whether socio-geographic factors might—at least in part—explain the differences in the patterns of SDG interlinkages (and also the SDG progress scores) observed across different EU member states. Before running the ANOVA, we ensured that its assumptions concerning normal data distribution and equality/homogeneity of variances were met by means of the Shapiro–Wilk test and Levene's test.

3.2.3 | Progress measure

In order to calculate the progress EU member states have made towards the SDGs over the past 5 years, we applied the method used by Eurostat in their annual SDG monitoring reports and modified by Hametner and Kostetckaia (2020). The method involves calculating the CAGR between two points in time, referring to the past five-year period (usually 2013–2018 or 2014–2019), followed by non-linear transformation to calculate scores ranging from −5 (worst score, indicating strong unsustainable trends) to +5 (best score, indicating strong sustainable trends), with 0 (zero) meaning no movement in either direction. The CAGR formula is given in Equation (1).

$$\mathrm{CAGR} = \left(\frac{y_t}{y_{t_0}}\right)^{\frac{1}{t-t_0}} - 1 \quad (1)$$

where t_0 = base year, t = most recent year, y_{t0} = indicator value in base year, y_t = indicator value in most recent year.

The modified progress score calculation then applies a non-linear transformation to the growth rate of each indicator, using a cut-off point of 6% per year for 'sustainable' CAGR values and of 2% for 'unsustainable' values (Hametner & Kostetckaia, 2020). These different cut-off points reduce compensability of unfavourable trends (e.g., increase in GHG emissions) through favourable ones (e.g., in GDP growth) during the aggregation of country scores via the arithmetic mean. For a more detailed explanation of the method behind the applied progress measure, see Hametner and Kostetckaia (2020).

3.2.4 | Regression analysis

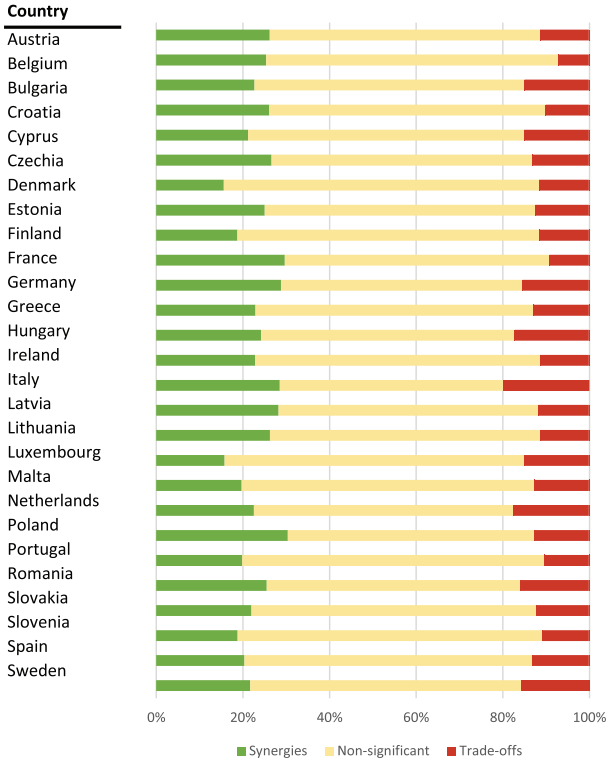
Linear regression analysis was applied to explore the relationship between SDG interlinkages and progress. The shares of synergies and trade-offs between a country's indicator pairs were used as independent variables, and the progress of this country towards the SDGs over the past 5 years as the dependent variable. While claiming a causal relationship based purely on statistical analysis might not be possible (Pearl, 2009), regression analysis helps us reveal whether the shares of synergies and trade-offs are statistically associated with the progress of countries towards the SDGs.

4 | RESULTS

The results from the correlation analysis reveal that the majority of the indicator pairs are actually non-correlations, meaning the results for Spearman's rho are either not significant or do not cross the threshold for being identified as a synergy or trade-off. As depicted in Figure 1, across the EU countries the shares of synergies vary between 15.6% for Denmark and 30.4% for Poland, while the shares of trade-offs range from 7.2% for Belgium to 19.9% for Italy. Aggregating the results at EU level reveals that there are on average about two times more synergies (23.6%) than trade-offs (13.0%), although it is noteworthy that these two together only account for slightly more than one third of all possible interactions (since almost two-thirds of the indicator pairs are not significantly correlated).

As indicated by the ratio of synergies to trade-offs in Figure 1, there are usually more positive than negative interlinkages across EU countries. The only exception is Luxembourg, with an almost equal share of synergies and trade-offs. The other extremes are Belgium and France, two neighbouring countries with over three times more synergies than trade-offs across all indicator pairs. Figure 1 also shows that the amount of indicator pairs available for the correlation analysis varies considerably across countries, from 3484 for Malta to 4475 for France.

