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Review

Translating Sustainable Development Goal (SDG) Interdependencies into Policy Advice

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Abstract: The 17 Sustainable Development Goals (SDGs) of the 2030 Agenda, and their 169 targets, are interdependent and interlinked. The successful implementation of all SDGs will rely upon disentangling complex interactions between the goals and their targets. This implies that implementing the SDGs requires cross-sectoral processes to foster policy coherence. Over recent years, academic research has produced a number of different proposals for categorizing the SDGs, systematically mapping the linkages between them, and identifying the nature of their interdependencies. The aim of this review article is to provide ideas of how to move from generic appraisals of SDG interdependencies towards translating these interdependencies into policy action. To do so, the article first provides an overview of existing frameworks for the systematic conceptualization of the SDGs and the interlinkages and interdependencies between them. Secondly, the article critically discusses advantages and limitations of these frameworks, with a particular focus on methodological weaknesses, practical applicability to specific contexts, and utility for the development of policy strategies for coherent SDG planning and implementation. Based on this discussion, the article proposes a roadmap for how research on interdependencies can meaningfully provide orientation for policy action.

Keywords: SDGs; interdependencies; 2030 Agenda; synergies; trade-offs; policy-coherence

1. Introduction: The Integration Challenge

In 2015, the United Nations General Assembly adopted the Sustainable Development Goals (SDGs), which constitute the centerpiece of the 2030 Agenda for Sustainable Development. The agenda's 17 core goals are broken down into 169 associated targets to direct global development strategy until 2030. These goals and targets encompass economic, social, and environmental aspects of sustainable development in an unprecedented way. While the SDGs combine the human development process of the Millennium Development Goals (MDGs) and the sustainable development Rio+ process, they also expanded the range and depth of topics covered substantially and signaled the necessity of a shift in governance strategies [1]. Compared to previous understandings of global development, one outstanding principle of the 2030 Agenda is its indivisibility, i.e., the understanding that the development objectives formulated by the SDGs and their targets are fundamentally interdependent and interlinked. This implies that implementing the SDGs will require striving for more policy coherence—both vertically and horizontally—as well as the participation of non-state actors. Beyond this, coherence also refers to geographically and temporal disconnected areas and actions. In accordance with the Organization for Economic Co-operation and Development (OECD) [2] (p. 90), we define policy coherence as *"the systematic promotion of mutually reinforcing policy actions across government departments and agencies creating synergies towards achieving the defined objective."* [2]. In our understanding, coherence has an institutional, geographical, temporal and sectoral dimension.

However, given the indivisible nature of the 2030 Agenda, each of the SDGs resulted from a protracted process of several years of multi-stakeholder consultations and intergovernmental negotiations [3,4]. As a consequence, the targets of one SDG may now overlap, reinforce, or contradict the targets of one or several other SDGs [5,6]. Thus, it is likely that implementing the 2030 Agenda will bring about synergies—i.e., situations in which achievements on one goal contribute towards progress on other goals—as well as trade-offs—i.e., situations in which progress achieved on one goal will produce effects detrimental to other goals (or parts thereof). Against this background, a strong integration between goals and targets was called for at the Rio+20 Conference, at which the pursuance of the SDGs was decided. Achieving such integration will require identifying the interdependencies between and within the SDGs, as well as understanding the nature, magnitude, and potential implications of these interdependencies.

Given the interlinkage of seemingly each goal with nearly every other goal, achieving a coherent integration of the SDGs within national public policies appears a daunting task. In view of its complexity, one rather defensive approach for policy makers would be to continue with business as usual, while hoping that some actions will eventually match one of the 169 targets. However, such inertia involves the risk of incoherent, siloed policies and, ultimately, adverse impacts of policies and programs. By contrast, a more proactive approach would seek to identify critical interdependencies and agree upon the most important themes and areas for action within all responsible and affected stakeholders at the national and subnational level, as well as in partnership with regional neighbors and organizations in order to mediate trade-offs and foster synergies.

To facilitate the latter, proactive, approach, scholarly literature has, over recent years, produced a number of different proposals for categorizing the SDGs, systematically mapping the linkages between them, and identifying the nature of their interdependencies. However, despite their common basic objective, these proposals differ considerably with regard to their methodological approaches, the level at which their analysis is performed, and the potential implications for policy action that can be derived from them.

In view of this, the purpose of this paper is to review this rich and diverse academic mapping of interdependencies and to lay the groundwork for translating it into advice for coherent policy making. To do so, the remainder of this paper unfolds as follows:

The following Section 2 provides an overview of existing frameworks for the systematic conceptualization of the SDGs and the interlinkages and nature of interdependencies between them.

Section 3 critically discusses advantages and limitations of these frameworks, with a particular focus on methodological weaknesses, their practical applicability to specific contexts, and their utility for the development of policy strategies for coherent SDG planning and implementation.

Based on this discussion, Section 4 formulates ideas for a roadmap of a transdisciplinary research that facilitates translating these interdependencies towards change for integrated implementation of the SDGs within spatial reference units (exemplified with the landscape approach). This last step aims to assess the complexity of SDG interdependencies at a generic level and, at the same time, lays the groundwork for the generation of knowledge for concrete action towards sustainable development.

2. Literature Overview: Frameworks for the Conceptualization of Sustainable Development Goal (SDG) Interlinkages and Interdependencies

This and the following sections present a critical review of the existing literature on SDG interlinkages, and the related frameworks. Following standard critical reviews, the literature (articles, reports and studies) considered in these sections was selected through website searches and snowball techniques starting with the most cited and recent publications. The aim of the article was not to perform a meta-analysis or a systematic review. This is also driven by the fact that the literature, especially the empirical evidence on interlinkages between a large amount of goals, is fairly young and small compared to other research streams.

2.1. Clustering SDGs According to Their Systemic Function

The first generation of attempts to structure the SDGs systematically by categorizing them according to their main intended outcomes was largely inspired by a framework, nicknamed "the doughnut" for its distinctive visualization, which was first published in an Oxfam discussion paper by Raworth [7,8]. Raworth's doughnut seeks to combine an environmental ceiling beyond which Earth systems may become irreversibly unstable, based on the planetary boundaries approach [9], with a social foundation below which it is unjust for people to fall below.

Drawing on the doughnut framework, Niestroy [10] proposes a framework model consisting of concentric circles, in which a core of people-centered SDGs (SDGs 1, 3, 4, 5, 10) relies on and is embedded into a middle circle of SDGs that are related to the production, distribution, and delivery of services (SDGs 2, 6, 7, 8, 9, 11, 12). These, in turn, depend on the conditions of the natural environment and are hence embedded into an outer circle of SDGs that relate to natural resources and ecosystems: climate, oceans, biodiversity, and land (SDGs 13, 14, 15). SDG 16 (peace, justice and strong institutions) and SDG 17 (means of implementation) are depicted outside the model as underlying and enabling goals (see Niestroy [10–12], p. 11, https://www.die-gdi.de/uploads/media/DP_9.2016.pdf).

