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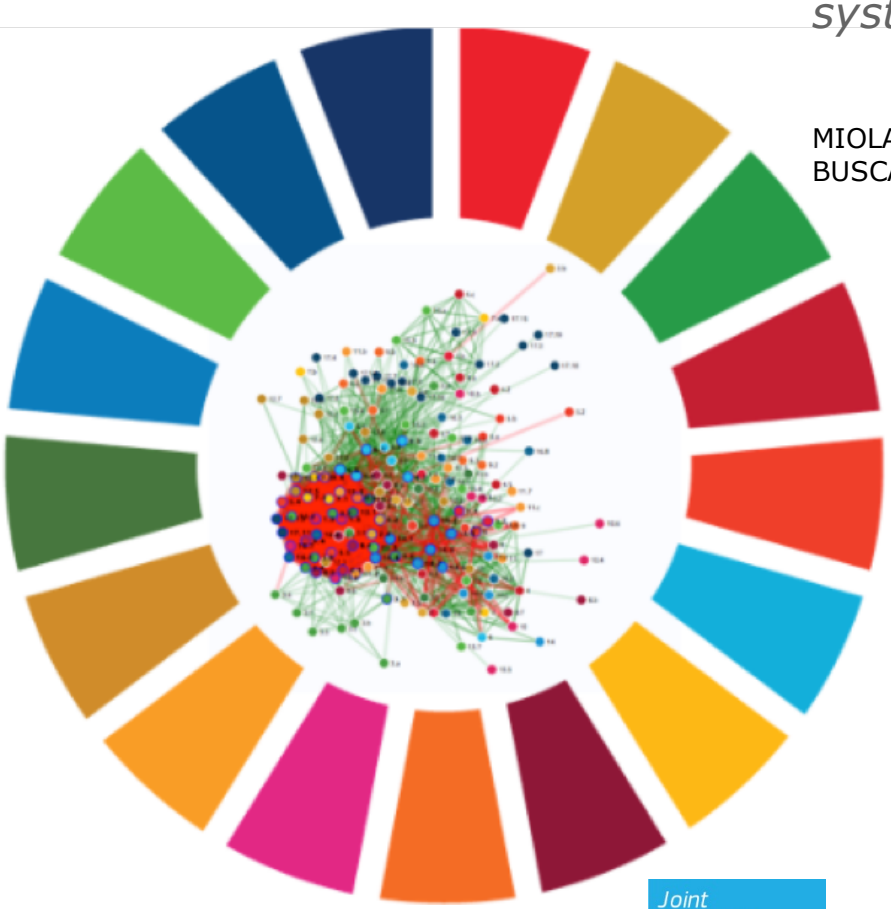
Interlinkages and policy coherence for the Sustainable Development Goals implementation

An operational method to identify trade-offs and co-benefits in a systemic way

MIOLA A., BORCHARDT S., NEHER F., BUSCAGLIA D



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Contact information
Name: Apollonia Miola
Email:apollonia.miola@ec.europa.eu

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Acknowledgements

Authors

The idea was conceived by A. Miola who wrote the report with S. Borchardt who implemented the data base and applied the R^2 method to design the two dashboards. F. Neher contributed to the identification of the classes to classify the literature. D. Buscaglia is the main author of the statistical analysis in the Annex.

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Comments on the report would be gratefully received and may be sent to:

Apollonia Miola

European Commission, Joint Research Centre

Apollonia.miola@ec.europa.eu

Abstract

The broad scope and complexity of the Sustainable Development Goals (SDGs) constitute a new challenge for policy. The identification of effective implementation strategies would need to be supported by coordinated policies that take into account the multiple relationships existing between the different dimensions of sustainability.

This report proposes an original method to identify and deal with inter-linkages. This method enables the identification of inter-linkages in a systemic way as a pivotal element of science supporting policy coherence for SDGs implementation and consistent with the key principles guiding the 2030 Agenda implementation in the international context.

The proposed method consists of two tools adopting two different perspectives. The first tool is based on the review of the current literature on inter-linkages by identifying the main approaches and classifying the literature along them. This exercise allows the development of a first dashboard indicating the “agreed” inter-linkages from the literature. The second dashboard, developed starting from the existing European Union legislation, allows the identification of policy priority areas where the EU added value is maximized and where EU policy nodes can represent the levers to exploit synergies for the SDGs implementation.

The combination of the two dashboards provides an effective operational method to develop policy implementation strategies at Goal and target levels which can support the overall policy coherence for sustainable development.

1 Introduction

The first postulation of the sustainable development was in 1987 when the Report of the Brundtland Commission (1987) defined as sustainable the development that "meets the needs of the present without compromising the ability of future generations to meet their own needs". The vagueness of this definition has often prevented the full implementation of the sustainable development concept and thus limited its power in practically orienting political choices.

In 2015 the adoption of the UN 2030 Agenda gave the political endorsement to the sustainable development concept and the definition of 17 Sustainable Development Goals, 169 Targets and a set of 244 indicators (even within their limits) allows a real operability of the sustainability paradigm. Based on an expansion of the core components of the Millennium Development Goals (MDGs), the UN 2030 Agenda and its Sustainable Development Goals (SDGs), aim to 'improve people's lives and to protect the planet for future generations'.

By including elements of economic development, social inclusion and sustainable environmental management, the SDGs have been defined according to the triple-bottom-line sustainability approach. The main objective is to deal with a set of problems that affect developed and developing countries. For this reason, a global perspective has been adopted in the definition of the goals and in the identification of the guiding principles for the policy framework (Sachs, 2012; Beishem et al., 2015).

In particular, goals 1 to 6 build on the core agenda of the MDGs, while goals 7 to 17 incorporate new ideas (UNSDSN, 2 2015). Three main principles that stemmed from the convergence of the MDGs and the Rio+20 Conference have been used to shape the SDGs, namely (UNEP, 2015):

1. leave no one behind;
2. ensure equity and dignity for all;
3. achieve prosperity within Earth's safe and restored operating space.

The sustainable development approach adopted in the SDGs is based on the idea that economic prosperity, environmental protection and social well-being are interconnected elements that cannot be addressed separately (Andreoni, V. Miola, A., 2016).

An integrated approach, based on the promotion of equity and equality, the inclusion of multiple cultural values, prosperity and development, human rights and environmental conservation, has been used to identify the goals and targets of the SDGs. The SDGs have been specifically formulated, based on four main elements (UNEP, 2015): Human well-being is intrinsically linked to the health of natural ecosystems; global environmental challenges not only affect the development of the poores, but also pose a threat to the long-term prosperity of development; addressing inequalities in the distributive benefits of development is critical for global sustainable development; sustainable resource management, and maintenance and safeguarding of natural capital are fundamental aspects.

As already pointed out, many of the goals included in the SDGs are multidimensional, covering the three main dimensions of sustainability: economy, society and the environment. Many synergies and complementarities can exist among the different SDGs. But trade-offs are also possible where improvements in one dimension could trigger negative results in another. A systemic approach needs to be adopted in dealing with this aspect.

