

Approaches to study SDG interactions:

Literature review of relevant frameworks

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Introduction

The United Nations 2030 Agenda for Sustainable Development consists of 17 Sustainable Development Goals (SDGs) and 169 targets that address social, economic and environmental factors that affect sustainable development across the world. The SDGs are integrated in one framework, which means efforts to realise one goal may contribute to or raise new challenges for the pursuit of one or more other goals (Barbier & Burgess, 2017; Griggs et al., 2017). In other words, the integrated and indivisible nature of the 17 SDGs means that their interaction can yield far reaching and various (both positive and negative) effects. While complex, contradictory and consecutive effects are a reality, for analytical purposes and clarity, in this literature study we have made a distinction between two types of interactions, being: synergies and trade-offs. Given the complex interactions, researchers, development practitioners as well as policy makers need tools and approaches to systematically explore and better understand how synergies between SDGs can be realised and trade-offs minimised (Griggs et al., 2017). It is with those aims in mind that the Dutch Research Council (NWO) initiated the 'Sustainable Development Goals Interactions and Policy Interventions in Developing Countries' programme (*SDG Interactions Programme*).

This literature review is the first knowledge product produced by the project team responsible for the Knowledge Brokering and Synthesis project (KBS project) under the SDG Interactions Programme. By identifying and outlining the most relevant and recent scientific approaches to study SDG interactions, it serves a dual goal: 1) acquire a first insight into the state-of-the-art literature and current scientific debates on SDG Interactions; 2) provide the three selected research consortia with a 'springboard' from which they can commence their literature reviews targeted to their own thematic foci.

About the SDG interactions programme

The research programme 'SDG Interactions and policy Interventions in Developing Countries' is part of the Dutch Research Agenda (NWA) programme and initiated by the Dutch Ministry of Foreign Affairs (MFA).

The aim of the programme is to gain new insights into the interdependencies between the SDGs and what their effects and impact are on policy interventions. For this programme, three central themes have been identified:

1. Governance and decision-making regarding the SDG process
2. Synergy and trade-offs between individual SDG objectives
3. Climate change as a security risk

One research consortium is funded within each theme, in addition to which a fourth consortium is funded for carrying out a 'Knowledge Brokering and Synthesis' (KBS) project which serves to bring insights of the three research consortia together and ensure that their results become more than the sum of its parts.

While the review provides relevant insights on SDG interactions, it mainly focuses on works that seek to make conceptual and methodological contributions to the study of those interactions. To identify these studies and approaches, a quick-scan of relevant literature based on a Google Scholar search was conducted. By using pre-established keywords on SDG interactions, we looked for academic articles that have been published between 2015 and 2021.¹

To complement the Google Scholar search, we further followed a snowball sampling method: We looked at the reference list of each identified article, at articles that were cited by the identified articles, and at related articles on Google Scholar. In this phase, we selected the most relevant articles by looking at the title and keywords. The initial Google Scholar search combined with the snowball sampling method yielded a list of 116 articles. Of these articles we read the abstracts and introductions, selecting those studies that: 1) propose a particular approach to study SDG interactions; 2) present insights on effects of SDG interactions or; 3) look at SDG interactions between different domains (e.g. social and ecological) rather than only within domains. Studies with a concrete focus on policies or intentions that did not adhere to any of the three aforementioned criteria were not included in the analysis. This exercise resulted in a more narrow selection and analysis of 29 articles that are included in Table 2 in the Annex of this document (page 13). This table provides an overview of, among others, the methodology of the study, the proposed measurement to study SDG interactions, and the universality of the proposed approaches and analysis. As the table also shows, our literature study suggests that there exists a wide variety of approaches and measurement instruments to study how SDGs interact, with the research question and methodological framework defining to a large extent the approach undertaken by scholars. This finding illustrates the lack of common language to study SDG interactions, which has implications for both analysis and policy making.

The following document presents the most important findings of our literature review. The first section presents general insights and patterns in studies on SDG interactions that we distilled from the analysed 29 articles. Chapter 3, thereafter, will look in greater detail at approaches to study SDG interactions. Finally, in chapter 4, this literature review concludes with key take-aways for academics studying SDG interactions.

¹ We used the following keywords on Google Scholar: “sustainable development goals” OR “SDGs” AND synergies OR synergy OR trade-off OR interaction OR interdependency OR interdependencies OR hierarchies OR hierarchy OR quantitative approach OR linkages AND methodology OR Approach.