Drawing the attention to the limited nature of natural resources that constitute the necessary input for a multitude of SDGs, this conceptualization underlines the importance of adopting mitigation strategies to reduce degradation of natural resources if the goals of all four dimensions of the 2030 Agenda are to be achieved everywhere, for everyone.

In a similar fashion, a model proposed by the global research initiative The World in 2050 [13] represents the SDGs as delineated by the planetary boundaries. Within these boundaries, global partnerships for sustainable development (SDG17) and governance (SDG16) provide the frame in which the remaining goals of Agenda 2030 are represented as interlinked clusters, grouped according to five main categories of SDGs: social and economic development (SDGs 8, 9, 11), universal values (SDGs 4, 5, 10), basic human needs (SDGs 1, 2, 3), and sustainable resource use (SDGs 6, 7, 12).

The common denominator of the models described above is that they not only categorize goals according to their intended individual outcome, but also cluster them in a similar manner according to their systemic role. Goals related to securing basic human needs are considered as ultimate goals or outcomes of development by these models, and are thus located at the center. They are embedded within a layer of goals related to the process of obtaining socio-economic goals that constitute the necessary means to achieve these ultimate goals. Goals related to both outcome and process are confined by an outer layer of goals related to bio-physical preconditions which, at the same time, represent the limited amount of resources and sinks that are available to achieve the outcome- and process-related goals.

These conceptualizations fulfil the requirements of what Wackernagel et al. [14] and O'Neill, et al. [15] describe as the essence of any serious definition of sustainable development—the improvement of the quality of human life within the carrying capacity of supporting ecosystems—and the importance of the provisioning system (both social and physical) in achieving this goal. At the same time, however, these conceptualizations reflect an interpretation of sustainable development that has been criticized for its anthropocentric nature. Anthropocentrism is a current in the philosophic discipline of environmental ethics that perceives nature as the human habitat which has a mere instrumental value insofar as the wellbeing of present and future generations depends on its preservation [16]. In this line of thinking, clearly what is considered worthy of being *sustained* is human well-being rather than the environment [17]. Critics of anthropocentric interpretations have postulated complementing anthropocentric interpretations of sustainable development with biocentristic interpretations that emphasizes the intrinsic value of all living beings and facilitate the adoption of new perspectives for a broader ethical foundation of the SDGs [16,18].

Put in a nutshell, the clustering exercises described above illustrate the importance of systemic thinking when implementing the 2030 Agenda, given that the individual SDGs are inextricably linked by input–outcome relations. However, they fail to elucidate the causal relations that link

the SDGs, which are rather located at the underlying level of their associated targets. In view of this, the second generation of attempts to conceptualize the SDGs has put an explicit focus on the target-level interlinkages between the SDGs.

2.2. Towards the Exploration of SDG Interlinkages at the Target Level

Le Blanc [19], for example, presents the SDGs as a network of related targets. Combining the methodologies of network analysis and content analysis, Le Blanc explores the existence of links between the SDGs based on the wording of the individual targets. For example: Target 12.4 of SDG 12 (responsible consumption and production) is linked to SDG 3 (good health and well-being) due to its wording: "by 2020 achieve environmentally sound management of chemicals and all wastes throughout their lifecycle in accordance with agreed international frameworks and significantly reduce their release to air, water and soil to minimize their adverse impacts on human health and the environment". While the network resulting from Le Blanc's analysis provides useful insight into the different degrees of interconnectedness between the SDGs, it informs neither about whether the nature of these connections is positive or negative, nor about the empirical underpinnings of these connections. Furthermore, Le Blanc's analysis does not provide specific advice on how to get started with tackling the complexity that results from the interconnectedness between the SDGs.

2.3. Establishing a Priority Order for Policy Action in Implementing the SDGs

Picking up on this latter problem, a research collaboration between the OECD and the think tanks New America and Green House has made an advance toward the establishment of a priority order, which they describe as an adequate, logical sequence in which the SDGs should be addressed [20]. To do so, Scott, Leitner, and Hynes surveyed 85 experts from think tanks, governments and private institutions, the World Bank, the OECD, universities, and foundations, and civil society organizations. However, in order to obtain clear judgments from their respondents, Scott et al. first had to break the SDG targets down into their essentials. Given that the SDGs' targets resulted from a long process of reiterated consultations and amendments, their wording is at times overly complex and complicated. To get to the essence of the targets, the researchers first excluded targets that were in fact policies or other "means of implementation" and retained only those that formulate true objectives. In the next step, the researchers extracted the core aim of the remaining targets, by removing explanatory details such as who should be involved and how and by when it should be done. By doing so, they arrived at 117 straightforward targets. Each respondent was then asked to select 20 out of these 117, which, according to his/her judgment, should be addressed first in order to help fulfill all of the SDGs.

Interestingly, in the resulting aggregate ranking targets concerning rights, governance, and people's basic conditions of life are given a considerably higher priority than those that refer to environmental concerns.

While the priority order that results from this approach makes intuitive sense for certain developing-country contexts, it appears less appropriate for countries in which certain standards of human rights have already been achieved and basic conditions of life are guaranteed for the majority of the population. It also stands in stark contrast with the message of the clustering exercises introduced earlier, which stressed the important systemic role of the goals related to the biophysical-input dimension of development.

An alternative proposal for establishing a priority order that underlines the importance of systems analysis and network analysis has been presented by Allen, Metternicht and Wiedmann [21]. The authors apply a multi-criteria analysis (MCA) decision framework for the prioritization of SDGs in the Arab region. The three criteria used by Allen et al. are (i) "level of urgency" (using trends); (ii) "systemic impact" (using network analysis and semi-quantitative studies); and (iii) "policy gap" (coverage of targets in national development strategies).

2.4. Applied Empirical Analysis of Synergies and Trade-Offs between the SDGs

A proposal for an evidence-based approach to cross-check for interactions between SDGs, motivated by the very concern about potential trade-offs between socio-economic development and global environmental sustainability was brought forward by Griggs et al., 2014 [22]. The authors propose to formulate equations that represent simplified assumptions about the trade-offs between socio-economic and biophysical development objectives at the global level. In such equations, factors that critically shape these trade-offs are represented by letters or symbols that act as placeholders for parameter values. In order to apply these equations empirically and analyze how trade-offs between specific goals play out in specific contexts, the parameter placeholders then need to be replaced by actual, data-based parameter values.