This report proposes a new operational method consisting of two tools to identify interlinkages by adopting two different perspectives. One is purely scientific oriented as it is based on the review of the scientific literature on inter-linkages in the SDGs framework and the one is policy oriented and based on EU legislation.

This method enables the identification of inter-linkages in a systemic way as a pivotal element of science supporting policy coherence for SDGs implementation and consistent with the key principles guiding the 2030 Agenda implementation in the international context.

Chapter 2 proposes and discuss how science and policy can interact to implement the SDGs framework and the role of inter-linkages in this context. The main blocks of how science can support policy coherence for SDGs implementation are identified to address some of the key issues such as: (a) how SDGs can be achieved in a systemic way? (b) how to identify and assess coherent implementation strategies?

Chapter 3 describes the state of the art regarding inter-linkages in the SDGs context by identifying the key elements of the current debate from the grey and peer reviewed literature. The current debate is characterized by a plurality of methods, approaches, assumptions and results which are synthesized in five main methodological approaches: the linguistic approach, the literature approach, the argumentative/ expert judgement approach, the quantitative approach, and the modelling approach.

Chapter 4 reports on the results of the review of the literature on SDGs inter-linkages and organizes them in a dashboard. This dashboard summarizes the results of the analysis which aims to address the following questions: Do different methods arrive at similar conclusions? Which inter-linkages are universally agreed on?

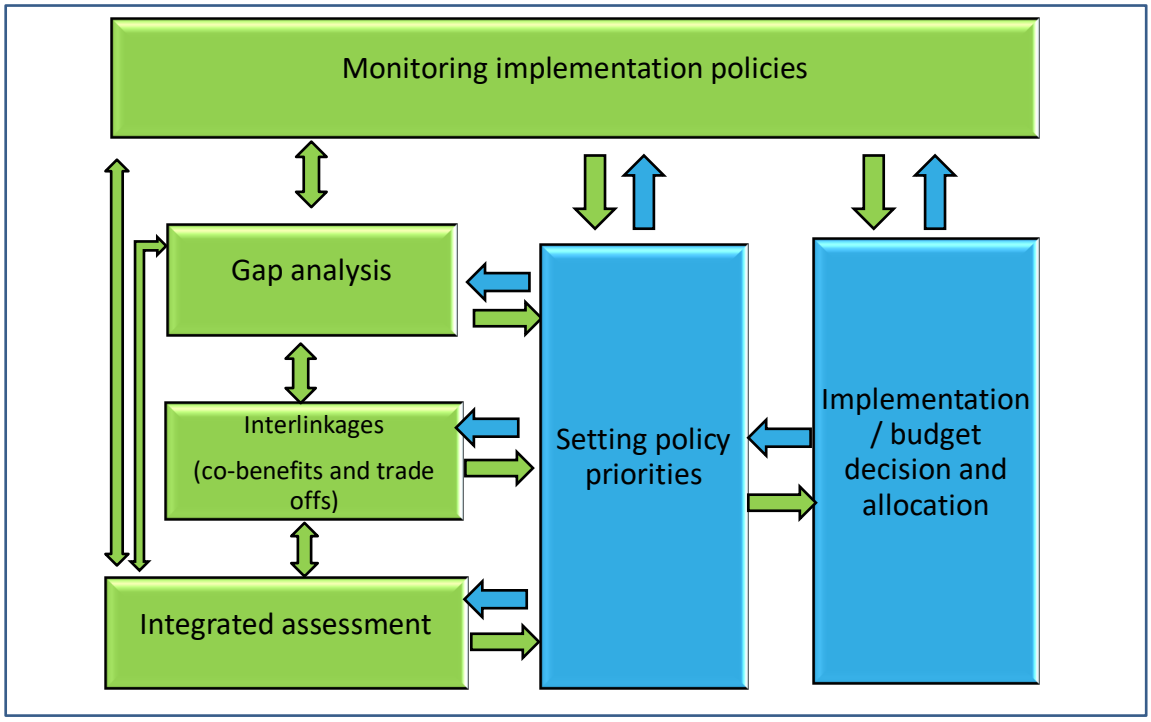
Chapter 5 introduces and develops a new perspective to deal with inter-linkages by adopting a policy point of view and applying it for the European Union context, while chapter 6 provides a practical example on how the main blocks of the science-policy interface supporting the SDGs policy coherence could operate in the European Union context. The two proposed dashboards, in combination with more analytical tools such as those to identify gaps and integrated assessment models, can offer a knowledge base to adopt a systemic and holistic approach to SDGs from a policy perspective and to identify all action levers for a fully coherent set of policies for sustainable development.

2 Science -Policy interface for policy coherence on SDGs implementation

As often pointed out by several international organisations and scholars, the successful implementation of the UN 2030 Agenda requires a coordinated and coherent set of policies. At the same time, the simultaneous formulation of a comprehensive set of policy targets, as laid down in the SDGs, together with a proposition on suitable indicators for measuring them, allows for the systematic analysis of implied synergies and trade-offs which can help improve overall policy coherence.

The focus of our analysis is the development of operational tools to support policies for SDGs implementation in the context of a science policy interface as described in Figure 1. It summarises the main channels through which science can support policy coherence for Sustainable Development Goals implementation to address some of the related key issues such as: how SDGs can be achieved in a systemic way? How to identify and assess coherent implementation strategies?

Figure 1: Science-policy interface for policy coherence on SDGs implementation



Source: Author's elaboration.

The green blocks in the figure are the areas that primarily pertain to science and are aimed at developing analytical tools supporting SDGs implementation. The blue blocks refer to policy. The green and blue blocks interact with each other with two-way relationships. Taking up the analysis of the science blocks, they are as follows.

Indicators for ex ante and ex post monitoring. The SDG-process puts a strong emphasis on the development of "a solid framework of indicators and statistical data to monitor progress, inform policy and ensure accountability of all stakeholders"

(A/RES/71/313). The UN Statistical Commission (UNSC) has developed an indicator framework for monitoring and reporting of the SDG implementation process on the global level acknowledging that different indicators might be appropriate in a different context. The UN indicator set is "intended for global reviews and… not necessarily applicable to all national contexts and country reviews". Appropriate indicators for the measurement have been decided upon. However, many of those either do not exist as of now or do not have sufficient data coverage or data quality.[1]

Because of different data quality, availability and coverage, but also due to appropriateness and context, the adaptation of indicator sets to local contexts and needs is explicitly acknowledged by the UN. In fact, optimal use of statistical indicators to measure the SDGs is context dependent and in general there is a trade-off between breadth of coverage and comparability on the one hand and detail and availability of information on the other hand. For example, for global coverage there is the possibility of misaligned indicators (e.g. poverty or malnutrition) and low data quality (irregular updating, missing data, reliability) versus country-level or region level (EU28) data, capturing the appropriate information for the given context with high quality data.