General insights on SDG interactions

2.1 Trend overviews 2015-2021

Since their adaptation in 2015, an increasing body of literature evaluates how SDGs and their underlying 169 targets are interrelated and mutually influence each other's outcome. Similarly, a variety of academic studies has proposed models and approaches that researchers and policymakers can use to evaluate the interaction among SDGs (Biggeri et al., 2019; Breuer et al., 2019; Kroll et al., 2019). A quick search of academic literature on Google Scholar demonstrates the absolute and cumulative growth in studies and (quantitative) approaches on SDG interactions, as the following figure shows²:

SDGs AND interactions en SDG interacion AND quantitative approach

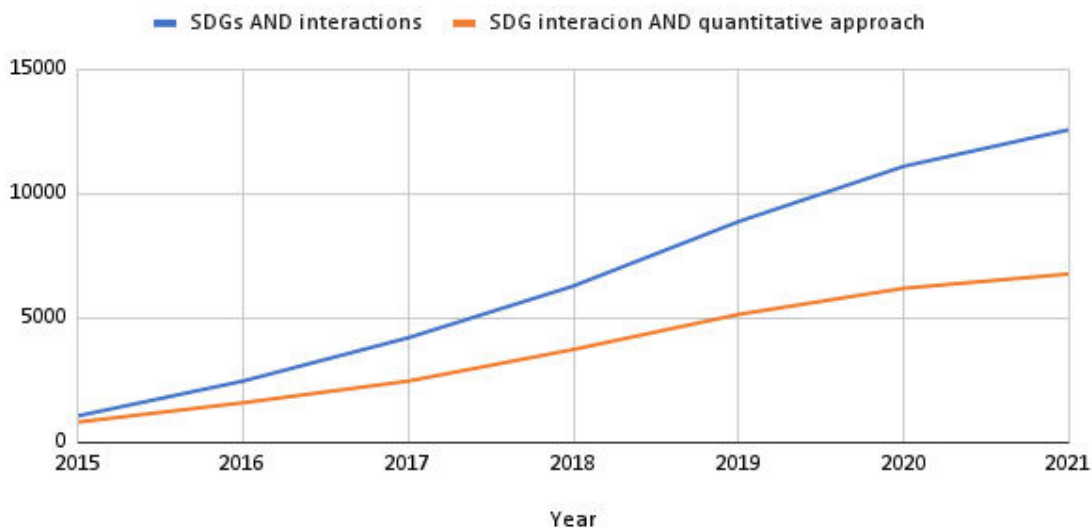


Figure 1: Absolute growth of studies and approaches to SDGs interaction

2.2 Focus and degrees of interaction

Most studies seek to improve on existing approaches on SDG interactions (e.g. Biggeri et al., 2019; Breuer, Janetschek & Malerba 2019; Kroll, Warchold & Pradhan, 2019) and only a few present novel approaches to evaluate how SDGs interact (e.g. Dolley et al., 2020; Hegre et al., 2020). One interesting example of a study that suggests a novel approach is the *'Guide to SDG interactions'* by the [International Council for Science \(2017\)](#). This report explores the nature, strength and potential impact of SDG interactions by using a 7-point scale to evaluate the key target-level interactions between one selected 'entry goal' and all other goals and attribute a score to these interactions. Using this approach, the authors demonstrate that the four analysed SDGs in the study – SDG 2 (Zero Hunger), 3 (Good Health and Wellbeing), 7 (Affordable and clean energy) and 14 (Life below water) – are mostly synergic with other SDGs.

² Please note: the 2021 number predicted is based on the trendline in previous years.

As presented in table 2 included in the Annex, there are a multitude of approaches to study the indivisible nature of SDGs, using different measurement scales and degrees of interaction. While some studies specifically focus on trade-offs or synergies between SDGs (Barbier & Burgess, 2017; Dörge et al., 2018; Zelinka & Amadei, 2019), the majority of the consulted literature on SDG interactions captures both synergies *and* trade-offs. Fader et al. (2018), for instance, use positive and negative indicators to capture both synergies and trade-offs among targets of SDGs 2, 6 and 7. Indicators in this measurement scale range from ‘Cancelling (-4) to Indivisible (4) (See Table 1). Based on their method and this measurement scale, the authors demonstrate that in some cases targets are mutually supportive, while in others no interactions among the targets can be identified. Similarly, their analysis shows that, for some areas, the targets are in conflict with each other.