It appears then, that analyses of the interaction between the SDGs, which are helpful in providing strategic advice for a defined group of actors in a given context setting, should start from a particular goal (or set of goals) as an entry point and look at how this goal interacts with others in the context of interest. One example is the PricewaterhouseCoopers (PwC) Business Navigator [23] which seeks to help business leaders understand how their companies' activities impact the achievement of each individual SDG (either positively or negatively). The online diagnostic tool, developed by PwC, taps into a database that pulls together 240 performance indicators, drawn from numerous global databases, to create a country score against each SDG. These scores intend to help business leaders identify the SDGs that are of most relevance given their companies' countries and sectors of operation.

An approach intended to assist policy-makers increase policy coherence in SDG planning is the use of simulation models [24]. Modeling and simulation (M&S) refers to the computer-aided use of mathematical, physical, or other logical models that allow the representation of the dynamics of complex systems via simulation. Typically, such systems consist of a large number of input parameters, the variation of which can have a significant impact on the performance of the entire system. M&S is applied to explore how such systems behave over time under the variation of input parameters in situations where real world experiments are either not possible or too risky. One example is the World Economic Forecasting Model (WEFM), which was developed to allow the UN Development Policy Analysis Division (UNDPAD) to produce consistent forecasts for the global economy [25]. Another example is the iSDG model, developed by the Millennium Institute, which aims to enable decision-makers and civil-society stakeholders to visualize the long-term trajectory of their country's current development path and help them to devise alternative coherent policies that are better suited to achieving the SDGs. The Millennium Institute has been working on the prototype of the iSDG model since 2014, and first applications of the model to specific pilot countries are now underway: Collste, et al. [26], for example, use the model to analyze the impact of investments in photovoltaic capacity on SDG 3 (health and well-being), SDG 4 (education), and SDG 7 (affordable and clean energy) in Tanzania. Another major modelling exercise, building upon and enriching Integrated Assessment Models (IAM) used for the Intergovernmental Panel on Climate Change (IPCC), is underway with the global research initiative The World in 2050 [27].

In the advent of the first global progress review at the UN High Level Political Forum in 2016, Nilsson, Griggs, and Visbeck [28] proposed a scale to help policy makers understand the different interaction types between the SDGs and their targets in order to support decision-making on national priorities. The seven-point scale, which attributes scores to the different potential interactions, differentiates between three degrees of positive interactions (indivisible = +3, reinforcing = +2, and enabling +1), neutral interactions (consistent = 0), and three degrees of negative interactions (constraining = −1, counteracting = −2, and cancelling = - 3).

This proposal was taken up and further developed in a report published by the International Council for Science (ICSU) in 2017 [5]. The authors of the report complement the scale proposed by Griggs et al. by five key dimensions ((1) governance, (2) geography, (3) time, (4) technology, (5) directionality) that shape and contextualize the interactions [5,29]. These dimensions are considered

as crucial for the practical application of the scale since in most cases the assignment of an interaction score will depend on these contextual dimensions, as illustrated in the following examples:

(1) In many cases, the negative nature of a relationship is the result of poor governance. The production of renewable energy (Target 7.2), for instance, can be associated with the infringement of rights (Target 1.4), when mega-projects for renewable energy are realized without consultation or compensation of the affected local communities. However, this negative interaction is not intrinsic to the production of renewable energy itself, but rather the result of inadequate governance.

(2) Some relationships are generic across borders, while others are specific to a particular geographic context. The trade-off between bioenergy (Target 7.2) and food (SDG 2), for example, appears more prominently in the southern hemisphere than in northern European countries.

(3) Some interactions develop in real time, while others show significant time lags. For example, increasing fertilizer use or harvesting remaining fish stocks can boost agricultural productivity (Target 2.4) and thereby food security (SDG 2) in the short term. However, these practices may have longer-term negative impacts on several SDGs, such as the conservation of oceans (SDG 14), and halting biodiversity loss (SDG 15).

(4) In some cases, existing trade-offs could be significantly mediated or even eliminated by the development of suitable technology. The growth in personal mobility, for instance, at present conflicts with climate-change mitigation efforts. In the future, however, the transition to cars fueled by renewable electricity could mediate this trade-off.

(5) Interaction between two SDGs or targets can have different directionalities. A unidirectional relationship means that objective A affects B, but B does not affect A. For example, electricity access (Target 7.1) is needed for powering clinics and delivering health care (Target 3.8), but health care is not needed for providing electricity access.

Having explained the framework, the authors of ICSU 2017 go on to apply it to a selection of four entry goals (SDGs 2, 3, 7, and 14) in order to evaluate the key target-level interactions between these goals and all other SDGs [5]. Each interaction is attributed a score based on the authors' expert judgment and existing scientific literature. Based on this analysis, the authors come to the conclusion that no fundamental incompatibilities exist between goals—where one target as defined in the agenda would make it impossible to achieve another. However, they identify a number of potential constraints and interdependencies that require coordinated policy interventions to protect vulnerable groups, promote equitable access to services and development opportunities, and manage competing demands over natural resources to support economic and social development within environmental limits [5] (p. 8).

While ICSU 2017 [5] maps interactions between SDGs through a qualitative approach based on expert judgment, a quantitative mapping exercise has been conducted by Pradhan et al., 2017 [30]. By using available data on SDG indicators and statistical techniques, their analysis assesses interlinkages between and within goals, at both country and national level. Significant negative correlations are classified as trade-offs, and significant positive correlations as synergies. Their findings show that, within SDGs, synergies largely outweigh trade-offs. With regards to interactions between SDGs, SDG 1 (No poverty) was found to have synergies with most other goals; while SDG 12 (Responsible consumption and production) is the one that presents most trade-offs with other SDGs. Interestingly, some of the findings by Pradhan, et al. [30] differ from those of ICSU [5]. While the latter mostly found synergies between SDGs 2, 3, 7, and 14, the former arrive at a more mixed picture. One of the reasons could be that while Pradhan et al. aim to assess correlations through the use of Spearman's rank correlation, ICSU tries to identify causal and functional relations.

Pushing the applied analysis of interactions further Weitz, Carlsen, Nilsson and Skånberg [6] present an approach to assessing the systemic and contextual interaction of the SDG targets. Their explicit aim is to provide policy-making with a context-sensitive tool that facilitates coherent SDG planning and effective priority-setting in view of limited national budgets.

Specifically, Weitz et respond to the call for analytical approaches that (1) treat the 2030 Agenda as an indivisible whole (i.e., do not focus on a single specific policy area, goal or target) and (2) take into account that interactions between targets may play out very differently, depending on geographic context, existing governance arrangements and available technological options. However, in contrast to the analysis by ICSU [5], Weitz et al. [6] do not limit their analysis to a selection of a few SDGs as entry points. Instead, they select two targets from each SDG (excluding SDG 17) that are deemed to be of particular importance in Sweden as the selected country case (see the cross-impact matrix of SDG targets in Sweden: https://link.springer.com/article/10.1007/s11625-017-0470-0#Fig2).