Different entities (European Commission [2], National Statistical Offices [3]) have chosen different indicator sets. For example, using a collaborative process, EUROSTAT has developed an indicator set to monitor and report on the SDGs in the EU (ESTAT, 2017, 2018), making a trade-off between comparability across countries on the one hand and data quality and appropriateness on the other hand.

While the use of the UN indicators would facilitate the comparison of the EUs progress on the SDGs with the other countries in the world, for many targets no information would have been available and many indicators for targets would not have been fit for the context. For example, two targets in SDG1 refer to absolute poverty as defined by the availability of 1.9$ per day. This kind of poverty de facto does not exist in the EU. Accordingly, the indicators for Goal 1 in the EU context are chosen to capture poverty in the EU context.

The issue becomes even clearer for target 2.2. on malnutrition. In the global context the prevalence of stunting and wasting in children is used to measure malnutrition. In the EU context, undernourishment and resulting stunting and wasting are a very rare phenomenon and accordingly the obesity rate has been employed to capture malnutrition. The same trade-off had to be done for the OECD member states, resulting in an OECD indicator set (OECD 2017). In general, an indicator set needs to account for the specific context of the reality it is meant to measure.

Progress/Gaps analysis. A gap analysis is based on the evaluation of the current and observed performance with the desired objective which in our analysis consists of the achievements of the SDGs. The gap analysis allows for an understanding of where countries stands in the different domains from the "achievement" of the SDGs in 2030. Accordingly, the analysis can inform policy makers of how much effort is needed and thus can support the formulation of priorities for policy.

The OECD (2017) distance analysis, ESTAT (2018) measuring progress towards SDGs and SDSN SDGs (2017, 2018) dashboard are prominent examples of these tools. They use different methods and different indicator sets. Taking a circumstantial look at OECD (2017)

[1] All indicators are classified by the IAEG-SDGs into three tiers on the basis of their level of methodological development and the availability of data at the global level, as follows:
Tier 1: Indicator is conceptually clear, has an internationally established methodology and standards are available, and data are regularly produced by countries for at least 50 per cent of countries and of the population in every region where the indicator is relevant.
Tier 2: Indicator is conceptually clear, has an internationally established methodology and standards are available, but data are not regularly produced by countries.
Tier 3: No internationally established methodology or standards are yet available for the indicator, but methodology/standards are being (or will be) developed or tested.

[2] https://ec.europa.eu//eurostat/web/sdi

[3] Un example is provided by ISTAT, 2018

and SDSN SDGs (2017) dashboard[4] their results were compared for the EU countries. Overall the OECD distance analysis finds, somewhat surprisingly, that OECD countries "have some distance to travel to reach […] the goals related to gender equality, education, the economy and jobs, and institutions" while they are "closer to meeting targets on water, biodiversity, cities, poverty and oceans" (OECD 2017, p. 17). In contrast, the SDSD/Bertelsmann dashboard indicates that "the greatest challenges exist on sustainable consumption and production (SDG12), climate change (SDG13), clean energy (SDG7), and ecosystem conservation (SDGs14 and 15) (SDSN/Bertelsmann 2017, p.12).

It is quite clear that the two studies contradict each other to some extent. On the country level, eyeballing the results for Belgium and Italy from both studies, there is some indication of conflicting findings for a number of goals as summarized in Table 1. Progress/gap analysis play an important role as supporting analytical tools for SDGs implementation policy, but existence of multiple, in principal equally justifiable indicator sets and the possibility of conflicting results from their use creates a politically tricky situation. In addition, in this case a gap/progress/distance analysis needs to account for the specific context of the reality it is meant to measure.

Table 1: Overview: results of OECD distance analysis and SDSN/Bertelsmann dashboard – SDGs with discrepancies –Belgium, Italy

SDGs	Belgium			Italy		
	OECD	**SDSN**	**Comparing Results**	**OECD**	**SDSN**	**Comparing Results**
4	Long Dist	Yellow	Not Available	Long Dist	Green	Conflict
5	Long Dist	Yellow	Not Available	Long Dist	Yellow	Not Available
8	Long Dist	Green	Conflict	Long Dist	Red	Agreement
12	Short Dist	Red	Conflict	Short Dist	Red	Conflict
13	Medium Dist	Red	Not Available	Short Dist	Red	Conflict
14	Short Dist	Green	Agreement	Short Dist	Red	Conflict
15	Short/ Med Dist	Red	Not Available	Short Dist	Yellow	Not Available
16				Long Dist	Red	Agreement
17				Long Dist	Green	Conflict

Source: Author's elaboration.

Inter-linkages. Policies improving a specific dimension can generate impacts in other dimensions, with a large set of possible cascading positive or negative effects in both the short and the long terms (inter- and intra-generational effects) as well as with regard to impacts on different geographical levels, possibly causing transboundary spill-over effects. The simultaneous formulation of a comprehensive set of policy targets, as laid down in the SDGs, together with a proposition on suitable indicators for measuring them, allows for the systematic analysis of implied synergies and trade-offs which can help improve overall policy coherence. As shown in the following chapters, science can offer many analytical tools to identify such inter-linkages.

[4] ESTAT measuring progress method was not compared because ESTAT does not provide an analysis at country level but just at EU level.

Integrated and systemic assessment. The widely accepted *ceteris paribus* condition, which analyses the behavior of each system independently, cannot be considered helpful in the UN 2030 Agenda context. More holistic approaches are required as the contextual evaluation of several systems together is fundamental. For this reason, integrated and systemic approaches such as quantitative models and qualitative methods such as foresighting tools are pivotal for an ex-ante and ex-post assessment of any policy implementing SDGs. The integrated assessment based on these tools could give more details on the dynamics of the involved variables and interactions and could provide alternative scenarios to select policy priorities.

With regard to the political blocks, setting policy priorities requires evidence but also the adoption of a participatory approach, involving many stakeholders (such as citizens, private sectors, NGOs, etc.). The inclusiveness of the process allows for coherence with the "leave no one behind" principle of the 2030 Agenda while the definition of sectoral policies and the budget allocation will be the operational tools. The next sections will give an overview about the state of the research on inter-linkages.

3 Inter-linkages: main characteristics of the current debate

At global, regional and local level there is an increasing demand for understanding the relationships among the components of the SDGs framework in order to adopt a systemic approach. Meeting this demand is fraught with difficulties due to the multitude of objectives/criteria that need to be considered as well as to the interrelated nature of these domains, which are dynamic and evolving over time. Potentially, there are a large number of synergies and complementarities among the different SDGs and targets. Thus, an international debate along with multiple research efforts to identify possible synergies and trade-offs between goals and targets is underway.

This section describes the state of the art regarding inter-linkages in the SDGs context by identifying the key elements of the current debate from the grey and peer reviewed literature.