Figure 2 depicts the geographical patterns in the distribution of synergies and trade-offs in the EU member states. The results from



Country	Synergies	Non-significant	Trade-offs	Ratio (S/T)	No. of indicator pairs
Austria	26.2%	62.4%	11.4%	2.30	4214
Belgium	25.4%	67.4%	7.2%	3.52	4468
Bulgaria	22.7%	62.3%	15.0%	1.52	3939
Croatia	26.1%	63.8%	10.1%	2.59	3714
Cyprus	21.2%	63.8%	15.0%	1.41	3744
Czechia	26.6%	60.3%	13.1%	2.04	4299
Denmark	15.6%	72.8%	11.6%	1.34	4397
Estonia	25.1%	62.4%	12.5%	2.00	4283
Finland	18.8%	69.7%	11.5%	1.63	4130
France	29.7%	61.1%	9.2%	3.22	4475
Germany	28.8%	55.8%	15.4%	1.87	4373
Greece	22.9%	64.2%	12.9%	1.78	4006
Hungary	24.2%	58.6%	17.2%	1.41	3760
Ireland	22.9%	65.8%	11.4%	2.02	4449
Italy	28.5%	51.6%	19.9%	1.43	4107
Latvia	28.3%	60.0%	11.7%	2.41	4196
Lithuania	26.2%	62.4%	11.4%	2.30	4024
Luxembourg	15.8%	69.2%	15.0%	1.05	3907
Malta	19.7%	67.6%	12.7%	1.55	3484
Netherlands	22.5%	59.8%	17.6%	1.28	4209
Poland	30.4%	56.8%	12.8%	2.38	4122
Portugal	19.9%	69.9%	10.3%	1.93	4088
Romania	25.5%	58.5%	16.0%	1.59	3637
Slovakia	22.0%	65.7%	12.3%	1.79	3864
Slovenia	18.8%	70.3%	10.8%	1.74	4290
Spain	20.4%	66.4%	13.2%	1.54	4042
Sweden	21.7%	62.6%	15.6%	1.39	4206

FIGURE 1 Shares of synergies, non-correlations and trade-offs (as well as the ratio of synergies and trade-offs) in the total amount of indicator pairs per European Union member state [Colour figure can be viewed at wileyonlinelibrary.com]

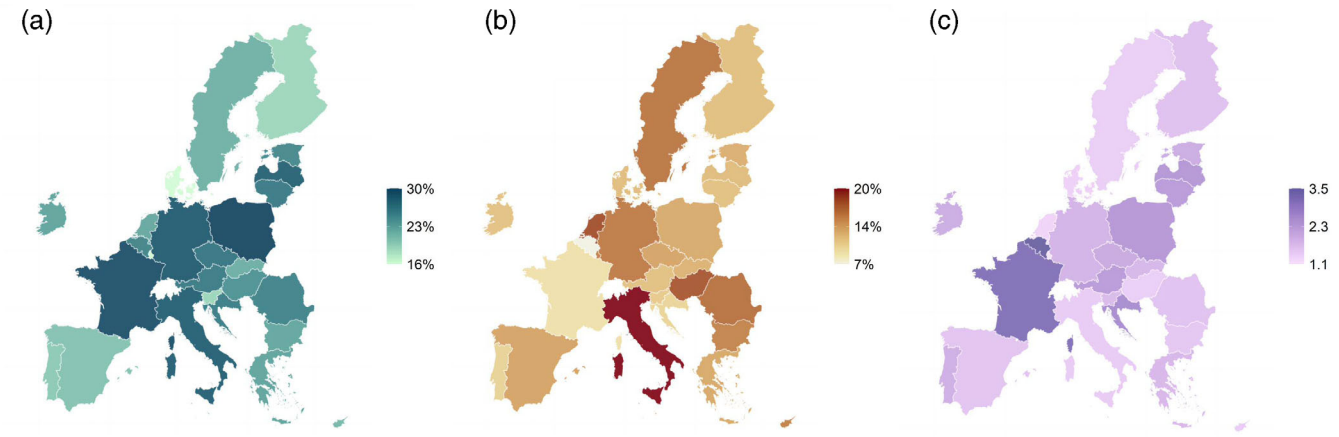


FIGURE 2 Visualisation of the shares of (a) synergies and (b) trade-offs and (c) the ratio of synergies to trade-offs in the European Union member states [Colour figure can be viewed at wileyonlinelibrary.com]