Using the seven-point scale proposed by Nilsson et al. [28], they begin their analysis by constructing a cross-impact matrix that aggregates expert assessments of how the 34 selected targets would affect one another in the case of Sweden. The resulting matrix consists of 1,122 boxes (34 × 33), each of which represents how the achievement of a row target would affect the column target.

The row-sums of the matrix inform about the net influence a target exerts on all other targets–whether interactions are positive or negative and to what degree on the seven-point scale. A high positive row-sum suggests that a target has a positive net influence on other targets, whereas a negative row-sum suggests that progress on this target would make it generally more difficult to achieve other targets. In turn, the column-sums inform about the net influence a target receives from all other targets. A high column-sum suggests that a target is very positively influenced by other targets. A negative column sum means that progress in other targets makes it more difficult to reach the target.

The information contained in the impact matrix could potentially provide a useful starting point for national governments to rationalize targets and identify those that present particular challenges and opportunities in their specific national contexts.

For example, policies and measures to achieve targets with a net negative influence must be handled with care as they could, otherwise, neutralize efforts to achieve other targets.

For another example, targets that receive most positive influence from progress in other targets may not need much targeted support themselves since they can benefit from investments elsewhere. At the same time, however, they are highly dependent on other targets, and policy-makers who are responsible for the implementation of such highly influenced targets have little control over their own issue area. Thus, they are well advised to establish close relationships with the actors in charge of the targets that hold the key to their development.

The cross-impact matrix provides first indications about policy sectors that pose particular opportunities and challenges in the national planning of SDG implementation. Nevertheless, the authors deem it insufficient to guide priority-setting. In order to prioritize action, they argue, working-level ministerial staff need to have a robust understanding of how the realization of their ministry's priority targets affect, or are affected by, targets under the responsibility of other ministries. To obtain an understanding of the systemic impact of targets, it is necessary to resort to an analysis that parts from individual targets as entry points. Using network analyses that build on the information provided by the cross-impact matrix but that looks at the network of targets from the perspective of selected individual targets, Weitz et al. [6] illustrate how these selected targets impact their immediately neighboring targets, as well as targets that are further away in the network. As the authors argue, it cannot be expected that ministerial bureaucrats would maintain an overview of such complex systemic effects in their daily work—this would more likely be the responsibility of coordinating functions such as the Head of State's office. However, working-level bureaucrats should internalize which actors outside their own ministry influence the targets under their sectoral responsibility in order to negotiate compromises and collaboration strategies that generate the best possible outcome for the SDGs.

For the development of cross-sectoral strategies of coordination and collaboration, Weitz et al. [6] recommend performing a cluster analysis of the full network of targets. Cluster analysis, a statistical method based on algorithms, is a common technique used for the recognition of organizational

patterns. It is based on the core idea that elements of a network are more closely related to nearby elements (with which they are grouped together in a cluster) than to elements farther away in the network. In the realm of SDG implementation and planning, cluster analysis may be useful for governance innovation because it can reveal that a set of actors corresponding to the targets included in a cluster may be different from the present logic of how political responsibility is currently divided (e.g., across ministries by policy area or topic). According to the analysis by Weitz, et al. [6] this is indeed the case in the example of Sweden. This finding goes in line with the observation of Tosun and Leininger [4] that, to date, national strategies to implement the 2030 Agenda often appear to be shaped by domestic-path dependencies rather than by the interlinkages of the SDGs. This involves the risk that instead of tackling the more substantial institutional reforms needed to achieve socially optimal integrated solutions, policy-makers merely seek to accommodate the interests of powerful established actors. Against this backdrop, information obtained through cluster analysis could be highly valuable when it comes to designing strategic frameworks that can promote the collaboration between relevant national ministries, private and public sector stakeholders, and transnational actors that is needed to achieve policy coherence.

Finalizing this section, Table 1 provides an overview of the discussed conceptualization approaches that indicates their scope and the level at which their analysis is performed, and summarizes their primary declared intent.

Table 1. Scope, level of analysis and primary intent of SDG conceptualization approaches.

	Global	**Global & National**	**National**
All SDGs	Niestroy 2016 / TWI 2050: Clustering SDGs according to main intended outcomes and systemic functions (goal level) Le Blanc 2015: Illustrating degrees of interconnectedness between the SDGs at target level Scott et al 2017: Establishing a priority order for implementing the SDGs (target level)	Pradhan et al. 2017: Providing a systematic, data-driven analysis of interactions between all SDG indicators (target level)	PwC-GMIS-UNIDO 2017: Distinguishing interaction types between all SDGs (target level) Weitz et al (2017): Understanding interaction types between SDG targets and mapping national level responsibilities for SDG implementation (target level)
Selected SDGs as entry points	ICSU-ISSC 2017: Understanding interactions between selected SDGs (target level)	Simulation Models by TWI2050, WEFM, UNDPAD 2017: Forecasting global system dynamics over time (target level)	Collste et al. 2017: Forecasting national system dynamics over time (target level)

3. A Critical Discussion of Existing Frameworks and Mapping Approaches

The previous section provided an overview of the current state of scholarly research on interdependencies between the SDGs and the existing frameworks and approaches towards studying and mapping these interdependencies. Although these approaches offer promising starting points for a systematic study of SDG interdependencies, they demonstrate several limitations that hamper their practical application, particularly when it comes to translating their findings into concrete policy advice for coherent SDG planning and implementation in national contexts.

To structure our discussion of these limitations, we apply three broad criteria: (1) methodological and conceptual challenges that are relevant to the empirical analysis of SDG interlinkages; (2) context sensitivity that is necessary for analysis and national implementation of the SDGs; (3) a critical ranking of goals that will be inevitable for the implementation of the SDGs under the conditions of limited availability of natural resources [9]. As these categories are not mutually exclusive, they may at times overlap, and many limitations are shared between them.

3.1. Methodological Challenges

Regarding methodological challenges, three main limitations deserve highlighting. The first limitation is a conceptual one: many SDG targets cannot be properly translated into measurable indicators due to the conceptual complexity. For example, it is challenging to identify a suitable indicator for the target 8.5 of achieving "decent work" for all. The Global Indicator Framework for the Sustainable Development Goals proposes Average hourly earnings of female and male employees, by occupation, age and persons with disabilities as an indicator to measure this target. This indicator provides information about the fairness of income. However, it only captures part of the concept of "decent work" defined by the International Labour Organization (ILO), which also includes aspects such as security in the workplace and social protection for families, better prospects for personal development and social integration.

