Interrelations of the Sustainable Development Goals in Ierms of Alignments and Conflicts between Each Pair of Goals.

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Abstract

The purpose of this research was to investigate the Sustainable Development Goals (SDGs) by analyzing the interrelations and the possible conflicts among each pair of goals. Since there are 17 Sustainable development Goals (SDG1 - SDG17) in different aspects such as economics, subjective well-being, environmental concern, some pairs of goals might be complementing while some goals might be achieved at the expense of other goals. The results that were obtained based on the data during the COVID 19 pandemic (2020-2021). Data of all goals during the year 2020-2021 from countries in European region were collected from the Sustainable Development database. The nonparametric Spearman's rank correlation (ρ) analysis was employed to examine the monotonic associations between all possible combinations of the unique goal data pairs. The evidence from this study was beneficial for policy makers to form optimal strategies aimed to achieve the overall SDGs or to be aware of any possible conflicts among goals and develop some mechanisms to reconcile these existing conflicts. In addition, it also revealed the dynamic of interrelations and conflicts among SDGs during the crisis interval compared to the long-term span.

Keywords: Sustainable Development Goals, Economic Growth, Spearman Rank Correlation Analysis

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ความสัมพันธ์ระหว่าง SDGs ในด้านที่ไปในทิศทางเดียวกันและตรงกันข้ามกัน

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บทคัดย่อ

การวิจัยครั้งนี้มีวัตถุประสงค์เพื่อตรวจสอบเป้าหมายการพัฒนาที่ยั่งยืน (SDGs) โดยการวิเคราะห์ความสัมพันธ์และความขัดแย้งที่เป็นไปได้ในแต่ละคู่ของเป้าหมาย เนื่องจากมีเป้าหมายการพัฒนาที่ยั่งยืนมี 17 ประการ (SDG1 - SDG17) ในด้านต่างๆ เช่น เศรษฐศาสตร์ ความเป็นอยู่ที่ดี ด้านสิ่งแวดล้อม เป้าหมายบางคู่จึงอาจช่วยเสริมได้ในขณะที่บางเป้าหมายอาจทำได้สำเร็จโดยมีความขัดแย้งกับเป้าหมายอื่น ผลลัพธ์ที่ได้มาจากข้อมูลในช่วงการระบาดของ COVID 19 (2020-2021) ข้อมูลเป้าหมายทั้งหมดระหว่างปี 2563-2564 จากประเทศต่างๆ ในภูมิภาคยุโรป รวบรวมจากฐานข้อมูลการพัฒนาที่ยั่งยืน การวิเคราะห์อันดับสหสัมพันธ์ (ρ) ของ Spearman แบบไม่อิงพารามิเตอร์ถูกนำมาใช้เพื่อตรวจสอบความสัมพันธ์แบบโมโนโทนิก ระหว่างชุดค่าผสมที่เป็นไปได้ทั้งหมดของคู่ข้อมูลเป้าหมายที่ไม่ซ้ำกัน หลักฐานจากการศึกษานี้เป็นประโยชน์สำหรับผู้กำหนดนโยบายในการสร้างกลยุทธ์ที่เหมาะสมที่สุดโดยมีเป้าหมายเพื่อให้บรรลุเป้าหมาย SDG โดยรวม หรือเพื่อรับทราบข้อขัดแย้งที่อาจเกิดขึ้นระหว่างเป้าหมาย และพัฒนากลไกบางอย่างเพื่อประนีประนอมความขัดแย้งที่มีอยู่เหล่านี้ นอกจากนี้ ยังเผยให้เห็นไดนามิกของความสัมพันธ์และความขัดแย้งระหว่าง SDGs ในช่วงวิกฤตเมื่อเทียบกับช่วงระยะยาว