the ANOVA (see Table 2) reveal that the four socio-geographic groups—categorising the EU member states into northern, southern, eastern and western European countries—differ significantly in terms of SDG synergies ($F_{3,23} = 5.01$, $p = .008$). Tukey post hoc analysis (see Table 3) reveals that it is mainly northern and eastern European countries that show a statistically significant difference in their shares of synergies ($p = .028$), with the latter on average having a significantly higher share of synergies than the former. Differences are also observable between southern and eastern European countries ($p = .051$) and between western and northern countries ($p = .057$). In contrast, there are no significant differences between the four socio-geographic groups concerning the shares of trade-offs ($F_{3,23} = 0.175$, $p = .912$). Table 4 depicts the results of the Shapiro–Wilk test and Levene's test, showing that ANOVA is viable for the data.

In line with Pradhan et al. (2017), we also calculated the top-10 synergy and trade-off pairs based on data for all EU countries.

TABLE 2 ANOVA to test the differences in means between socio-geographic country groups in terms of SDG synergies, trade-offs and progress

Variable	Groups	*df*	Sum of squares	Mean square	*F*	Sig.
Synergies	Between groups	3	0.01656	0.00552	5.011	0.008
	Within groups	23	0.02534	0.00110		
Trade-offs	Between groups	3	0.00045	0.00015	0.175	0.912
	Within groups	23	0.01986	0.00086		
Progress	Between groups	3	0.539	0.1796	1.087	0.375
	Within groups	23	3.802	0.1653		

Abbreviations: ANOVA, analysis of variance; SDG, Sustainable Development Goal.

TABLE 3 Results for post hoc multiple comparisons (Tukey HSD)

			95% confidence interval		
Variable	Group comparison	Mean difference	Lower bound	Upper bound	Sig.
Synergies	North–East	−0.0573	−0.1097	−0.0049	0.0285
	South–East	−0.0457	−0.0917	0.0002	0.0511
	West–East	−0.0030	−0.0526	0.0466	0.9983
	South–North	0.0115	−0.0408	0.0639	0.9278
	West–North	0.0543	−0.0013	0.1099	0.0573
	West–South	0.0428	−0.0068	0.0924	0.1083

TABLE 4 Results for Levene's test for homogeneity of variances and the Shapiro–Wilk normality test

	Levene's test		Shapiro–Wilk test	
Variable	*F*	Sig.	*W*	Sig.
Synergies	0.5045	0.683	0.92836	0.063
Tade-offs	2.1368	0.1232	0.96236	0.4176
Progress	0.5206	0.6723	0.97875	0.8331

FIGURE 3 Visualisation of top-10 SDG pairs by the shares of synergies and trade-offs on the EU member state level. EU, European Union; SDG, Sustainable Development Goal [Colour figure can be viewed at wileyonlinelibrary.com]

Figure 3 shows that climate change (SDG 13) has many synergistic relationships with other goals, such as clean and affordable energy (SDG 7), good health and well-being (SDG 3) and responsible consumption and production (SDG 12). Conversely, fighting climate change (SDG 13) in the EU appears to be negatively associated with ending poverty (SDG 1) and hunger (SDG 2). Additionally, indicators on partnerships for the goals (SDG 17) show quite many trade-offs with other goals.

In order to assess how SDG interlinkages influence progress towards the goals, we then calculated the progress the EU countries have made towards (or away from) the SDGs over the past 5 years according to the progress measure by Hametner and Kostetckaia (2020). Table 5 shows the resulting country ranking according to the calculated progress score; the result is also visualised in Figure 4.

In line with Hametner and Kostetckaia (2020), we find that some countries from southern and eastern Europe have generally progressed most strongly towards the SDGs over the analysed time period, while western and northern European countries tend to lag behind (or have even moved away from the SDGs). Exceptions to this pattern include Ireland, showing the strongest overall SDG progress (with a score of 1.35), and the eastern European countries Bulgaria and Hungary, which have moved rather slowly towards the SDGs over the past 5 years. Two countries—Sweden and Luxembourg—show negative progress score results, indicating quite strong unsustainable trends for many indicators that have resulted in an overall moving

TABLE 5 Ranking of EU member states according to the progress measure (the past 5-year period) across all SDG indicators

Rank	Country	Progress score
1	Ireland	1.35
2	Greece	1.32
3	Czechia	1.30
4	Croatia	1.20
5	Slovenia	1.19
6	Latvia	1.04
7	Portugal	1.01
8	Italy	0.88
9	Lithuania	0.86
10	Estonia	0.84
11	Slovakia	0.78
12	France	0.71
13	Belgium	0.68
14	Poland	0.65
15	Malta	0.59
16	Spain	0.57
17	Denmark	0.57
18	Finland	0.48
19	Romania	0.47
20	Austria	0.47
21	Cyprus	0.44
22	Germany	0.44
23	Netherlands	0.29
24	Bulgaria	0.21
25	Hungary	0.21
26	Luxembourg	−0.13
27	Sweden	−0.16

Abbreviations: EU, European Union; SDG, Sustainable Development Goal.