Interaction	Name	Explanation
-4	Canceling	Makes it impossible to reach another goal
-3	Restricting	Obstructs the achievement of another goal
-2	Counteracting	Clashes with another goal
-1	Constraining	Limits options on another goal
0	Consistent	No net significant positive or negative interactions
1	Enabling	Creates conditions that further another goal
2	Reinforcing	Aids the achievement of another goal
3	Supporting	Strongly facilitates the achievement of another goal
4	Indivisible	Inextricably linked to the achievement of another goal

Table 1: Example of a measurement scale to capture synergies and trade-offs between SDGs, Fader et al. (2018)

2.3 System thinking and time series analysis

In general, existing studies confirm the idea that SDGs and their targets are intimately linked. This means that developments towards one goal (or underlying targets) will inevitably affect others. The notion of ‘system thinking’ is a central idea underpinning most of the studies. That is, most studies underline the indivisible nature of the SDGs: the goals should be considered as part of an interlinked system and not studied individually or in pairs (Biggeri et al., 2019; Karnib, 2017). Rather, the key is in their interactions and although some studies draw attention to the neutral and negative effects of interactions (Fonseca et al., 2020; van Soest et al., 2019; Zelinka & Amadei, 2019), the majority of studies conclude that synergies largely outweigh such trade-offs.

It is important to note that while a few studies make an effort to look at the various SDGs across a period of a few years, this literature review did not identify approaches that apply a systematic time series analysis that seeks to evaluate the *longitudinal* fluctuation of trade-offs and synergies between SDGs. Hegre et al.’s study (2020) forms an exception. In their research, the authors design and implement a time-series, tracing changes in SDG interactions for the period 2000-2016. The limited amounts of literature conducting a time series analysis could be explained by a lack of data (Moinuddin & 周, 2017; Zelinka & Amadei, 2019; Zhao et al., 2021), that is why further research is needed to understand how SDGs interact with each other over a longer period of time.

Synergies and priorities

In addition to confirming the indivisible nature of SDGs, most studies also provide a framework for both researchers and policymakers to understand how SDGs should be prioritised when faced with limited resources. Models that shed light on how SDGs interact provide a valuable foundation for decision making as they allow for interventions that generate more synergies and avoid trade-offs between the SDGs.

When looking for synergies and deciding on what SDGs to prioritise, various studies point out that some goals cannot be achieved before addressing a prerequisite goal (Kumar et al., 2018). Pradhan et al. (2019), for instance, conclude that SDG 1 (No Poverty) is associated with synergies across most SDGs and ranks five times in the [global top-10 synergy pair list](#). This means that achieving other SDGs associated with SDG 1 becomes easier if the goal of 'no poverty' is actively pursued in tandem with the other goals. As the next section shows, most quantitative, non-systemic studies subscribe to this conclusion (Barbier & Burgess, 2017; Fonseca et al., 2020; Hegre et al., 2020; Kroll et al., 2019). This idea is also supported by the analysis of 'causal loops networks' by Dörgő et al. (2018), emphasising the interlinked nature of the problems of poverty, proper sanitation and economic support in sustainable development. Similarly, Breuer et al. (2019) confirm the general belief that SDG 6 (Clean Water and Sanitation) has the highest number of potential synergies (a total of 124), which implies that achieving water targets facilitates the pursuit of other targets.

In conclusion, while the various presented approaches for studying the SDGs are interesting and valuable from an academic standpoint, for policymakers and practitioners the findings on interactions are most helpful. It is these findings, after all, that have direct implications for those who seek to realise policy coherence and stimulate synergies between the SDGs.

2.4 Disciplines and methodologies

An important feature of studies of SDG interactions is that they are not bound to a specific field or methodology. Although field-specific approaches (e.g. economics, development studies and environmental studies) are well represented, most studies have an inter- or transdisciplinary character. Quantitative and statistical analyses represent the majority in the consulted studies on SDG interactions. Qualitative and mixed methods are also well represented among methodological choices (see Table 1 for an overview).

Whether a study on SDG interactions takes a conceptual or empirical approach largely depends on factors such as the research question, availability of data and the level of analysis. Conceptual studies are mostly qualitative and tend to provide a line of argumentation through which synergies and trade-offs can be understood (Bali Swain & Ranganathan, 2021; Zhao et al., 2021). Empirical studies tend to present a systematic evaluation of relationships among SDGs by using a specific research method, most often by looking at the interaction between a pair of (or various) targets (Mainali et al., 2018; Pradhan et al., 2017).