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Introduction

Recently, sustainable development has gained value as a concept to an achievement of human development goals that consider as well the sustainability in natural environments. The desirable outcome for sustainable development is a society where human necessities can be continuously satisfied in term of living standards and required resources at the same time, not having to impair the moral and stability of the natural system. The notion of sustainable development has been emphasizing not just economic development, but also social development and environmental preservation as important components of the overall process. In 2015, the UN General Assembly approved the 2030 Agenda for Sustainable Development, which was endorsed by 193 of its members. The UNGA established a framework for sustainable development planning and programming at the national, regional, and global levels over the following 15 years, until 2030, in order to meet the global Sustainable Development Goals (SDGs). The structure had 17 overall goals, 169 specific targets, and 232 measurable indicators. In 2016 led to the establishment of the SDGs framework's implementation. A worldwide agreement to eradicate poverty had a list of goals to defend all that makes the world habitable and assure that everyone would be able to gain peace and prosperity in the present and future generations. The SDGs recognized that the world needed a substantially more sustainable approach. The aims gave a well-researched framework that was adequate, scientifically, politically acceptable, and intuitive to the public. In addition, the goals offered the best opportunity to ensure the essential collaboration and alignment in the execution of global approaches pertinent to a just, healthy, and prosperous future for people, their children, and grandchildren. As part of the Global Transformation for Sustainable Development, the 2030 Agenda presented the concepts and agreements for a more equal and sustainable future for all people. The Sustainable Development Goals included SDG1 (No poverty), SDG2 (Zero hunger), SDG3 (Good health and well-being), SDG4 (Equality of education), SDG5 (Gender equality), SDG6 (Clean water and sanitation), SDG7 (Affordable clean energy), SDG8 (Decent work and economic development), SDG9 (Industry, innovation, and infrastructure), SDG10 (Reduce inequalities), SDG11 (Sustainable cities and communities), SDG12 (Responsible consumption and production), SDG13 (Climate action), SDG14 (Life below water), SDG15 (Life on land), SDG16 (Peace, justice and strong institutions), and SDG17 (Partnerships to achieve the goals).

For this reason, we will look at how the Sustainable Development Goals (SDGs) interact with one another, as well as any potential conflicts that may arise between them. The following sections are the literature review, the data and methodology section, the discussion of the results section, and the conclusion section.

Literature Review

The concept of sustainable development has been in an attention for more than two decades. Bossel (1999) provided a thorough explanation for sustainable development in his book including the different definitions, prerequisite for sustainable development, concepts, constraints, and suggested indicators to measure sustainable development. Whereas the Member States of the United Nations adopted a new universal agenda for sustainable development in September of 2015, there has been an increase in the number of efforts being made to gain a better understanding of the linkages and interrelationships among the Sustainable Development Goals. This has resulted in an increase in the number of people working toward this goal. The 2030 Agenda for Sustainable Development is the target of these activities, which focused at attaining it (SDGs). As a consequence of this, many individuals are of the opinion that it is of the highest significance to build integrated plans and strategies that take into account the possibility of conflicts and trade-offs among various goals, while also fostering synergies across a broad range of objectives.

The International Council for Science (ICSU) and the International Social Science Council (ISSC) have recently collaborated on a paper in which they discuss the manner in which each of the Sustainable Development Goal objectives are related to other goals (ICSU & ISSC, 2015). The United Nations Global Sustainable Development Study for 2015 and 2016 embraced the Sustainable Development Goals (SDGs) as a linked network of goals as the major basis for the report. This report was published in 2015 and 2016. (United Nations, 2015, 2016). SDG6 (UN-Water, 2016) and SDG4 (Vladimirova & Le Blanc, 2016) have both produced detailed lists of relationships between the aims of one SDG and those of other SDGs. Work of a similar kind is now being done in other SDG domains. Generic network maps of the Sustainable Development Goals were suggested in Le Blanc (2015). (ICSU, 2017). The International Resource Panel has conducted research into the links that exist between the Sustainable Development Goals and natural resources (UNEP, 2015).

Ngankam (2019) examines positive associations between each pair of SDGs from countries in South Africa, noting that researchers are mostly in agreement that the SDGs are connected. Unsurprisingly, his research found that there was a correlation between SDG7 (which focuses on

affordable and clean energy) and SDG13, which focuses on ending poverty (climate action). In addition, the research found a further point of convergence between SDG8 (achievement of decent employment and economic growth) and SDG13 (climate action). These evidences of correlation were particularly noteworthy due to the fact that economic expansion equals higher industrial progress.

Likewise, Nilsson et al. (2016) make the same observation: The SDG logic implies that the objectives are interdependent, even though there was no clear explanation precisely how. For example, it was underlined that SDG4 (Equal access to education) should improve SDG3 (Good health and well-being) and SDG1 (No poverty), SDG5 (Gender equality), and a part of SDG8 (economic growth). Additionally, Nilsson et al. (2016) discuss characteristics of SDGs associations, such as interaction intensity, uni- vs. bi-directionality, and if an association was synergistic (or positively correlated) or antagonistic (or negatively correlated). In specific, it was often believed that the relationship between poverty and hunger was strong, bidirectional, and synergistic. Pradhan et al. (2017) noted a lack of data-driven analyses of connections across SDGs indicators while arguing that the SDGs were inherently linked. Positive correlations were interpreted as synergies and negative correlations as tradeoffs between indicator pairs within across the SDGs. Spearman's rho (ρ) > +0.6 indicates synergy between two SDG metrics, while -0.6 indicates that tradeoffs must be evaluated. In the recent research work by Pradhan et al. (2017), it was shown that SDG1 (Zero poverty) had a substantial positive link with SDG5, which aims to ensure that no one lives in extreme poverty (Gender equality). Although they are not among the top ten realized synergies, SDG1 (No poverty) and SDG2 (Zero hunger), as well as SDG5 (Gender equality) and SDG2 (Zero hunger), have significant synergistic relationships. However, there were both synergies and tradeoffs between SDG13 (climate action) and SDG2 (Zero hunger). Larson and Larson (2019) The results confirm significant interrelationships between the sustainable development goals (SDGs); particular, SDG1 (No poverty), SDG2 (Zero hunger), SDG5 (Gender equality), and SDG13 (climate change). No poverty, fostering gender equality, and environmental goal appeared to step in the direction of eliminating world hunger.