3.1 Concepts and terminology

Since 2016, an increasing body of literature has emerged to identify inter-linkages among SDGs. Nevertheless, no common understanding (nor terminology) exists on what an inter-linkage is.

In the context of the UN SDGs framework inter-linkages are mainly identified between:

(i) goal and goal;

(ii) target and target;

(iii) indicator and indicator;

(iv) environmental, socio economic pillars of sustainability.

The entry point of the analysis can be a goal, a target, an indicator, a nexus (Karnib, (2017); Boas, (2016), Mainali, (2018); Liu et al., (2018)), a theme (McCollum et al., (2018)); a policy mechanism or objective (Vandyck et al., (2018); Haines et al., (2017)); reporting tools (Iyer et al., (2018); Tosun and Leininger, (2017). Of course, the inter-linkages become more and more complex when the trans-boundary and inter-generational effects of SDGs implementation are taken into account.

The variety of interpretations of interlinkages is due to many factors such as: the conceptual confusion around the key elements of the SDGs framework due to different scientific communities that are trying to resolve it; the vagueness of definitions and objectives for the international political context dealing with SDGs implementation; limited reflection about how to implement such concepts in terms of analytical tools, data in developing and developed countries.

This aspect is more evident when we focus on the role of the inter-linkages within the context of the Voluntary National Reviews[5] (VNRs). The inter-linkage concept appears in 23 countries that presented a VNR by July 2018. Most of the VNRs refer to inter-linkages in general, others offer concrete solutions, or specific examples.

In that context, the analysis of inter-linkages is characterized by heterogeneity in terms of:

- terminology: consequences, trade-offs, conflicting interests, winners and losers, policy conflicts, externalities, interactions, co-benefits, are some of the used terms;

[5] Voluntary National Reviews are explicitly indicated in paragraph 84 of the 2030 Agenda. They are voluntary and state led . They are the results of a process by which country take stock of and assess progress in the implementation of the SDGs framework. More information are available at the website: https://sustainabledevelopment.un.org/hlpf

- focus of the analysis (for example, in Botswana the focus is on HIV / AIDS while Denmark emphasizes job creation and income inequality);
- tools for their identification (for instance, Belize applied a budgeting tool). Some countries also identify specific tools for their management. In the case of Botswana, the country identified oil revenue investments as a tool to manage the spread of HIV / AIDS.

In order to carry out a review of the literature, we define inter-linkages within the SDG framework as causal and/or statistical relationships between goals, targets and indicators. If the inter-linkage (i.e. the causal or statistical relationship) is positive we talk of synergies, if it is negative we refer to trade-offs.

3.2 Main approaches

The current debate is characterized by a plurality of methods, approaches, assumptions and results that can be synthesized in five main methodological approaches: the linguistic approach, the literature approach, the argumentative/expert judgement approach, the quantitative approach and the modelling approach.

1. For the **linguistic approach**, the assessment of the relationship between different targets is based on their respective wording and meaning such as a keyword search in order to make findings reproducible. However, this approach can present some ambiguities. Some targets have similar meanings without sharing a keyword, while others share keywords without sharing meaning. The choice of appropriate keywords can also be contested.

   Le Blanc (2015) applied such an approach and developed a matrix of inter-linkages where all targets are linked to Goals based on their wording. Nunes et al. (2017) identified to which sectors the goals are referring to. However, the paper does not explain how the authors arrive at their conclusion and the definition of sectors at the goal-level is not suitable to derive the respective keywords at the target level. In Stafford-Smith et al. (2017) finance, technology, capacity and trade are the key words to identify inter-linkages between the SDG 17 and all the Goals and targets. Coopman et al. (2016) applied a text-based, discourse approach, which is complemented by a limited number of specific publications. In sum, the linguistic approach is a first and easy step to establish obvious inter-linkages, mainly synergies, between goals and targets.

2. The **literature approach** refers to inter-linkages which are established in the scientific literature, mostly without direct reference to the SDGs.

   Prominent examples include the co-benefits from the climate change literature: e.g. CO_2 emission reduction simultaneously mitigates climate change (Goal 13), improves air quality, prevents premature deaths from respiratory diseases (Goal 3, target 3.9) (Vandyck et al. (2018)). Accordingly, there is a synergy between the related Goals. Le Blanc et al. (2017) and Vladimirova et al. (2016) used a modified literature approach in the sense that they restrict the analysed literature to UN-flagship reports. Haines et al., (2017) identified the links between measures to reduce short-lived climate pollutants and SDGs. Many papers are related to the literature on Nexus, an approach which fits with the inter-linkages analysis (Karnib (2017), Boas (2016), Mainali et al. (2018)). In IGES, (2017) an extensive literature review (scientific and policy docs) is performed to identify binary inter-linkages between SDG targets. This is the core basis to develop a dashboard for Bangladesh indicating co-benefits and trade -offs.

   The literature approach is an exploratory approach. The immense size of the scientific literature and its constant growth makes a complete review of the literature impossible, and inter-linkages have to be recorded and catalogued as they are established.

An indeterminacy in this approach arises from the need to connect the concepts of the scientific publications to respective targets, since some interpretation is needed. This approach is often proposed in combination with the

3. **The argumentative/expert judgement approach** links targets to each other using argumentation by identifying relationships among the concepts involved.

   For example, the improvement of quality and reduction of pollution of water (target 6.3) can be argued to be linked to the conservation and sustainable use of inland freshwater ecosystems (target 15.1). In this approach, experts suggest inter-linkages which are often elaborated in group discussions and, if no agreement is reached, they can be backed by scientific publications. Fuso Nerini et al.,(2018) uses a consensus-based expert elicitation process in order to identify inter-linkages related to SDG7 implementation and the 2030 Agenda as a whole. Agarwal (2018) analyses the role of SDG 5 (Gender equality) in the implementation on SDG2 on Food Security. The inter-linkages mainly focused on the impacts on land and marine life (SDG 15 and SDG 14) with a geographical focus (developing countries). Singh et al. (2018) proposed a method combining the review of the literature with the results of a formal framework during a series of workshop sessions with experts focusing on SDG14.

   ICSU (2017) and Nilsson et al. (2016) provide a prominent example which has caught much attention. Their approach consists of expert judgment and literature review which inform a group-based discourse. Interactions are assessed on the basis of a 7-point scale ranging from -3 ('cancelling') to +3 ('indivisible') with 0 (neutral) in between. The seven points approach has been adopted in several papers and adapted to the context.

   Weitz et al. (2017) applied this approach and developed a cross-impact matrix using Sweden as case study. Data are explored by using a network analysis technique. McCollum et al. (2018) applied the 7 points scale in order to guide the expert judgement focusing on energy in the SDGs context in a two phases approaches including an extensive review of the literature on sustainable development (the search of the literature does not use the specific SDGs terminology).