2.5 Level and scope of analysis

Many of the consulted studies underline the importance of conscious reflection on the level and scope of analysis when presenting models to study SDG interactions (Alcamo, 2019; Breuer et al., 2019; Kroll et al., 2019; Kumar et al., 2018; Moinuddin & 周, 2017; Siakwah et al., 2020). Such reflection helps to determine whether the proposed approach is useful to analyse the interaction of all the 17 SDGs and whether it is applicable across various regions and countries. To a limited extent, disaggregating data helps to take care of the problem of scale and zoning [effects](#). The disaggregation of data also helps to acquire insights into the extent of [geographic spill-over](#) effects and to take [the context and cultural sensitivity](#) into account when analysing how various SDGs interact. Data disaggregation supports, for

instance, Moyer & Bohl's (2019) argument that the most vulnerable countries (MVCs) should be the focus of global efforts to sustainably improve human development. In their future scenario analysis, the authors note that when assessed at the global level, many SDGs appear achievable; yet, if one looks at country level, 'many small poor countries do not achieve targets in any scenario'.

Universal studies and approaches, which analyse the interaction of all 17 SDGs across various regions and countries (see for instance: Dörgő et al., 2018; Fonseca et al., 2020; Hegre et al., 2020; Velis et al., 2017), may allow for more general conclusions across all SDGs. They run the risk, however, of lacking in-depth and detailed insights. Non-universal studies, which focus on the interaction between a limited number of goals and selected geographic locations – in most cases with a special focus on The Global South (Mainali et al., 2018; Moyer & Bohl, 2019) – may offer more in-depth insights for these specific goals and areas but may be less suitable for generalizations (see for instance: Alcamo, 2019; Philippidis et al., 2020).

The level and scope of analysis is often dependent on the availability of data. While Siakwah et al. (2020), for example, expressed the ambition to conduct a global analysis on SDG interactions, the authors had to contend themselves with a focus on OECD countries due to the lack of good data for other nations.

Approaches to SDG interactions

The approaches presented in the consulted scientific studies on SDG interactions are divided along two lines: First, they are classified based on their methodological approach (quantitative, qualitative and mixed methods) and second, they are divided along the lines of systemic or non-systemic approaches (see Table 1 in the Annex). Relevant studies have been grouped together based on their approach types (quantitative, qualitative, mixed methods, and systemic or non-systemic) to explore each type's strengths and weaknesses as well as specific findings.

3.1 Quantitative, non-systemic studies

Starting off with the most populated cluster, quantitative, non-systemic studies explore synergies and trade-offs among pairs of SDGs. In terms of their findings, the most significant commonality among those studies is their agreement over SDGs' synergistic relations prevailing over trade-offs (Fonseca et al., 2020; Grigga, 2017; Hegre et al., 2020). SDGs 1 and 2 feature most prominently in the analysis of most studies, with SDG 1 having the largest number of positive interactions with other goals (Barbier & Burgess, 2017; Fonseca et al., 2020; Hegre et al., 2020; Kroll et al., 2019; Pradhan et al., 2017). While SDG 2 is shown to have a significant number of positive interactions with other goals as well, Fader et al. (2018) found that the goal also has 26 negative interactions (Fader et al., 2018). Additionally, SDG 3 was shown to have an effect on all other goals (Scharlemann et al., 2020). More specifically in terms of synergistic relations, SDGs 1 through 8 and 17 were identified as the goals most frequently embedded in positive interactions (Hegre et al., 2020). SDGs 11, 13, 14 and 16, by contrast, are most often cited as resulting in trade-offs or having no associations with other goals (Hegre et al., 2020; Kroll et al., 2019).

Within this cluster of studies, Hegre et al.'s (2020) study stands out in that the authors design and implement a time-series, tracing changes in SDG interactions for the period 2000-2016. The importance of applying a time-series analysis lies in the results, which showcase that synergies between and within SDGs prevail over time. Finally, quantitative, non-systemic studies seem to fall short of moving from correlational analyses to causal inferences. Correlational analysis is useful in so far as it can establish the existence of a causal relation, but it cannot be used to evaluate which variable constitutes the predictor and which the outcome in a relationship. The employment of causal inference is, thus, of paramount importance in drawing causal conclusions.