There is also a need for a stronger theoretical basis in relation to the integrated SDG implementation. In fact, theories and models explaining the effects of interlinkages between goals are often missing or incomplete. Therefore, conceptual clarity and theoretical arguments on the links between, and integration of, the SDG targets are a precondition for the actual measurement of the indicators.

The second limitation relates to issues of operationalization: the data needed to empirically assess interlinkages between the SDGs in a comprehensive manner are not always available [31]. So far, the Inter-Agency and Expert Group on SDG Indicators (IAEG-SDGs) has agreed on 230 indicators to assess success towards the achievement of the 17 SDGs and their 169 targets. While some of these indicators are easy to define and measure, roughly half of them lack acceptable country coverage, cross-country comparability, or agreed-upon methodologies for measurement [32]. To give an example, in many developing countries household censuses are conducted infrequently and often ask different sets of questions. Therefore, the tracking of changes in poverty and inequality is constrained in many cases. Moreover, data and estimates are often missing for relevant countries or segments of the population. Sticking to the previous example, this implies incomplete data for many countries with high poverty rates or large segments of the population living in poverty. Similar problems exist with regards to data on environmental outcomes. Therefore, the possibility of achieving a full assessment of interactions between SDGs is severely limited in many circumstances. Such data constraints are one of the reasons why the practical application of some of the reviewed frameworks and approaches has thus far remained limited to specific cases, for which information availability is high [5,22,26,30]. This presents a particular challenge for developing countries with poor data availability.

The third methodological issue is related to the processes used to estimate the nature, strength, and relevance of interlinkages between SDGs, as well as the possibility of replicating (i.e., reproducing and verifying) these processes. Some frameworks use a qualitative approach to estimate the nature of interlinkages of SDGs. ICSU [5] and Nilsson et al. [28], for example, propose a seven-score scale to evaluate target-level interactions between the SDGs. In the practical applications of the framework [5,6], the attribution of scores to specific interactions is obtained through the work of a team of scientists who base their assessment on their expert judgement and the review of available scientific literature. As the authors concede, this has serious implications for the replicability of the framework in other contexts and by different teams of experts. Moreover, some of these frameworks focus just on a restricted number of goals [5] or targets [6], which may result in a selection bias.

Recent attempts to empirically model and measure interlinkages between the SDGs have started, and may, at least partially, address the issue of replicability. Currently, M&S approaches appear, subject to data availability, to be best suited to address the problem of replicating previously outlined analytical frameworks (such as the 7-point scale) in different country contexts, which is both time-consuming and challenging in terms of comparability of the findings and answers. Nonetheless, M&S approaches have other limitations, such as the need to use assumptions, as well as the lack of transparency often encountered. Typically, complex simulation models consider

interlinkages between more than two goals. Relevant examples are Griggs et al. [22], as well as the modelling tools employed by TWI2050 and UNDESA. Allen, et al. [33] review a large number of models used in the empirical literature and conclude that, "while some existing models are particularly relevant, it is unlikely that an ideal model can analyse all SDG targets and variables of interest within a single modelling framework". M&S approaches have also advantages compared to other quantitative and replicable approaches. For example, Pradhan et al. [30] explore associations and not causality between indicators; and they consider just the first order effects. However, and as mentioned above, the success of M&S approaches is critically linked to the issue of limited data availability. Simulation models are based on assumptions and estimations that need to be correctly specified, and in many developing countries, the necessary data to do so is missing. We will further elaborate in the following section.

3.2. Context Sensitivity

The second main concern regarding existing frameworks and mapping approaches is their inadequacy to account sufficiently for the diverse nature and specificity of different contexts. This problem is closely related to the issue of replicability discussed in the previous section. The importance of context specificity is a recurrent topic within the SDG literature [5,29]. It was one of the 5 points mentioned in the ICSU report, Section 2. Similarly, Weitz, Carlsen, Nilsson and Skånberg [6] state that there is a need to understand how SDG targets interact in given contexts. A final, and more conceptual, critique is brought forward by Nilsson et al., 2018, who argue that it is crucial to understand the actual meaning of an SDG target in context.

Despite the policy relevance, just a few studies take directly into account the context specificity of SDG interactions. In their application of the seven-point scale proposed by Nilsson et al. [28], Weitz et al. [6], for example, select two targets they deem particularly relevant for the case of Sweden. This involves the evaluation of 1,122 target-level interactions. Due to complexity, the replication of such a comprehensive endeavor may unfortunately remain restricted to a low number of countries and case studies and requires extra capacities in the countries where it is to be carried out.

Similarly, Pradhan et al. [30] look at trade-offs and synergies for all countries and indicators, assessing interlinkages between goals, and between targets within goals. Moreover, they assess associations at both global and national levels. The differences in top synergy and trade-off pairs are identified on a global scale and for individual countries. Especially in the context of trade-off, they find significant heterogeneity. These results imply that policy priorities for achieving the SDGs need to be differentiated based on the observed extent of SDG synergies and trade-offs in the considered country.

Finally, Nilsson et al. [29] present evidence on interlinkages related to the SDGs on health, energy and the ocean. They show how the interactions depend on geographical context, resource endowments, time horizon and governance. For example, if the expansion of renewables in a certain country includes hydropower as an option, the achievement of SDG 7 (Affordable and Clean Energy) may negatively interact with freshwater ecosystems (SDG 6).

Given the need to improve the availability of the evidence context sensitivity some solutions are proposed in the literature. Quantitative approaches try to deal with the issue of context. For example, simulation and computable general equilibrium (CGE) models (e.g., Collste et al. [26]) can be applied to specific countries. However, the feasibility and reliability of CGE modeling is restricted by the methodological challenges discussed in the previous section. As assumptions need to be made, especially in the case of simulations, they can be significant and change both findings and the policy implications based on these findings. This is a relevant limitation for both conceptual frameworks (such as in ICSU [4]), as well as simulations and empirical exercises. Therefore, assumptions need to be made explicit and transparent and discussed for different context settings.

3.3. Critical Ranking of Goals

The issue of goal prioritization remains largely unaddressed in the literature reviewed for the purpose of this paper. While ICSU [5], for example, state that their scoring exercise provides a starting point in order to stimulate further discussion and research, the authors abstain from formulating explicit advice on which targets to focus on first.

There are several conceivable reasons for the avoidance of this topic. For one thing, the prioritization of individual goals might appear at odds with the principle of indivisibility of the 2030 Agenda; for another, the prioritization of certain goals and targets over others indubitably involves moral and ethical ramifications [34,35]. The latter would particularly be the case if goals or targets related to economic or environmental outcomes were to be prioritized over those related to basic conditions of dignified human life or human rights.