4. The **quantitative approach** aims to establish inter-linkages between goals and targets by quantitative statistical analysis of the underlying indicators. This historical data is often employed in data mining exercises to understand covariation and correlation across goals and targets, but also across space (Mainali et al. 2018) and time. Such an exercise can also help to establish the context-specificity of some inter-linkages. For example, correlation analysis might reveal that for one group of countries the correlation between two indicators is positive, for another group it is negative, and for a third group there is no correlation whatsoever.

   So far, we identified many studies which apply this approach with a limited geographical scope. Most of these studies are from countries' statistical offices and analyse inter-linkages among indicators with a specific geographical scope such as Italy (ISTAT, 2018). Annex A provides an example of this approach with a case study on the EU 27. Inter-linkages are identified between SDGs at indicator level through statistical evaluation using historical time-series data for two sets of indicators (Eurostat - Sustainable Development Indicators and the United Nations - SDG Indicators - Global Database). The results are shown using a network visualization which enables a user friendly understanding of the main nodes related to the identified inter-linkages. This approach could encompass the unbalanced approach that frequently characterizes qualitative literature, where the identified inter-linkages may be biased due to asymmetric knowledge on individual targets and their causal links with others.

5. **Modelling complex system interactions** can help to understand interdependencies among variables. Some papers highlight the relevance of a specific model to identify inter-linkages in a specific sector and/or policy but without providing new evidence or quantitative results developed for the SDGs implementation. For instance, scenario modelling support are developed in Stechow et al. (2016) clustering 2 degree pathways

to meet a set of energy related SDGs. In Vandyck et al. (2018) the results of the analysis investigating the co-benefits related the implementation of climate mitigation policies and air quality, health are extended to SDG3, SDG7 and SDG 13. In Scherer et al. (2018), a quantitative analysis is performed to assess the environmental impacts of ending poverty (related to SDG 1: no poverty), and reducing inequality (related to SDG 10: reduced inequalities). In the opinion of the authors the "modelling" community has started to face the SDGs without developing a new specific tool, but trying to adapt already existing models.

In many cases there is no effort to adapt the model with the integration of specific indicator sets (Campagnolo et al. 2018), or hypotheses able to capture the holistic approach of the 2030 Agenda. In most cases the results of the models are interpreted by applying the SDGs terminology as a reading key. Allen et al. (2016) give a picture of the current state of the art on modelling and their contribution to the SDGs integrated assessment by reviewing 80 quantitative models that have the potential to support national SDG planning and implementation.

The authors assess those models by applying a multi criteria analysis on the basis of 10 criteria. The main criterion is the identification of a broad integrated systems-based approach, encompassing many SDGs and targets and their inter-linkages. They classify those models as low performing models that focus on a narrow set of SDG policy issues with limited linkages and feedbacks to broader systems, as well as with limited national application, and complicated difficult-to access interfaces. They conclude that just 8 models met the two screening criteria (integrated, policy relevant) 1 top-down CGE model (MAGNET), one top-down systems dynamics model (Polestar) and 6 hybrid models (IMPACT, International Futures, Threshold 21, EC4MACS, InVEST, LowGrow).

Table 2 provides a summary about the approaches that were classified as being relevant for the current debate on inter-linkages among the SDGs. Moreover, our review identifies some gaps: for example, most of the studies focus on the analysis of inter-linkages in the context of domestic policy, while analyses of the role of inter-linkages as impacts beyond national boundaries (trans-boundary effects) are almost absent. When they are mentioned, they are mostly in the environmental and social ecological literature (carbon footprint, planetary boundaries) with the risk of losing the holistic aspect of the SDGs framework that does not set any priority. The same gap is identifiable in the analysis of intergenerational effects, that are often limited to the future well-being literature but do not find a systematic vision within the SDGs literature.

Table 2: Summarising Key Aspects of the Methodological Approaches.

Linguistic Approach	Literature Approach	Argumentative/ Expert Judgment	Quantitative Approach	Modelling Approach
•assess interlinkages based on common keywords •ambiguities when goals share meaning but no keyword or vice versa •requires qualitative text interpretation •First easy step to identify obvious interlinkages	•identifying interlinkages that are established in the scientific literature •exploratory approach •requires interpretation when scientific concepts have to be connected with respective targets	•often in combination with literature approach •links targets to each other by identifying relationships among the concepts involved •judgment made by individuals or groups of sector-specific experts	•identifying interlinkages by performing quantitative statistical analysis with the underlying indicators •historical data - often employed in data mining exercises •more robust than the qualitative approaches where individuals do the evaluation	•Modelling complex systems interactions can help to understand interdependencies among variables •no specific tool for modelling SDGs does exist so far •rather expanding on existing models by adapting them

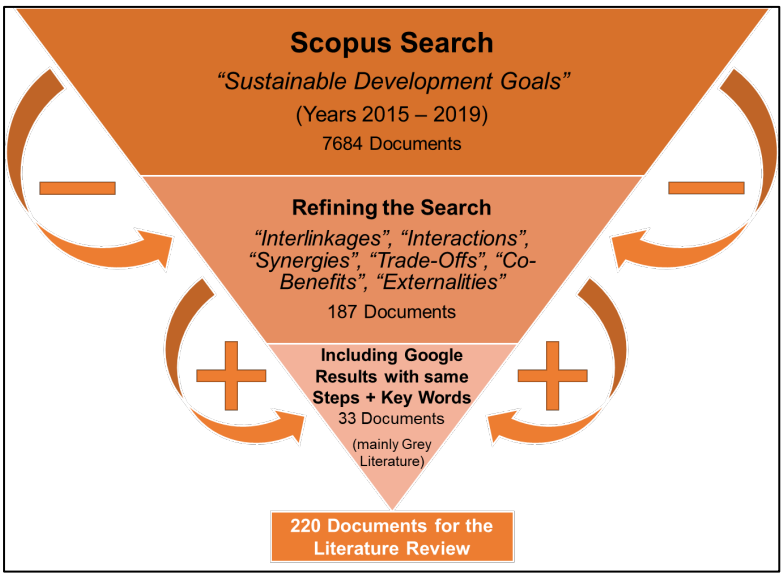
Source: *Author's elaboration.*

4 Inter-linkages: from the review of the literature to an operational tool to identify synergies and trade-offs

This chapter presents the results of the review of the literature on SDGs inter-linkages and organizes them in a dashboard. This dashboard summarizes the results of our analysis which aims to address the following questions: do different methods arrive at similar conclusions? Which inter-linkages are universally agreed on?

In order to answer these questions, we first searched in Scopus for the keywords "Sustainable Development Goals" by imposing as a temporal limit the documents published from 2015 and 2019, from the year of the Adoption of the UN 2030 Agenda up to the articles still in press[6].

Figure 2: Scheme of the literature selection process.