According to Le Blanc et al. (2017) it is evident that there are considerable interdependencies between the goals. However, the "real-world" repercussions of what is done in one target zone on other regions are frequently unanticipated and can be either useful or detrimental. This is because the "real-world" effects can come from either positive or negative actions. In addition, a number of targets are primarily the recipients of interlinkages, meaning they are impacted by a significant number of other targets.

Data and Methodology

The index score of 17 SDG goals from 46 countries in Europe during the year 2019-2020 were collected from the online database for the Europe Sustainable Development Report 2021 by Sachs et al. (2021). The dimension of data set was 17 goals x 46 countries x 2 years. The data contained the SDG Index Score calculated over time using the indicator sets for each goal. For example, SDG1: No poverty index score was calculated based on three indicator sets which were (1) people at risk of income poverty after social transfer in percentage, (2) severely materially deprived people in percentage, and (3) poverty headcount ratio at $5.50 per day in percentage (Indicator sets for each goal was available in the Appendix). In each country, each of the 17 goals in the year 2020 was categorized into 4 layers namely (1) goal achieved, (2) challenges remain, (3) significant challenges, and (4) major challenges. According to the time series of the index score during the year 2019-2020, the goal was categorized into 4 layers namely (1) on track or maintaining achievement, (2) moderately increasing, (3) stagnating, and (4) decreasing.

The nonparametric Spearman's rank correlation (ρ) analysis was employed to examine the monotonic associations between each pair of all the SDG goal index scores. Spearman's correlation coefficient (ρ) was developed by Spearman (1904) as a measurement for estimating how strong an association was between two variables. According to Hauke & Kossowski (2011), Spearman's correlation method was superior to the Pearson's correlation due to its relative less sensitivity to outliers and its ability to capture the nonlinear association between the two variables. Spearman's rank correlation was extensively applied to evaluate nonlinear association between two variables in wide ranges of disciplines including biology (Zhang, 2015), fuel engineering (Andriani et al., 2020), and finance and economics (Bilan et al., 2019).

The Spearman's rank correlation analysis was performed on the data pairs that contained more than three data points in order to avoid the probability of false findings of complementing or controverting as a consequence of an inadequate amount of data. The correlation value would be considered as a strongly significant association when its p-value was less than 0.01 (***), a moderately significant association when its p-value was less than 0.05 (**), and a weakly significant association when its p-value was less than 0.1(*).

An association between each pair of SDG index scores was specified into three categories as followed (1) complementing goals, (2) controverting goals, and (3) unclassified.

Discussion of Results

Selecting 2 from all of the 17 SDG index scores resulted in 272 permutations. The values of Spearman's rank correlation and related statistics were reported in Table 1:

Table 1: Statistical Results

	SDG2	SDG3	SDG4	SDG5	SDG6	SDG7	SDG8	SDG9
SDG1	-0.2104	-0.2181	0.0397	0.1154	0.0346	0.1392	0.4525	0.5048
	-1.3945	-1.3778	0.2575	0.7438	0.2218	0.9325	3.3273	3.7442
	0.1705	0.1763	0.7981	0.4612	0.8256	0.3562	0.0018	0.0006
							***	***
SDG2		-0.0275	-0.1098	0.0000	0.0880	-0.1729	-0.4046	0.0873
		-0.1780	-0.6813	0.0000	0.5655	-1.1243	-2.9345	0.5745
		0.8595	0.4998	1.0000	0.5748	0.2674	0.0053	0.5686
							***	
SDG3			0.1518	0.1932	-0.0839	0.2331	-0.0889	0.0045
			0.9952	1.3060	-0.5584	1.5903	-0.5920	0.0297
			0.3253	0.1994	0.5795	0.1195	0.5571	0.9765
SDG4				0.3027	0.2153	0.0894	0.0252	0.0794
				2.0340	1.4621	0.5888	0.1613	0.5222
				0.0485	0.1508	0.5591	0.8726	0.6042
				**				
SDG5					-0.0359	0.3466	0.1349	0.5614
					-0.2383	2.4228	0.8718	4.4491
					0.8128	0.0197	0.3884	0.0001
						**		***
SDG6						-0.0718	-0.0861	0.0868
						-0.4723	-0.5532	0.5711
						0.6391	0.5831	0.5709

Table 1: Statistical Results (Continue)

	SDG2	SDG3	SDG4	SDG5	SDG6	SDG7	SDG8	SDG9
SDG7							0.4007	0.3000
							2.8001	2.0621
							0.0078	0.0453
							***	**
SDG8								0.1001
								0.6598
								0.5129

Note: The three numbers for each pair of SDG index scores were the Spearman's correlation value, the t-value, and the p-value. *** indicated significance at 1%, ** indicated significance at 5%, and * indicated significance at 10%.