Nonetheless, in view of budgetary, political, and resource reasons, it will be almost inevitable that countries prioritize certain goals, targets and indicators over others [5]. Furthermore, it is only rational for national governments to tailor their agenda of SDG implementation to the needs and specificity of their countries.

Among the different approaches reviewed here, the only one that explicitly addresses the issue of prioritization is the priority order established by Scott, Leitner and Hynes [20]. Their ranking is based on a survey of 85 experts from different institutions and organizations. Yet, the ranking proposed by these authors presents two of the flaws, which have already been discussed in the previous sections: it lacks methodological clarity, and it represents a global (abstract and general) perspective. Because of the latter, it is difficult to derive policy implications for specific contexts, in particular for developed countries.

Nonetheless, a few ideas for the prioritization of goals can be indirectly derived from the previously analyzed frameworks, as well as from other literature, in particular work on social priorities. Barbier and Burgess [36], for example, consider the impact of changes in the SDGs on welfare. In general terms, they suggest focusing on goals and targets associated with the highest monetary returns and contributions to social welfare. This is especially relevant in the presence of budget constraints, frequently experienced by developing countries. Investments and interventions in the field of childhood health, for example, are regarded as having large returns due to long-term gains. Moreover, childhood health is assumed to have important synergetic effects on education and poverty. Public policy already widely uses cost-benefit analysis to choose among several interventions.

An alternative approach could be derived from the approaches dealing with environmental boundaries [8,10,13]. These approaches could be read as a suggestion to prioritize the conservation of supporting ecosystems if irreversible effects need to be avoided. Socio-economic goals would then be optimized within the constraints of these environmental constraints. In this sense, prioritization can also be seen and conceptualized based on the urgency of the different goals, and the cost of inaction. For example, climate action is urgent, as the consequences of climate change can become irreversible if action is not taken soon and environmental boundaries (such as certain levels of CO_2 concentration in the atmosphere) are passed.

Yet another approach—in line with the call of SDG 16 to promote inclusive and participatory decision-making—would be to achieve prioritization through societal bottom-up processes in which national-level policy decisions regarding SDG implementation are informed by the needs and priorities expressed by local communities. Some examples have been proposed, such as the use of national constitutions to prioritize certain goals and targets.

In summary, the scholarly discourse on the moral question of prioritization of goals and targets over others needs to be advanced in order to tackle also ethical questions underlying the implementation of the 2030 Agenda

3.4. Cross-Cutting Issues

Four further, more general limitations crosscut the three limitations outlined above. First, the existing frameworks for the study of SDG interlinkages do not explicitly deal with the tension between global public goods and the measurement of the SDGs at the national level. Global public goods can be defined as goods with benefits (or costs) that extend to the entire current and future global population, as opposed to goods that affect just one national or otherwise geographically limited area. While the SDGs are meant to be addressed by each country individually, the achievement of some goals is heavily dependent on the international order and patterns of global cooperation, and action on these goals will have repercussions beyond national borders. For instance, the way in which a country proceeds in order to achieve universal access to education (SDG4) is unlikely to have significant trans-boundary impacts. By contrast, if a country reduces its emissions and meets its national emission goals, the same country will still suffer from the effects of climate change if other countries increase (or fail to decrease) their own emissions. As CO_2 emissions accumulate in the atmosphere that we globally share, the contribution towards reducing emissions (e.g. SDG 7, SDG 12 and SDG 13) in one country goes beyond the actions taken by that country. More generally speaking, the achievement of some SDG targets at the national level may depend on policies implemented by other countries, as well as on action on intra- (ministries within one country), inter- and supra-national levels of governance. Therefore, while policy coherence and horizontal integration is usually strongly advocated in the context of the interlinkages between SDGs, it is also necessary to directly address multi-level coherence and vertical integration between policy levels.

Second, only few frameworks (e.g., [8,10]) distinguish between process-related and outcome-related goals. Economic growth (SDG 8), for example, can be considered as a process that will have a positive effect on outcomes such as the quality of education (SDG 4) and health (SDG 3), but could have negative effects on environmental goals (SDGs 13—15). It could be argued, then, that process-related goals should be considered differently than outcome-related goals. Nonetheless, this distinction is made only implicitly or even discarded in most contributions. For example Weitz, Carlsen, Nilsson and Skånberg [6] do not distinguish between links with final goals or process-related SDGs when computing the scores for the interlinkages of each SDG.

Third, the issue of time horizons is crucial for the assessment of interlinkages. In fact, SDGs that are synergetic in the short term may show trade-offs in the long run. The opposite might also be true. Alternatively, two goals that do not have a significant interdependency in the short (long)-run might develop one over a longer (shorter) period. This is particularly relevant for capital and skills accumulation. For example, increased investments in education might not have an immediate effect on economic growth, but the returns will materialize in the future. Therefore, the time horizon of the analysis needs to be made explicit. This issue is taken into account in economic models related to the intergenerational sharing of environmental resources [37], for example using discount factors. Nonetheless, a better conceptual understanding of the period under consideration when analyzing the interlinkages between SDGs is needed.

Fourth, the analytical frameworks discussed in this paper adopt a rather technical approach towards conceptualizing SDG interlinkages that gives little consideration to the way in which different actor and power constellations might shape national integration strategies. Across the board, either SDG 16 is defined as crosscutting all other SDGs, or "good governance" is generically referred to as an enabler of the 2030 Agenda. With the exception of Weitz et al. [6] who, based on their cluster analysis of SDG target interactions, elaborate on the implications of their findings for the collaboration between actors and institutions with responsibility for the different policy areas covered by the SDGs, the issue of necessary institutional reforms to foster synergies or mediate trade-offs is left for future research.

Summing up this section, the frameworks and analytical approaches reviewed in this paper are useful insofar as they identify general, abstract interconnections, synergies and trade-offs between the SDGs. On a positive note, the majority of these publications resulted from team

efforts that brought together experts from social, economic, and technological/environmental science backgrounds. Such interdisciplinary collaboration is an important first step towards breaking up research silos and creating a common knowledge base about what is really needed to integrate the SDGs. However, a "perfect methodology" should include the following properties: methodological rigor and replicability; context sensitivity; and advice regarding a critical ranking of goals that could guide policy makers in devising SDG integration strategies that suit their national contexts. While the demand for such a "perfect methodology" may ultimately be impossible to comply with, improvements could be implemented that result in policy-oriented research that provides specific responses to the question of how to achieve integrated SDG implementation.

The next section outlines a possible roadmap towards this end.