Source: *Author's elaboration.*

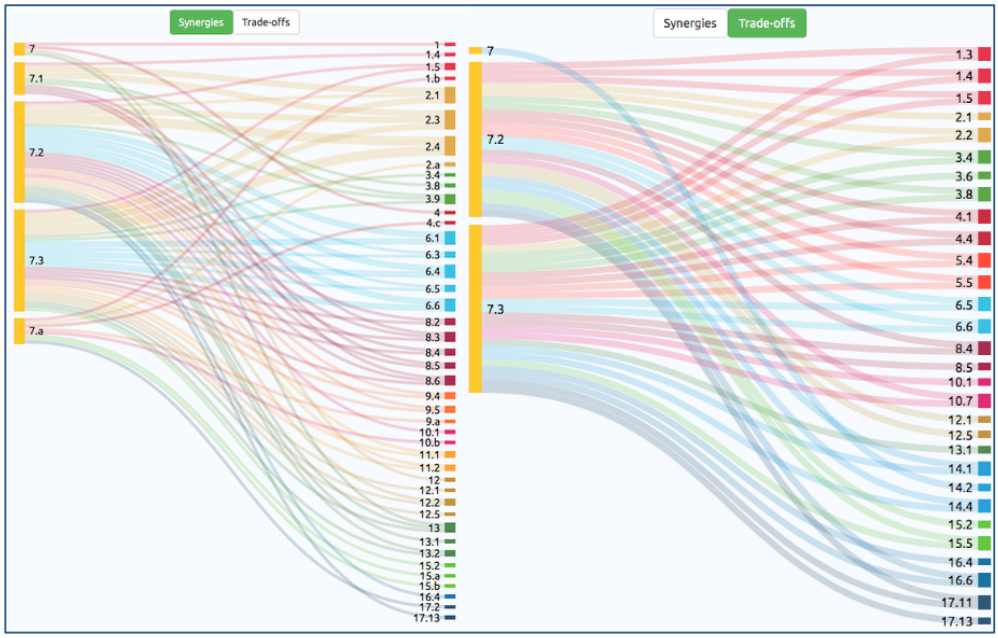
The figure above illustrates the scheme we applied for the literature selection process. The first search in Scopus has produced 7,684 documents. We have therefore imposed additional limits by introducing the key words: inter-linkages, interactions, trade-offs, synergies, co-benefits, externalities. This further refinement has given 187 Documents from Scopus. In addition to these documents we added 33 documents from a google search, which was carried out by applying the same steps and key words. In this case, documents are mostly from the grey literature (OECD, ESTAT, UN reports, VNRs). We kept just those papers which clearly indicated inter-linkages and those documents which simply describe the topics were not included in the relational database.

The current database (status: 28/11/2018) contains 3490 entries based on 20 papers of the screened and reviewed papers. The database has been made public and it is available in the knowSDGs platform[7]. The platform provides the access to the cumulative results and figure 3 shows an example focusing on SDG7.

[6] The fact that publications to the subject are only now forthcoming makes the analysis an ongoing study, but our cut-off date was November 27, 2018. It is also important to underline that the analysis was limited only to the literature in English: this choice obviously poses a limitation since it is the opinion of the authors that there are currently many more relevant publications in different languages. The scope of our analysis can then be extended in the future.

[7] http://knowsdgs.jrc.ec.europa.eu/interlinkages/info

Figure 3: Review of the literature on SDGs inter-linkages - cumulative results on the SDG 7.



Source: *Author's elaboration.*

The following sections describe the results of our review of the current literature on inter-linkages identified as reported in the figure 2.

4.1 Workflow

The validity analysis has been carried out in R[8]. Firstly, some of the data in the inter-linkages database needed to be edited for the comparison (dealing with missing values, some cells contained more than one target etc.). Afterwards, same source-target combinations were identified, since only matching source-target combinations could be compared with each other. At this stage, there were 1041 entries with matching source-target combinations identified.

In the next step, the type of interlinkage (plus or minus) was included for the comparison to see whether the results extracted from the literature drew the same conclusion. After dropping the duplicates, 629 matching source-target combinations remained for the final analysis. This analysis revealed that for 342 combinations no clear interlinkage could be identified, meaning that different publications came to different conclusions. By having a closer look, two publications (LeBlanc et al. (2017); ICSU (2017)) even showed disagreements on the inter-linkages between SDGs within their own publication itself. The reason for that can be found in the evaluation process of the two publications.

When their methodological approach could not clearly determine the nature of the interlinkage, both options, plus and minus were provided for the source-target combination to indicate the ambiguity of this combination.

[8] *R is a programming language and an open software environment for data analysis which is widely used among data analysts and statisticians. For the present analysis, RStudio – an Integrated Development Environment that serves as Graphical User Interface – has been used for writing and running the code. The final results have been exported to several Excel files.*

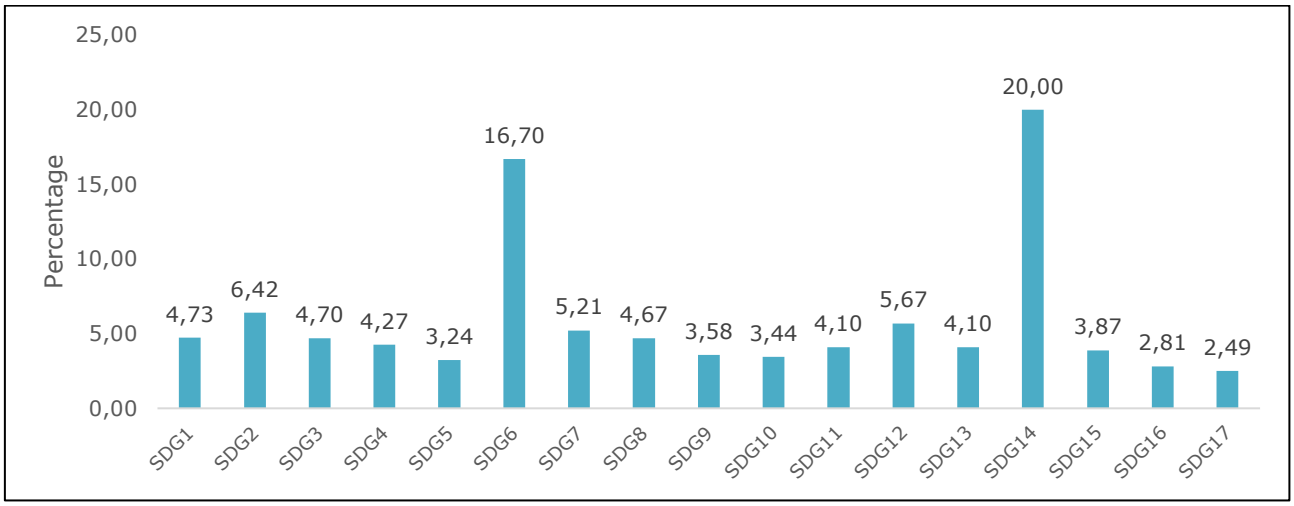
Since this issue was not relevant for the conducted comparison and since the validation rather targeted to compare results between different publications to check for agreement, these 87 combinations were removed from the sample.