Table 2: Statistical Results (Continue)

	SDG10	SDG11	SDG12	SDG13	SDG14	SDG15	SDG16	SDG17
SDG1	0.2906	0.1776	-0.1615	-0.1564	0.1262	0.1881	0.0429	-0.2615
	1.9912	1.1271	-1.0479	-1.0506	0.8438	1.1170	0.2846	-1.7768
	0.0528	0.2666	0.3008	0.2992	0.4034	0.2718	0.7773	0.0827
								*
SDG2	-0.2073	-0.0367	0.3555	0.0103	0.0990	-0.4821	-0.1449	0.0412
	-1.3571	-0.2411	2.3755	0.0657	0.6597	-3.6504	-0.8542	0.2735
	0.1822	0.8106	0.0225	0.9479	0.5129	0.0007	0.3990	0.7858
			**			***		
SDG3	-0.1231	0.1351	0.0693	0.1615	-0.2249	0.0426	0.0156	0.1542
	-0.8229	0.9048	0.4609	1.0852	-1.5308	0.2828	0.1036	1.0355
	0.4151	0.3709	0.6472	0.2845	0.1335	0.7787	0.9180	0.3077
SDG4	0.3561	0.0724	-0.2136	-0.0089	0.0592	-0.0100	0.2554	-0.0209
	2.3799	0.4648	-1.4501	-0.0591	0.3456	-0.0660	1.7321	-0.1369
	0.0223	0.6445	0.1541	0.9531	0.7318	0.9477	0.0904	0.8917
	**						*	
SDG5	0.2083	0.0094	0.0036	0.1597	-0.3127	0.0303	0.3623	0.1133

Table 2: Statistical Results (Continue)

	SDG10	SDG11	SDG12	SDG13	SDG14	SDG15	SDG16	SDG17
	1.3298	0.0599	0.0241	1.0729	-1.9199	0.2011	2.5487	0.7476
	0.1913	0.9525	0.9809	0.2892	0.0633	0.8415	0.0145	0.4588
				*			**	
SDG6	0.0532	0.4221	-0.2286	-0.2152	-0.0237	0.1946	0.2624	-0.3273
	0.3330	2.9811	-1.5579	-1.4617	-0.1381	1.3163	1.7835	-2.2716
	0.7409	0.0048	0.1264	0.1509	0.8910	0.1949	0.0816	0.0282
		***					*	**
SDG7	0.1815	0.2176	-0.2558	0.0607	0.3847	0.2319	0.1732	-0.1332
	1.1525	1.4273	-1.7549	0.4035	2.4301	1.5812	1.1530	-0.8816
	0.2561	0.1611	0.0862	0.6886	0.0205	0.1210	0.2553	0.3829
			*		**			
SDG8	0.2759	0.2979	-0.2854	-0.0621	0.2350	0.3567	0.3481	-0.3839
	1.7923	1.9984	-1.9750	-0.4126	1.4097	2.5330	2.4347	-2.7261
	0.0808	0.0523	0.0546	0.6819	0.1677	0.0150	0.0191	0.0092
	*	*	*			**	**	***
SDG9	0.0844	0.3584	-0.0644	0.0000	-0.0115	0.1200	0.2969	-0.1231
	0.5287	2.4578	-0.4282	0.0000	-0.0669	0.8020	2.0387	-0.8132
	0.6000	0.0183	0.6706	1.0000	0.9471	0.4269	0.0477	0.4206
		**					**	
SDG10		0.1039	-0.0876	0.0170	-0.0016	-0.1527	0.0820	-0.0176
		0.6688	-0.5832	0.1128	-0.0093	-1.0250	0.5396	-0.1152
		0.5074	0.5627	0.9107	0.9926	0.3109	0.5923	0.9088
SDG11			-0.2977	-0.4389	-0.0385	0.1914	0.3365	-0.3612
			-2.0689	-3.2397	-0.2249	1.2935	2.3433	-2.5400
			0.0445	0.0023	0.8234	0.2026	0.0238	0.0148
			**	***			**	**
SDG12				0.3338	-0.2025	-0.4117	-0.5011	0.1740
				2.3486	-1.2054	-2.9963	-3.7975	1.1585