4. Towards Integrated SDG Implementation: A Proposed Five-Step Roadmap for Co-Creation of Knowledge

The first section of this paper provided an overview of existing scientific methodological and conceptual approaches towards the identification of SDG interdependencies as well as the scarce literature on how to address the problematic issue of priority-setting in SDG implementation processes. The second section discussed the methodological and conceptual challenges of these approaches. It also highlighted the importance of an analytical approach that pays respect to the nature of the 2030 Agenda as a system of interlinked goals and targets. In both sections we emphasized that a systemic understanding of SDG interdependencies is indispensable if scientific research on these interdependencies is to be translated into policy-making that assures an integrated implementation of the 2030 Agenda, yet at the same time accounts for national circumstances and needs for priority-setting in policy-making. In fact, given the high number of targets and indicators, policy action to achieve one target of the 2030 Agenda in one geographic area or on one specific sector is likely to produce systemic effects with repercussions on other geographic areas or sectors. Stafford-Smith, et al. [38] demonstrate that greater attention must be paid to interlinkages in three dimensions: across sectors (e.g., finance, agriculture, energy, and transport), across societal actors (local authorities, government agencies, private sector, and civil society), and between and among low-, medium- and high-income countries.

To gain a systemic understanding of SDG interdependencies in local context settings, it is, on the one hand, necessary to identify the inputs that are needed for change such as, for example, the required financial resources, natural resources, and workforce. On the other hand, it is also necessary to define the nature of the outcome that a certain policy action aspires to. For example, what is the nature of the goal: is it a quantified target or a process? Furthermore, it is necessary to consider the positive and negative externalities that the aspired outcome may have for other SDGs or sectors (e.g., increase stress on water security or a higher number of energy users) as well as the diversified interests of all stakeholders affected by the outcome.

The implementation of the 2030 Agenda will largely take place at the national and sub-national level. Hence, analyses of SDG interdependencies that can be translated into policy-making need to be mindful of the nation state as the geographical unit from which SDG policy-making originates. Moreover, the complexity that results from the intertwined character of the SDGs and the urgency to achieve change requires a trans-disciplinary process of research with policy-making for the most powerful interventions for transformational change [39,40]. Understanding externalities of elements of change for all stakeholders and through various lenses as well as across policy sectors and over time is key for achieving an integrated implementation.

It follows from the above that policy-oriented analyses of SDG interdependencies need to be context-specific and hence linked to different levels of geographic boundaries. However, and in line with this, in this section we argue that systematically and fully mapping and assessing interdependencies between all SDGs in all conceivable contexts is nearly an impossible task. To move towards implementation and addressing interdependencies, we propose a roadmap for understanding SDG trade-offs and synergies for specific context settings.

Our proposed roadmap consists of 5-steps for academia to co-create knowledge about SDG interdependencies together with state and non-state actors and translate this knowledge into coherent SDG policy-making:

Step 1: Identify the problem situation and define an issue-based entry point (aspired output to achieve change for a specific SDG across policy sectors) and delineate the geographical reference points within which the output is to be achieved.

Step 2: Identify (i) the input needed; (ii) the stakeholders involved and their interests; (iii) external risks that may affect the output.

Step 3: Analyze the scale of direct and indirect synergies and trade-offs between the aspired output and all other goals and targets.

Step 4: Discuss the normative and ethical implications arising from the identified synergies and trade-offs.

Step 5: Based on the four previous steps, develop policy recommendations for targeted improvements in the area under research, including recommendations regarding goal prioritization and recommendations regarding the institutional reforms needed to foster synergies and mediate trade-offs. Finally, extrapolate lessons regarding the potential for scaling-up of solutions for the area under research und their transformation into policy recommendations to be applied in other contexts. These five steps will create dynamics for each other and may require being pursued in an iterative and duplicative process in order to give justice to the complexity of interdependencies.

4.1. Setting the Scene

Steps 1 and 2 set the scene of the research.

The first step consists in identifying the problem situation and defining an issue-based entry point into the network of interdependencies. This entry point can vary from process-oriented and qualitative situations to quantifiable targets to be achieved. To exemplify, one could decide to focus on SDG 2 (Food security) and more concretely on Target 2.4 (ensure sustainable food production systems), which is a combination of quantifiable and qualitative elements. Next, it would be necessary to address the issue of context specificity by selecting the geographical area, i.e., a certain landscape (for example a river basin) in which sustainable food production is to be achieved. Evidently, the choice of research issue and research area will determine the nature and quality of data available for the analysis, and thus addresses the methodological issue of operationalization discussed in Section 2.1. It also addresses the issue of differentiating between outcome-related and process-related goals discussed in Section 2.3. Choosing an entry-point is a critical step in the systemic understanding and should be closely linked to the concrete problem at hand. However, assuming that in such a first step of co-creation of knowledge, actors would identify multiple challenges in the problem situation, the entry-point needs to be transparent about the principles it is based on, be it e.g. urgency or compliance with human rights standards.

In the second step, the required inputs to achieve this outcome need to be identified. In the case of our example of aiming for sustainable food production systems, these inputs would include, among others, the sustainable management and re-use of natural resources, such as water (SDG 6) and soil (SDG 15). Moreover, varying forms of farm system (small-scale farming or large-scale, agro-industrial farming) need to be considered to reveal the various stakes and interests in the aspired outcome. Moreover, an assessment of the external risks (e.g., drought, rural depopulation) and uncertainty towards achieving the outcome that are particular to the chosen context is needed. This step is meant to address the issue of context sensitivity raised in Section 2.2.

4.2. Analyzing the Interlinkages

Step 3 consists in obtaining an in-depth understanding of the chosen context in order to determine the scales of the interdependencies as well as the scope (e.g., through applying the seven-point scale analysis proposed by Nilsson et al. [28]). This is essential because the extent of both synergies and trade-offs involved in achieving the outcome of interest may vary considerably between contexts. All inputs identified in Step 2, including those related to other SDGs, need to be considered in the analysis conducted in this step.

Sticking to our example of sustainable food production systems, in some contexts water resources (SDG 6) may be scarce and soil degraded (SDG 15). Securing the natural resource input needed may thus involve redistribution conflicts and the infringement of property rights (SDG 1.4 and SDG 5.a). In other contexts, however, the required natural resources may abound, but there is a lack of agricultural extension services (SDG 9, infrastructure), causing severe challenges for knowledge exchange and agricultural education (SDG 4). Evidently, arriving at such an in-depth understanding of interdependencies is only possible if the boundaries of the geographical unit of analysis are clearly delineated. In other words, research geared towards co-creation of strategic public policy knowledge needs to move beyond generic and abstract collections of all possible interdependencies [5]. One possible approach to gaining a context-sensitive understanding of goals, inputs, interlinkages, risks, and relevant stakeholders is to analyze specific interdependencies within bounded landscapes [41].