In a final step, the comparison was repeated with the remaining combinations to eventually identify 230 ambiguous inter-linkages that occur due to different evaluations made by the reviewed publications.

4.2 Results

All 17 SDGs were covered by the inter-linkages database, though some showed better coverage than others and especially SDG 6 and SDG 14 featured a great number of entries, since two of the reviewed publications specifically focused on these SDGs (SDG 6 had 583 entries, SDG 14 698 entries). On the other hand, SDG 16 and SDG 17 had the lowest number of entries (Figure 4).

Figure 4: Distribution of Database entries on Goal-Level

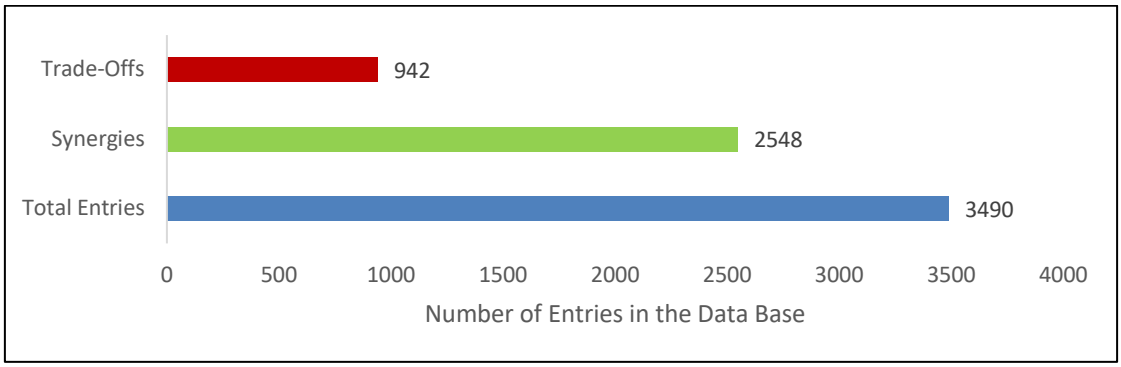


Source: *Author's elaboration.*

While the Goal-Level is sufficiently covered by the entries from the database, the targets are not well-covered. There are numerous targets (2.c, 3.1, 3.2, 3.5, 3.6, 3.a, 5.b, 5.c, 8.6, 8.7, 8.10, 8.a, 8.b, 9.6, 10.4, 10.5, 10.6, 10.a, 10.b, 11.3, 11.4, 11.7, 11.a, 11.b, 11.c, 15.4, 15.6, 15.7, 16.3, 16.7, 16.8, 16.9, 16.10, 16.a, 16.b, 17.3, 17.4, 17.5, 17.7, 17.8, 17.9, 17.10, 17.14, 17.15, 17.16, 17.17, 17.18, 17.19) whose potential inter-linkages with other targets or goals have not been addressed yet in the reviewed literature (see Figure 7).

In terms of the inter-linkages themselves, the analysis revealed that 2,548 out of 3,490 entries indicated positive inter-linkages between the SDGs, while the remaining 942 indicated potential trade-offs (Figure 5). This distribution can either be explained by the scopes of the reviewed publications or by the assumption that the SDGs basically feature more potential synergies than trade-offs due to their reinforcing nature.

Figure 5: Total distribution of Synergies and Trade-Offs



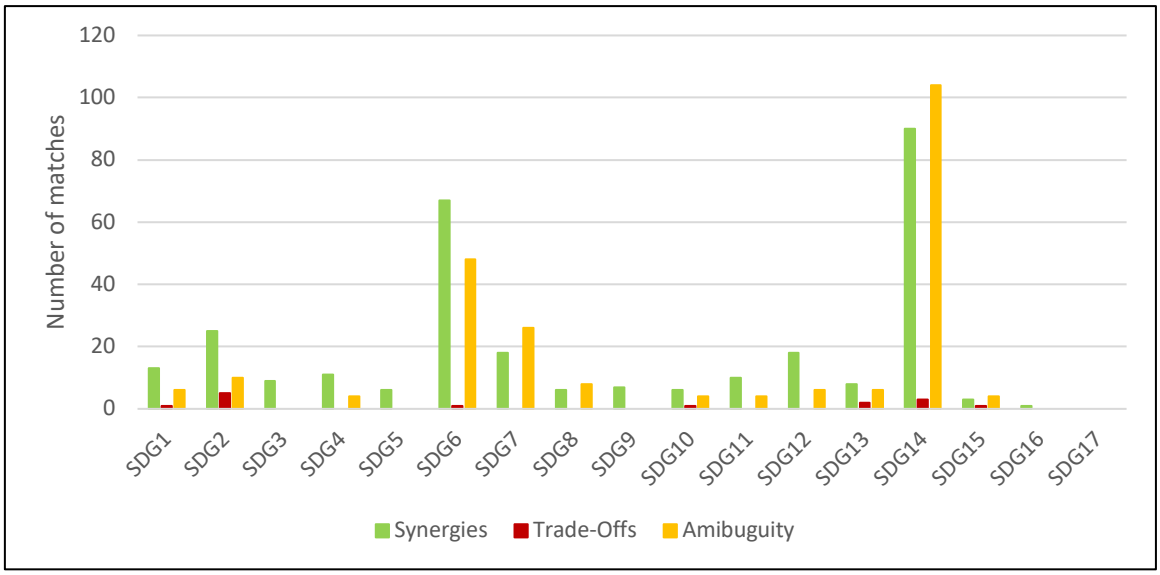
Source: *Author's elaboration.*

When taking a closer look on the reviewed literature, it becomes clear that there are only a few publications that specifically focus on trade-offs, while the majority puts a stronger focus on identifying potential synergies. Weitz et al. (2017) for instance, identified 647 trade-offs and 475 synergies, whereas Vladimirova et al. (2016), IGES (2017), ESTAT (2017) and SDSN (2015) only presented synergies without paying attention to potential trade-offs. Furthermore, Weitz et al. (2017) were the only ones that identified more trade-offs than synergies, the rest of the reviewed literature always presented either more synergies than trade-offs or synergies only.

However, it is important to note that the SDGs are also highly context related and thus the outcomes of their analysed inter-linkages do also strongly depend on their geographical scale (global, regional, national etc.), which is why the assessment on inter-linkages provided by Weitz et al. (2017) might differentiate from the analysis carried out by ICSU (2017), as they applied their assessment framework on a global scale, while Weitz et al. (2017) applied their cross-impact matrix on a national scale for the case of Sweden.

The following Figure shows the distribution of synergies, trade-offs and ambiguous linkages on the Goal-Level, excluding ICSU (2017) and LeBlanc et al. (2017), since the focus of this analysis has been placed on the comparison of the findings between different publications.