Table 2: Statistical Results (Continue)

	SDG10	SDG11	SDG12	SDG13	SDG14	SDG15	SDG16	SDG17
				0.0234	0.2364	0.0045	0.0005	0.2530
				**		***	***	
SDG13					-0.1679	-0.0962	-0.4313	0.3227
					-0.9933	-0.6413	-3.1347	2.2361
					0.3276	0.5247	0.0031	0.0306
							***	**
SDG14						0.1357	0.1870	-0.0767
						0.9088	1.2481	-0.5046
						0.3684	0.2188	0.6164
SDG15							0.3294	-0.2091
							2.2880	-1.4022
							0.0271	0.1680
							**	
SDG16								-0.2450
								-1.6570
								0.1048

Note: The three numbers for each pair of SDG index scores were the Spearman's correlation value, the t-value, and the p-value. *** indicated significance at 1%, ** indicated significance at 5%, and * indicated significance at 10%.

SDG5 (gender equality) and SDG9 (industry innovation and infrastructure): OECD (2022) agreed that with the development of industrialization and infrastructure, woman would be equipped with more capability to access the necessary services and to raise economic opportunities therefore the industrialization and infrastructure development were critical for gender equality.

SDG6 (clean water and sanitation) and SDG11 (sustainable cities and communities): This finding implied that improving the quality of water and sanitation contributed to sustainable cities and communities. It was in according to Ismayilova et al. (2019) who stated that to create the smart and sustainable cities, it required an effective and efficient water management system.

SDG7 (affordable and clean energy) and SDG8 (decent work and economic growth): This synergy had been criticized by several contradicting findings observed in different regions of the world. Gogu et al. (2021) reported that based on the empirical study conducted during the year 2000-2019 on 28 European Union countries, affordable and clean energy was a significant determination for the sustainable economic growth in the European Union. However, Ahmed et al. (2021) revealed that these two goals were tradeoff because research conducted in Japan found that an increased in carbon dioxide was triggered by economic growth.

The other pairs of SDGs that were *positively and moderately associated* were:

- SDG2 (no hunger) and SDG12 (responsible consumption and production)

- SDG4 (quality education) and SDG5 (gender equality)

- SDG4 (quality education) and SDG10 (reduced equalities)

- SDG5 (gender equality) and SDG7 (affordable and clean energy)

- SDG5 (gender equality) and SDG16 (peace, justice, and strong institutions)

- SDG7 (affordable and clean energy) and SDG9 (industry innovation and infrastructure)

- SDG7 (affordable and clean energy) and SDG14 (life below water)

- SDG8 (decent work and economic growth) and SDG15 (life on land)

- SDG8 (decent work and economic growth) and SDG16 (peace, justice, and strong institutions)

- SDG9 (industry innovation and infrastructure) and SDG11 (sustainable cities and communities)

- SDG9 (industry innovation and infrastructure) and SDG16 (peace, justice, and strong institutions)

- SDG11 (sustainable cities and communities) and SDG16 (peace, justice, and strong institutions)

- SDG12 (responsible consumption and production) and SDG13 (climate action)

- SDG13 (climate action) and SDG17 (partnerships for the goals)

- SDG15 (life on land) and SDG16 (peace, justice, and strong institutions)

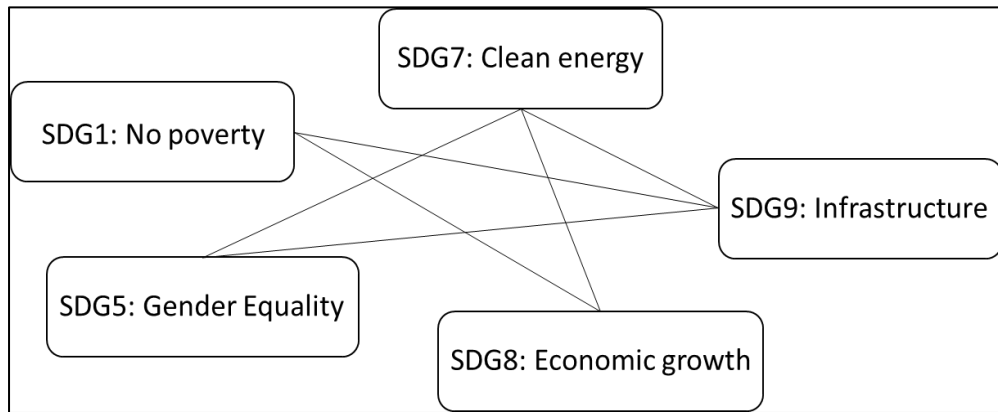The synergistic goals were summarized in Figure 1.