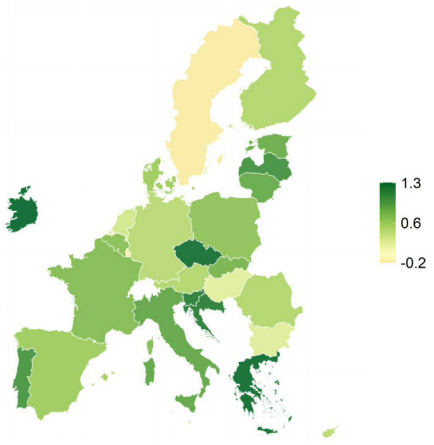


FIGURE 4 Visualisation of the progress the European Union member states have made over the past 5-year period according to the progress measure [Colour figure can be viewed at wileyonlinelibrary.com]

away from the SDGs over the analysed time span. In contrast to the ANOVA results for SDG interlinkages, however, the progress score means of the four socio-geographic country groups do not differ significantly from each other ($F_{3,23} = 1.087$, $p = .375$; see Table 2).

The final step in addressing the study's main research question is linking the results of the correlation analysis and the progress score calculations by means of regression analysis. The results in Table 6 reveal a significant relationship between the progress the countries have made towards the SDGs and the share of trade-offs among SDG indicators. The predicted progress score of a country with no synergies and trade-offs is 0.92, and each percentage point increase in the share of trade-offs decreases a country's SDG progress score by 0.07. At the same time, if the share of synergies increases by one percentage point, the expected progress score increases by 0.03. Thus, the results suggest that for an EU country, progress becomes slower with an increasing share of trade-offs and (only slightly) faster when the share of synergies increases.

Table 6 also shows that 28.5% of the variation in the EU countries' progress towards the SDGs can be explained by either synergies or trade-offs. It is, however, mostly trade-offs that drive the predicted power of the model. Nevertheless, despite the fact that the effect of the share of synergies is not large, it should not be dismissed. Almost 90% of the confidence interval for the share of synergies lies in the positive area, which indicates that it is quite likely that synergies between the SDGs positively influence progress of the countries towards the goals.

Correlation analysis confirms the results from the regression analysis. As shown in Table 7, there exists a significant negative correlation between the SDG progress score and the share of trade-offs as well as a moderate (though non-significant) positive correlation between SDG progress and the share of synergies. This means that countries with stronger progress towards the SDGs also face less trade-offs within and between the goals. Moreover, according to Table 7, these countries also show a higher ratio of synergies to trade-offs, indicating that not only trade-offs alone but also the combination of synergies and trade-offs seems to play a role for the progress countries can achieve towards the SDGs.

The results also reveal that, for EU countries, SDG synergies and trade-offs appear to be completely uncorrelated. In line with Figure 1 above, this indicates that synergies and trade-offs are not counterparts in an either-or situation, but that their occurrences are more or less independent.

5 | DISCUSSION

Performing regression and correlation analyses of countries' progress towards the SDGs and the shares of synergies and trade-offs between the goals in these countries yields interesting results. Countries that face more trade-offs between the SDGs also progress slower towards the SDGs, meaning that the presence of many trade-offs might be one of the reasons why some countries, especially from Northern and Western Europe, do not progress further towards the SDGs

TABLE 6 Results from the regression analysis of SDG progress (dependent variable) and the shares of SDG synergies and trade-offs (independent variables)

	Coefficient	*t*	Sig	95% confidence interval
Synergies	0.0276	1.57	0.129	[−0.0087, 0.0639]
Trade-offs	−0.0683	−2.71	0.012	[−0.1204, −0.0162]
Constant	0.9172	1.74	0.095	[−0.1705, 2.0049]
Number of obs.	27			
$F(2, 24)$	4.79			
Prob > F	0.0178			
R^2	0.2851			

Abbreviation: SDG, Sustainable Development Goal.

TABLE 7 Spearman's rank-order correlation coefficients between progress score, shares of synergies and trade-offs and ratio of synergies to trade-offs

	Progress	Synergies	Trade-offs	Ratio (S/T)
Progress	1			
Synergies	0.255	1		
Trade-offs	−0.547a	0.009	1	
Ratio (S/T)	0.615a	0.638a	−0.714a	1

[a]Denotes significant correlations at .05 level.