3.2 Quantitative, systemic studies

Scholars in this genre recognize the interrelated nature of SDGs, which prompts them to study the goals in clusters instead of pairs. There exists a consensus among those studies that the nature and degree of interaction among SDGs varies by country, which compels the authors to argue for country-disaggregated data (Moinuddin & 周, 2017; Scherer et al., 2018). Having established the interrelated nature of the goals, most scholars move towards creating a hierarchy of SDGs – in terms of driving power and dependency on other goals, with a high

ranking indicating strong driving power or dependency, and a low ranking weaker driving power and less dependency on advances on other goals (Kumar et al., 2018; Moinuddin & 周, 2017). Taking a closer look at the hierarchization of the goals, SDG 4 (Quality of education) appears to be the main driver in achieving all other SDGs; SDGs 14 and 15 (Life below water and Life on land, respectively) constitute linkage goals with strong driving and dependence powers; and SDG 17 (Partnership for the goals) is highly dependent on the achievement of other goals and has weak driver power (Kumar et al., 2018).

3.3 Mixed methods, systemic studies

The mixed methods, systemic study conducted by Zelinka et al. (2019) reaffirms the above findings that SDG 4 constitutes a main driver and that SDGs 14 and 15 comprise linkage goals (Zelinka & Amadei, 2019). Moinuddin et al.'s study stands out as the only other work that employs a time series for the period 2001-2014, investigating changes in the interaction between SDG targets 1.1 and 1.2 for 9 different countries. However, the main gap in the mixed method, systemic approach is the lack of integration of variables from all three dimensions of society, environment and economy. Scherer et al.'s (2018) study, for example, only focuses on environmental and societal goals, leaving out goals related to the economy. Considering the integrated nature of the SDGs and their simultaneous application, models that account for only some of the goals might lead to erroneous or incomplete results – though they might be useful in generating insights with regards to very specific goals and questions.

3.4 Qualitative, non-systemic studies

All the qualitative studies identified in this literature review take a non-systemic approach. Qualitative review articles tend to make conceptual contributions. Alcamo et al. (2020), for example, establish a conceptual distinction between synergistic interactions and synergy drivers. Another qualitative, non-systemic study identifies direct and indirect linkages among SDGs (Karnib, 2017). A mixed methods, systems study complements Alcamo et al.'s work, using SDGs 14 and 5 to argue that the absence of a direct relation does not necessarily mean the absence of an indirect interlinkage (Alcamo et al., 2020; Zelinka & Amadei, 2019).

Conclusion

A growing body of research across various fields confirms the idea that SDGs and their targets are intimately linked. Despite the fact that trade-offs can occur when aiming to achieve particular SDGs, the majority of studies conclude that synergies largely outweigh such trade-offs. Trade-offs can also change into synergies over time and vice versa, but we can only find out through time series analysis. It is, additionally, important to **work with country-disaggregated data**, in order to capture country- and context-specific interactions. Only with such data can country- and context specific trade-offs be prevented and synergies encouraged.

Factors such as the availability of data, research questions and level of analysis influence which approaches are most applicable to study the interactions between SDGs. Because some goals (such as SDG 1) have a large number of positive interactions with other goals, the **scientific studies on SDG interactions should help policymakers, when faced with limited resources, to decide which SDGs to prioritise** and which to tackle in tandem in order to maximize results and work towards policy coherence. More research is needed, however, to identify how synergies between and within SDGs prevail over a long period of time.

As the studies of SDG interactions often have an inter- and transdisciplinary character, there is a great diversity of theoretical frameworks and methodological approaches, with corresponding advantages and disadvantages. **Quantitative, non-systemic studies tend to have more robust measurement criteria**, but often fall short in moving from correlational analyses to causal inferences. **Quantitative, systemic studies, by contrast, recognise the importance of disaggregation in order to capture country- and region-specific factors**. Therefore, they tend to employ a wider range of measurement criteria to capture the nature and degree of interactions among SDGs.

For researchers studying the complex interactions between SDGs, it is of paramount importance to have a strong awareness of the **great diversity of existing approaches and measurement criteria** available to them. Depending on their goals and interests, some approaches might be better suited than others. Additionally, having an awareness of the wide variety of approaches will also allow for researchers from different fields to find a common language to talk about and better understand how SDGs interact and what that means for policy making. Given the integrated and indivisible nature of SDGs, researchers are encouraged to **work across disciplinary and geographic borders**. Studies and models that only account for one or very few of the goals or focus on narrow regions may yield fallacious or incomplete results when it comes to interactions between the 17 Sustainable Development Goals. Even on a micro-scale, researchers can design their research in such a way that lower level interactions between the economic, social and ecological domains can be captured.