Figure 1: The interrelation among synergistic goals

The goals that were positively correlated or having synergies could be relatively easier to manage. For this reason, we should be more interested in the goals that were negatively correlated or having conflicting directions. According to Table 1,

The essential pairs of SDGs that were *negatively and strongly associated* included:

SDG2 (no hunger) and SDG8 (decent work and economic growth): At the first glance, it might seem that economic growth would reduce no hunger. However, the result implied that hunger problem could not be solved by fostering economic growth (ρ = -0.4046, p-value = 0.0053). This evidence could be explained by McGuire (2013)'s study on the state of food insecurity in the world. In McGuire (2013), the economic growth measured by the gross domestic product (GDP) and per-capita income were investigated with the indicators of hunger and malnutrition. The results concluded that an improvement in economic growth did not essentially decrease food shortage and malnutrition in all people particularly the very poor ones. The explanation was that the poorest regularly had neither the financial resources to buy sufficient amount of food nor the non-financial resources to produce it. Furthermore, although the fiscal benefits of economic expansion did stretch to the poor, other psychological or habitual factors such as a persistent propensity to not purchase good nutrient foods could diminish their potentially nutritional position. As a result, advancement of economic growth that worsen the gap between the rich and the poor might therefore deteriorate the goal of no hunger.

SDG2 (no hunger) and SDG15 (life on land): The result revealed that the association between SDG2 and SGD 15 was ρ = -0.4821, p-value = 0.0007. The strong trade-off between no hunger and life on land was also mentioned by Zhang et al. (2021). However, Zhang et al. (2021) also provided mechanism to reconcile these two competing goals by using spatial optimization that aimed to

minimize conservation costs given a threshold level of biodiversity targets or alternatively to maximize biodiversity gains with the provided conservation budget.

SDG11 (sustainable cities and communities) and SDG13 (climate action): This evidence (ρ = -0. 4389, p-value = 0.0023) was against the study by Pradhan et al. (2017) that reported positive correlation between these two goals. However, Pradhan et al. (2017) also mentioned that the associations under past might not hold for the future due to changing paradigms in term of technology and economic condition.

The other strong conflicts found were tradeoff between SDG12 (responsible consumption and production) and SDG15 (life on land), SDG12 (responsible consumption and production) and SDG16 (peace, justice, and strong institutions), and SDG13 (climate action) and SDG16 (peace, justice, and strong institutions)

The pairs of SDGs that were *negatively and moderately associated* included SDG6 (clean water and sanitation) and SDG17 (partnerships for the goals), SDG11 (sustainable cities and communities) and SDG12 (Responsible Consumption and Production), and lastly, SDG11 (sustainable cities and communities) and SDG17 (partnerships for the goals)
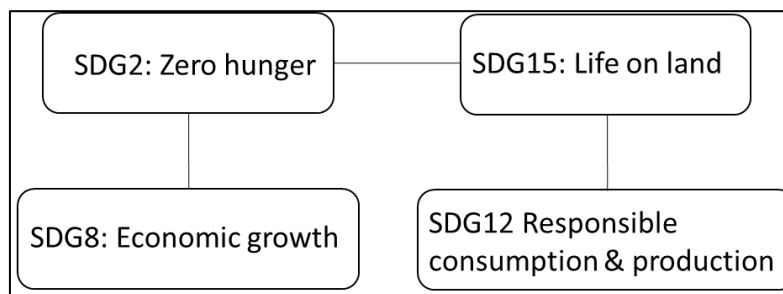
The conflicting goals were summarized in Figure 2.

Figure 2: The interrelation among conflicting goals

The only one SDG that was insignificant (neither complementing nor contradicting with all of the other goals) was SDG3 (Good health and well-being). This goal comprised of 18 indicators, some of these included the life expectancy at birth, percentage of population with good or very good perceived health, gap in self-reported health by income, suicide rate, mortality rate under the age of five, people killed in road accidents, percentage of surviving infants who received two WHO-recommended vaccines, and subjective wellbeing. Based on the result that it was not statistically significantly associated with other goals; it could be the easiest goal to manage without having to

consider its effect that might be contradicting with any other goals. Researcher proposed that well-being might be more associated with internal or psychological factors.