Over the past decade, the landscape approach has been used to approach complex problem situations within multi-level decision-making to respective spatial reference points, a socio-economic environment and biophysical conditions of natural resources. The approach understands landscapes as abstract concepts whose spatial boundaries and scale are defined by the needs, interests, and values of different stakeholders such as landscape inhabitants, civil society, private businesses, and policy makers. As a reference point, the landscape approach implies adopting both geographical–biophysical, as well as a socio-economic, variables towards analyzing the management and governance of the land, water, and natural resources needed to ensure ecosystem conservation and sustainable livelihoods. Rather than considering the core elements of a landscape (i.e., land, water, natural resources, socio-economic conditions) in isolation, the landscape approach investigates the environmental and socio-economic impacts produced by the interaction of these elements [42,43]. Therefore, it is useful to reduce the complexity of interdependencies by focusing on delineated spatial units and their socio-economic and environmental conditions.

Furthermore, and as previously outlined, there is a broadly shared perception that the task of implementing the 2030 Agenda will mainly fall on national governments. This perception is problematic in so far as it is based on the underlying assumption that the way in which citizens articulate their interests, exercise their rights and responsibilities, and regulate power among those who govern and are governed is mainly framed by processes of political decision-making within the boundaries of democratic state structures and public administration. However, such boundaries do not necessarily coincide with the biophysical, ecological, or socio-cultural boundaries that define a landscape.

By contrast, the term landscape governance describes the powers, authorities and responsibilities that individual and organizational, formal and informal, stakeholders exercise over a landscape. This approach also accounts for the fact that the governance of a landscape is not shaped by local conditions alone but also by processes and networks that transcend its physical and politico-administrative boundaries, as landscapes are becoming increasingly linked to wider global trends [42,44–46]. For landscape research, this implies that spatial decision-making needs to be analyzed beyond the formal political-administrative structures of nation states and also beyond state-actors. By conducting cross-sectoral analyses that adopt a multi-layered and multi-level perspective, landscape research can help to identify actor and power constellations that contribute to the aggravation of trade-offs between SDGs, as well as institutional arrangements and strategies

that have proved successful in mediating such trade-offs and/or fostering synergies between different SDGs.

4.3. From Understanding Interdependencies to Policy-Making

The last two steps consist in translating analysis and understanding of interdependencies into policy-making.

Step 4 requires a critical reflection of the previous findings in order to arrive at ethically justifiable decisions regarding the prioritization of policy actions. For example, the larger the extent of a trade-off, the more winners and losers the trade-off will likely produce; and the more difficult it will be to mediate the trade-off; or the higher the time urgency is to achieve a goal (for example extreme water scarcity), the costlier it will be to delay action. While the previous sections described how to arrive at an assessment of trade-offs and synergies, they are insufficient to set out rules and principles for policy action and implementation. Normative debates and ethical criteria may differ between contexts, depending for example on the social contract on which a society is based, or on the cultural norms that are prevalent in this society. Moreover, the prioritization of goals does not exclusively depend on the socio-political situation of the entry point and boundary under consideration, but also on the international agreements linked to the interdependency.

Finally, step 5 consists in formulating policy recommendations based on the previous four steps. In addition to advice regarding priority-setting, this will also include advancing possible and necessary institutional reforms to achieve better-integrated policymaking and to advance skills necessary science-based approaches towards SDG implementation [47]. However, these proposals need not necessarily be confined to the specific analyzed context. Rather, findings on local practices generated by the landscape research postulated in Section 3.2 should be extrapolated to answer questions of global interest such as: can networks that enable good local practices be scaled up and transformed into policy guidelines to be applied in other contexts? Which governance mechanisms observed at landscape level allow for global policy agendas to be embedded in local spaces? [48].

We are aware that the proposed roadmap can neither claim to be exclusive nor exhaustive for the entire agenda of research necessary on SDG interdependencies. Rather, we understand this roadmap as offering three main advantages.

First, the roadmap is designed to deal explicitly with complex systems of SDG interdependencies in specific contexts—whereas the majority of the existing research either assesses interdependencies abstractly, at the global level, or focuses on specific contexts but without integrating spillover effects for other geographical areas or sectors.

Second, the roadmap aims to spur transdisciplinary research for urgent and complex SDG interdependencies across scales and across time. It proposes to obtain an understanding of the nature and scope of interdependencies within bounded geographical units, through the assessment of inputs, outputs, external risks and stakeholder interests. Such in-depth understanding should help to estimate the complexity of the task to induce transformational change.

Third, the roadmap highlights the need to provide for transparent and socially just prioritization of action to achieve policy integration, and not just the simple prioritizing of certain SDGs over others. Prioritization remains a very critical step in implementing the 2030 Agenda and will cause winners and losers, also across time (temporal coherence of actions). Reconciling their interests is an issue policy-makers will have to deal with early on if the Agenda is to live up to its promise to be a blueprint for sustainable global development with peace at its heart and for future generations.

5. Conclusions

The SDGs are represented by a high number of interlinked goals, targets, and indicators. A growing number of recent research initiatives have tried to map synergies and trade-offs between the different goals and indicators, relying on different methodologies and approaches. This work has shown the high degree of interdependencies between the SDGs. While positive interactions

have been found to be more numerous than negative ones, the latter point towards the difficulty of achieving policy coherence. For example, it has been shown that in no simulation are all the SDGs reached [49]. Moreover, it has been strongly underlined how, in practice, the links between indicators are context specific and depend on a number of factors, such as geography, governance, or the socio-economic situation.

Given this background, this article has, first of all, provided a critical overview of the existing scholarly literature on mapping interdependencies between the SDGs. While we recognize that a fully comprehensive analysis of the linkages between all the SDGs for all contexts is an unrealistic task, it is crucial to understand the limitations of the current frameworks and studies in order to understand better how to use the existing knowledge for policy-making and advancing ongoing research on SDG interdependencies. Second, adding to existing literature, the paper has proposed a possible roadmap for co-generation of knowledge towards integrated implementation of the 2030 Agenda. The article, therefore, provides an example of a more practical way to deal with SDG interlinkages, taking into consideration the specificity of the contexts.

Finally, in relation to the limitations of existing frameworks, we also welcome proposals from other studies that aim to facilitate the collection of existing literature on SDG interlinkages. For example, Nilsson et al. [29] have proposed a knowledge platform for "assembling, systematizing and aggregating knowledge on interactions" from different disciplines and sources. This could achieve the dual goals of knowledge collection: overcoming the limitations of the existing single frameworks whilst also serving as a crucial instrument for policy-makers that would be able to select and consider evidence more closely related to their specific case.

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