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Annex

Table 2: Consulted literature and approaches on SDG interactions

System-level (horizontal) / Methodology (Vertical)

Systemic Studies	Quantitative approaches
Non-systemic Studies	Qualitative approaches
	Mixed Method

	Study	Contribution	Focus	Level of analysis	Measurement	Universality
A	Barbier & Burgess (2017)	Theoretical	Trade-offs	Indicator-level; interactions among pairs	Percentage index	Universal
	Philippidis et al. (2020)	practical	Trade-offs and synergies	Indicator level; access interactions among pairs of goals	Quantification	Non-Universal
	Pradhan et al. (2019)	Theoretical	Trade-offs and synergies	Indicator level; access interactions among pairs of goals	Quantification, Spearman's rank correlation (ρ)	Universal
	Scharlemann et al. (2020)	Theoretical	Degrees of interaction	Target-level; interactions among pairs of goals	Quantification, four-level influence matrix	Universal
	Tremblay et al. (2020)	Mixed	Trade-offs and synergies	Target level; interactions among pairs of targets	Seven-point measurement scale	Universal
	Breuer et al. (2019)	Theoretical	Interactions among SDGs	Not relevant	Checklist - a five-step roadmap	Non-Universal
	Fader et al. (2018)	Methodological	Trade-offs and synergies	Target level; interactions among pairs of targets	Nine-point measurement scale	Non-Universal
	Velis et al. (2017)	Empirical	Trade-offs and synergies	Target level; interactions among pairs of targets	Not relevant	Non-Universal
	Griggs et al. (2017)	Policy	Trade-offs and synergies	Target-level; interactions among pairs of SDG targets	Seven-point scale	Universal
	Alcamo et al. (2020)	Theoretical	Synergy drivers		Not relevant	Non-Universal
	Fonseca et al. (2020)	Policy	Trade-offs and synergies	Indicators; interactions among pairs of indicators	Spearman's rho	Universal
	Hegre et al. (2020)	Methodological	Trade-offs and synergies	Indicators; among pairs of indicators	Eigenvalues	Universal
	Karnib (2017)	Methodological	Trade-offs and synergies	Target-level; interactions among pairs of targets	Three-point measurement scale	Non-Universal
	Kroll et al. (2019)	Policy	Trade-offs and synergies	Indicator-level; interactions among indicator pairs	Correlation coefficient (rho value)	Universal
	Moyer & Bohl (2019)	Methodological/policy	Trade-offs and synergies	Goal level	Future scenario analysis	Universal
	Nerini et al. (2018)	Policy contribution	Trade-offs and synergies	Target level; interactions among SDG 7 and 167 targets	Factors, connections, and feedback loops	Non-Universal
Neumann et al. (2018)	Methodological	Trade-offs and synergies	Target level; interactions among groups of targets	Network analyses and nodes connection	Universal	
Dolley et al. (2020)	Policy contribution	Trade-offs and synergies	Target-level; interactions among pairs of indicators	Quantification, -1 to +1 scale to	Non-Universal	
B	Swain & Ranganathan (2021)	Theoretical	Synergies	Target-level; interactions among groups of goals	Quantification-three different thresholds.	Universal
	Bigerri et al. (2019)	Methodological	Trade-offs and synergies			Universal
	Van Soest et al. (2019)	Methodological				Universal
	Dörgó et al. (2019)	Methodological and policy	Correlation and causality	Indicators; interactions among clusters of SDG indicators	Degree of interaction between nodes	Universal
	Zelinka et al. (2019)	Methodological	Direct and indirect effects	Goal level; interactions among pairs of SDGs	Sven-point measurement scale developed	Universal
	Zhao et al. (2020)	Theoretical	Trade-offs and synergies	Target level; interactions within and among SDG target pairs	Monetary impact of interactions	Non-Universal
	Mainali et al. (2018)	Methodological	Trade-offs and synergies	Indicator-level; interactions and causality among indicator pairs	Pairwise Pearson Correlation	Non-Universal
	Kumar et al. (2018)	Empirical	Types of interaction:	Goal-level; interactions among pairs of goals	Wo-dimensional matrix to tap into degrees of interaction	Universal
	Moinuddin et al. (2017)	Empirical	Interactions and interlinkages	Indicator-level; systematic approach, interactions among groups of indicators	Array of centrality measures (degree centrality, eigenvector centrality)	Non-Universal
	Scherer et al. (2018)	Empirical	Trade-offs and synergies	Target-level; interactions among pairs of targets for two societal goals	Percentages	Universal

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