Conclusion

The analysis of results revealed that there existed several synergistic goals as well as conflicting goals in the European Countries. The goals that were found to have the most positive associations with other goals were SDG8 (decent work and economic growth) and SDG16 (peace, justice, and strong institutions). In particular, an economic growth was positively associated with the other six goals including SDG1 (no poverty), SDG7 (affordable and clean energy), SDG10 (reduced inequalities), SDG11 (sustainable cities and communities), SDG15 (life on land), and SDG16 (peace, justice, and strong institutions). This evidence confirmed an important role of decent work and economic growth on the other aspects of sustainable development regarding environmental and societal aspects. Policy makers could gain the benefits from strategies aiming to achieve a goal of decent work and economic growth that focusing on such indicators namely protection of fundamental labor rights, gross disposable income, youth not in employment, education, or training, unemployment rate, people killed in accidents at work, in work at-risk-of-poverty rate, and fatal work-related accidents embodied in imports which would contribute to an enhancement of the other synergistic goals. Nevertheless, an association might not imply causal influence, therefore, further investigations are needed to confirm whether there is any original root cause of these synergistic goals or whether any goal is the determinant of the others.

More remarkably, the goals that were found to have the most negative correlation with the other goals were SDG12 (responsible consumption and production) and SDG17 (partnerships for the goals). In specific, the strongest negative statistical significance was detected between SDG17 (partnerships for the goals) and SDG8 (economic growth). Therefore, policy makers may need to investigate the indicators in SDG17 including official development assistance, shifted profits of multinationals, corporate tax haven score, and statistical performance index and it could be further explored some mechanisms to reconcile these tradeoffs.

Limitations and suggestions for future research include firstly, due to data limitation, the research focused on countries in European region which may not be a good representative for other regions with different technological and economical paradigms. Further studies could be conduct to examine whether there is a different or similar association between each pair of goals in different

regions of the world, or across regions with different paradigms. Secondly, the results of associations were based on the historical data and it might be changing across time due to changing in paradigms as well. Thirdly, this study conducted exploration on associations between each pair of goals by employing correlation measure. For policy implementations, future studies maybe needed to further investigate on the causal effects between these goals, identifying the other common causes that influence the indicators in each pair of conflicting goals, studying the goal alignments and conflicts along the different time span, analyzing the association among goals that may differ across countries, and examining the possibility that the findings may change with other economic factors such as the per capita GDP or the real economic growth.

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Appendix

Appendix 1: Indicator sets for each goal

Goal	Indicator sets
SDG1: No poverty	People at risk of income poverty after social transfers (%)
	Severely materially deprived people (%)
	Poverty headcount ratio at $5.50/day (%)
SDG2: No hunger	Prevalence of obesity, BMI ≥ 30 (% of adult population)
	Human Trophic Level (best 2–3 worst)
	Yield gap closure (%)
	Gross nitrogen balance on agricultural land (kg/hectare)
	Ammonia emissions from agriculture (kg/hectare)
	Exports of pesticides banned in the EU (kg per 1,000 population)
SDG3: Good Health and well-being	Life expectancy at birth (years)
	Gap in life expectancy at birth among regions (years)
	Population with good or very good perceived health (% of population aged 16 or over)
	Gap in self-reported health, by income (p.p.)
	Gap in self-reported unmet need for medical examination and care, by income (p.p.)
	New reported cases of tuberculosis (per 100,000 population)
	Standardised preventable and treatable mortality (per 100,000 persons aged less than 75)
	Suicide rate (per 100,000 population)
	Age-standardised death rate attributable to household air pollution and ambient air pollution (per 100,000 population)
	Mortality rate, under-5 (per 1,000 live births)
	People killed in road accidents (per 100,000 population)
	Surviving infants who received 2 WHO-recommended vaccines (%)
	Population engaging in heavy, episodic drinking at least once a week (%)

Appendix 1: Indicator sets for each goal

Goal	Indicator sets
	Smoking prevalence (%)
	People covered by health insurance for a core set of services (%)
	Share of total health spending financed by out-of-pocket payments (%)
	Subjective Wellbeing (average ladder score, worst 0–10 best)
	Individuals that use the internet to make appointments with a practicioner (%)
SDG4: Quality education	Participation in early childhood education (% of children between age of 3 and starting age of compulsory primary education)
	Early leavers from education and training (% of population aged 18 to 24)
	PISA score (worst 0–600 best)
	Underachievers in science (% of population aged 15)
	Variation in science performance explained by students' socio-economic status (%)
	Tertiary educational attainment (% of population aged 25 to 34)
	Adult participation in learning (%)
SDG5: Gender equality	Unadjusted gender pay gap (% of gross male earnings)
	Gender employment gap (p.p.)
	Population inactive due to caring responsibilities (% of population aged 20 to 64)
	Seats held by women in national parliaments (%)
	Positions held by women in senior management positions (%)
	Proportion of ICT specialists that are women (%)
SDG6: Clean water and sanitation	Population having neither a bath, nor a shower, nor indoor flushing flushing toilet in their household (%)
	Population connected to at least secondary wastewater treatment (%)
	Freshwater abstraction (% of long-term average available water)