(Hametner & Kostetckaia, 2020). One of the reasons behind that might be that these countries have already exploited the most obvious synergies, such as when improvements in infrastructure lead to better access to health care and as a result better health outcomes, meaning that any further improvement might require disproportionally higher efforts. This is confirmed by the ANOVA results, showing that some eastern European countries exhibit higher levels of synergies than Western and Northern EU member states.

Another reason behind the lack of progress towards the SDGs and the high shares of trade-offs between and within the SDGs might be the problem of compatibility between the goals and the question of whether economic goals, focused on the GDP growth, can be achieved simultaneously with the environmental goals of staying within the planetary boundaries (a discussion on that can be found, e.g., in Hickel, 2019; Hickel & Kallis, 2020; Jain & Jain, 2020; O'Neill et al., 2018; Randers et al., 2019; Raworth, 2017; Robra & Heikkurinen, 2019; Wiedmann et al., 2020). While the topic of economic vis-à-vis environmental trends lies beyond the scope of the present study, our results indicate that trade-offs between, for example, GDP growth and resource and energy consumption in EU countries are indeed present.

Our results also demonstrate that synergies do not significantly influence EU countries' progress towards the SDGs. This is an important finding, taking into account that most sustainability policies tend to focus on positive interactions (synergies) between the SDGs and do not consider trade-offs (Nilsson & Weitz, 2019). For example, the 2030 Agenda only refers to 'win-win cooperation' between the goals (UN, 2015). Thus, focusing on trade-offs in addition to synergies might be a better strategy for policy-makers in order to achieve the global goals.

As noted in the previous section, synergies and trade-offs are completely uncorrelated to each other, meaning that a country with few synergies cannot automatically be expected to face many trade-offs (and the other way round). This illustrates the importance of also including non-significant correlations in the analysis of SDG interlinkages, as in their absence synergies and trade-offs appear to be perfectly correlated, creating an 'either-or' situation that might convey a misleading picture of the interactions between the 2030 Agenda's goals.

Our results showed that across the EU member states between 52% and 73% of all correlations were non-significant, indicating that the majority of SDG indicator trends are not correlated. This, however, does not imply that there is no relationship, but merely shows that over the past years these indicators did not evolve in parallel. One of the reasons behind this might be a time lag effect, when one variable reacts to changes in another with a certain delay (e.g., an economic contraction does not immediately lead to higher poverty rates; Warchold et al., 2021). Another reason might be due to the application of threshold—one of the methodological conditions for a correlation analysis—which could cause some correlations between indicator trends to remain undetected.

6 | CONCLUSIONS

The purpose of this study was to investigate the relationship between SDG interlinkages and progress towards the goals. Our results suggest that trade-offs among the goals slow down countries' progress towards achieving the objectives of the 2030 Agenda, while synergies exhibit a slight accelerating effect. The existence of such a relationship underlines the importance of exploiting synergies and resolving trade-offs between the goals in order for countries to improve on their SDG achievement. However, in contrast to the dominant view of focusing on win-win situations, we conclude that it is mainly trade-offs that determine a country's pace towards the 2030 Agenda's objectives. In line with Kroll et al. (2019), it therefore seems crucial to tackle the question how trade-offs can be overcome and ideally turned into synergies in order to ensure achievement of the SDGs in their entirety by 2030.

Our study has important implications for SDG policy making, especially in the EU member states. Since synergies and trade-offs are not correlated with each other, acting on synergies while also addressing trade-offs can be expected to yield better results than only focusing on one of these aspects. However, our study also suggests that the most

advanced countries in terms of SDG achievement from northern Europe might have already exploited most of the synergistic relationships between the SDGs. Addressing and overcoming the existing trade-offs seems more important for these countries since it might enable them to break free from their current stagnating SDG achievement and put them back on a path towards meeting the 2030 Agenda.

Moreover, our study also has important implications for research, especially on SDG interlinkages. Various studies, including our own, have demonstrated the existence of SDG interlinkages, with both reinforcing (i.e., synergies) and cancelling (i.e., trade-offs) relationships between different indicators. To support the achievement of the 2030 Agenda, future research should go one step further by putting a stronger focus on the nature of the prevailing trade-offs and how they might be overcome. Additionally, future research could investigate the relevance of other explanatory factors—beyond SDG interlinkages—that drive countries' progress towards the goals. For example, analysing SDG governance arrangements in relation to the progress score calculations could help improve our understanding of why many countries are currently not on track towards realising the 2030 Agenda's vision of the future.

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