Appendix 1: Indicator sets for each goal

Goal	Indicator sets
	Scarce water consumption embodied in imports (m³/capita)
	Population using safely managed water services (%)
	Population using safely managed sanitation services (%)
SDG7: Affordable and clean energy	Population unable to keep home adequately warm (%)
	Share of renewable energy in gross final energy consumption (%)
	CO2 emissions from fuel combustion per electricity output (MtCO2/TWh)
SDG8: Decent work and economic growth	Protection of fundamental labor rights (worst 0–1 best)
	Gross disposable income (€/capita)
	Youth not in employment, education or training (NEET) (% of population aged 15 to 29)
	Unemployment Rate (% labor force)
	People killed in accidents at work (per 100,000 population)
	In work at-risk-of-poverty rate (%)
	Fatal work-related accidents embodied in imports (per 100,000 population)
SDG9: Industry, Innovation, and Infrastructure	Gross domestic expenditure on R&D (% of GDP)
	R&D personnel (% of active population)
	Patent applications to the European Patent Office (per 1,000,000 population)
	Households with broadband access (%)
	Gap in internet access, urban vs rural areas (p.p.)
	Individuals aged 55 to 74 years old who have basic or above basic digital skills (%)
	Logistics performance index: Quality of trade and transport-related infrastructure (worst 1–5 best)

Appendix 1: Indicator sets for each goal

Goal	Indicator sets
	The Times Higher Education Universities Ranking:
	Average score of top 3 universities (worst 0–100 best)
	Average score of top 3 universities (worst 0–100 best)
	Scientific and technical journal articles (per 1,000 population)
SDG10: Reduced inequalities	Gini Coefficient
	Palma ratio
SDG11: Sustainable cities and communities	Urban population without access to green urban areas in their neighborhood (%)
	Overcrowding rate among people living with below 60% of median equivalized income (%)
	Recycling rate of municipal waste (%)
	Population living in a dwelling with a leaking roof, damp walls, floors or foundation or rot in window frames or floor (%)
	Exposure to air pollution: PM2.5 in urban areas (μg/m3)
SDG12: responsible consumption and production	Circular material use rate (%)
	Gross value added in environmental goods and services sector (% of GDP)
	Production-based SO_2 emissions (kg/capita)
	Imported SO_2 emissions (kg/capita)
	Production-based emissions of reactive nitrogen (kg/capita)
	Imported emissions of reactive nitrogen (kg/capita)
SDG13: Climate action	CO_2 emissions from fossil fuel combustion and cement production (tCO2/capita)
	CO_2 emissions embodied in imports (tCO_2/capita)
	CO_2 emissions embodied in fossil fuel exports (kg/capita)

Appendix 1: Indicator sets for each goal

Goal	Indicator sets
	Bathing sites of excellent quality (%)
	Fish caught from overexploited or collapsed stocks (% of total catch)
	Fish caught by bottom trawling or dredging (%)
	Fish caught that are then discarded (%)
	Marine biodiversity threats embodied in imports (per million population)
	Mean area that is protected in marine sites important to biodiversity (%)
SDG15: Life on land	Mean area that is protected in terrestrial sites important to biodiversity (%)
	Mean area that is protected in freshwater sites important to biodiversity (%)
	Biochemical oxygen demand in rivers (mg O2/litre)
	Nitrate in groundwater (mg NO3/litre)
	Red List Index of species survival (worst 0–1 best)
	Terrestrial and freshwater biodiversity threats embodied in imports (per million population)
SDG16: Peace, Justice, and strong institutions	Death rate due to homicide (per 100,000 population)
	Population reporting crime in their area (%)
	Gap in population reporting crime in their area, by income (p.p.)
	Access to justice (worst 0–1 best)
	Timeliness of administrative proceedings (worst 0–1 best)
	Constraints on government power (worst 0–1 best)
	Corruption Perceptions Index (worst 0–100 best)
	Unsentenced detainees (% of prison population)
	Exports of major conventional weapons (TIV constant 1990 million USD per 100,000 population)
	Press Freedom Index (best 0–100 worst)

Appendix 1: Indicator sets for each goal

Goal	Indicator sets
SDG17: Partnerships for the goals	Official development assistance (% of GNI)
	Shifted profits of multinationals (billion USD)
	Corporate Tax Haven Score (best 0–100 worst)
	Statistical Performance Index (worst 0-100 best)

Source: Lafortune, G., Cortés Puch, M., Mosnier, A., Fuller, G., Diaz, M., Riccaboni, A., Kloke-Lesch, A., Zachariadis, T., Carli, E. Oger, A., (2021). Europe Sustainable Development Report 2021: Transforming the European Union to achieve the Sustainable Development Goals. SDSN, SDSN Europe and IEEP. France: Paris.