Figure 6: Distribution of validated results - excluding ICSU and LeBlanc publications



Source: *Author's elaboration.*

The key findings of the present analysis focus on disagreements among the reviewed publications on the evaluation of the respective inter-linkages between the SDGs. Like stated above, only 230 combinations could be compared to each other, since those were the only matching source-target combinations with ambiguities after the additional ambiguous combinations that occurred within the same publication were removed.

The following table shows the distribution of these 230 ambiguous combinations on the Goal-Level as well as their share on the total number of identified matches along with the number of total entries in general and the number of identified synergies and trade-offs on which the publications agreed in their evaluation for the respective targets or goals.

Table 3: Distribution of Synergies, Trade-Offs and Ambiguities on Goal-Level, without ICSU 2017 & LeBlanc 2017.

	Total matches	Synergies	Trade-Offs	Amibuguity	Share of Ambiguity in %
SDG1	20	13	1	6	30.00
SDG2	40	25	5	10	25.00
SDG3	9	9	0	0	0.00
SDG4	15	11	0	4	26.67
SDG5	6	6	0	0	0.00
SDG6	116	67	1	48	41.38
SDG7	44	18	0	26	59.09
SDG8	14	6	0	8	57.14
SDG9	7	7	0	0	0.00
SDG10	11	6	1	4	36.36
SDG11	14	10	0	4	28.57
SDG12	24	18	0	6	25.00
SDG13	16	8	2	6	37.50
SDG14	197	90	3	104	52.79
SDG15	8	3	1	4	50.00
SDG16	1	1	0	0	0.00
SDG17	0	0	0	0	0.00

Source: *Author's elaboration.*

Table 3 reveals that no matching source-target combinations were available for Goal 17 and only one for Goal 16. Goals 5, 9, 10 and 15 do only have a few matches that could be compared. On the other hand, Goal 6 and 14 feature many entries as UNESCAP (2016), OECD (2017) and Singh et al. (2017) were specifically focusing on these two targets within their analysis. A lot of disagreement on the evaluations of the inter-linkages (more than 35 %) occurred within the Goals 6, 7, 8, 10, 13, 14 and 15.

Since the quantitative indicators for SDG 10 are seemingly vague, it is not surprising that there exists considerable disagreement among the reviewed publications on the inter-linkages for this Goal. Additionally, the sample size for SDG 10 is relatively small which is why diverging judgments may have a greater impact on the overall results. On the other hand, the values for Goal 6 and 14 indicate that disagreement might also increase with an increasing sample size since most of the entries were found for these Goals.

Since most of the publications used a qualitative methodological approach with subjective judgments (even though expert judgments), it can be expected that more different authors draw different conclusions that are based on different assumptions and will thus, come to different results for the evaluation. Goal 7 shows the highest share of ambiguities on the total number of identified matches. A closer look reveals that most ambiguities are present in target 7.2 and target 7.3, even though the affected targets with which 7.2 and 7.3 interlink vary greatly.

For SDG 15 the respective sample size is also comparably small and the ambiguities on inter-linkages for this Goal can again be based on subjective evaluations. Since SDG 15 is also addressing a highly complex and systemic topic, that also includes great preservation efforts which imply limitations, restrictions and regulations in other SDGs' activities, progress may be hampered in these SDGs and cause trade-offs that have been identified within some of the reviewed publications.

The same applies for SDG 13 and 14 as their targets are also aligning with restrictions and limitations in the use of natural resources. On the contrary, goals like SDG 8 or 11 rather imply a paradigm of growth that can be based on resource consumption and thus, adversely counteract with the preservation paradigm, even though it does not necessarily have to, which is why different publications may draw different conclusions.

In contrast to the previous SDGs which feature a considerable share of ambiguities, SDGs 1, 2, 3, 5, 9 and 12 showed a relatively low share of ambiguities. Goal 3, 5 and 9 even proved to have no deviations, thus indicating complete agreement on the evaluation of the type of inter-linkages among the publications, even though it has to be alluded to the fact that the sample size for these SDGs has also been considerably small.

Taking sample size into account, SDGs 2 performs best with an "only" 25 % share of ambiguous inter-linkages out of 40 entries. For SDG 1 ambiguities primarily occurred due to different evaluations made by Weitz et al., (2017), who come to a different conclusion than Cutter et al., (2015) and UNSDSN, (2015) by identifying potential trade-offs between the respective targets. Source 1.5 and target 2.4 can be used for having a closer look on potential ambiguities in the evaluation of their interlinkage. Since both targets actually strive for strengthening resilience towards climate related and other disasters, it can only be speculated why the authors came to different conclusions. One possible explanation could be that the implementation of sustainable food production systems and sustainable agricultural practices like proposed in 2.4 may conflict with the short-term scope of reducing vulnerability of the poor since non-sustainable practices might facilitate this desired outcome more immediately.

Summing up, the analysis revealed that the current database is covering all of the SDGs on the Goal-Level, but not all of the respective targets. Furthermore, it became apparent that the database needs to be extended in order to obtain enough data for a sufficient sample size on which further calculations can be based. Additionally, the results showed the subjectivity involved in the evaluation process, especially because most of the authors used a qualitative approach that was based on expert judgment. Depending on personal backgrounds and perspectives, the results can thus, greatly vary.

Nonetheless, a variety of qualitative approaches has been applied by the reviewed literature, be it cross-impact matrices, network analysis techniques, rapid assessment frameworks, qualitative nexus approaches or even synthesized approaches that tried to combine qualitative and quantitative methods. In this way, the diversity of qualitative approaches rather contributes to a better robustness of the data, even though the identified variance within the results may be explained by this circumstance as well.

Furthermore, it has to be taken into account that the different publications applied their methodological frameworks on different scales, not only geographical but also analytical (Target-Level or Goal-Level) and an analysis on the Goal-Level usually means a serious generalization and aggregation of information which may eventually lead to further ambiguity and disagreement in evaluations.

4.3 Dashboard on agreed inter-linkages from the reviewed literature

In our review we have tried to address the following questions: do different methods arrive at similar conclusions? Which inter-linkages are universally agreed on? The results of our analysis described in the above sections have been organized in a dashboard[9] and Figure 7 allows to identify and communicate whether "universally agreed" inter-linkages exist. Depending on the number of entries we have created a five color dashboard by attributing one out of 5 nuances to the target combinations that translate the number of entries and then, the level of agreement: Synergy, Trade-off, Strong Synergy, Strong Trade-off, Ambiguity (Table 4).

Table 4: Classes and related colour of the dashboard on the literature

Light Green	Synergy (+1: only one entry in the database)
Light Red	Trade-Off (-1: only one entry in the database)
Dark Green	Strong Synergy (+2: more than one entry that agrees on this type of interlinkage)
Dark Red	Strong Trade-Off (-2: more than one entry that agrees on this type of interlinkage)
Orange	Ambiguity (99: no agreement on the type of interlinkage for this Source-Target Combination)

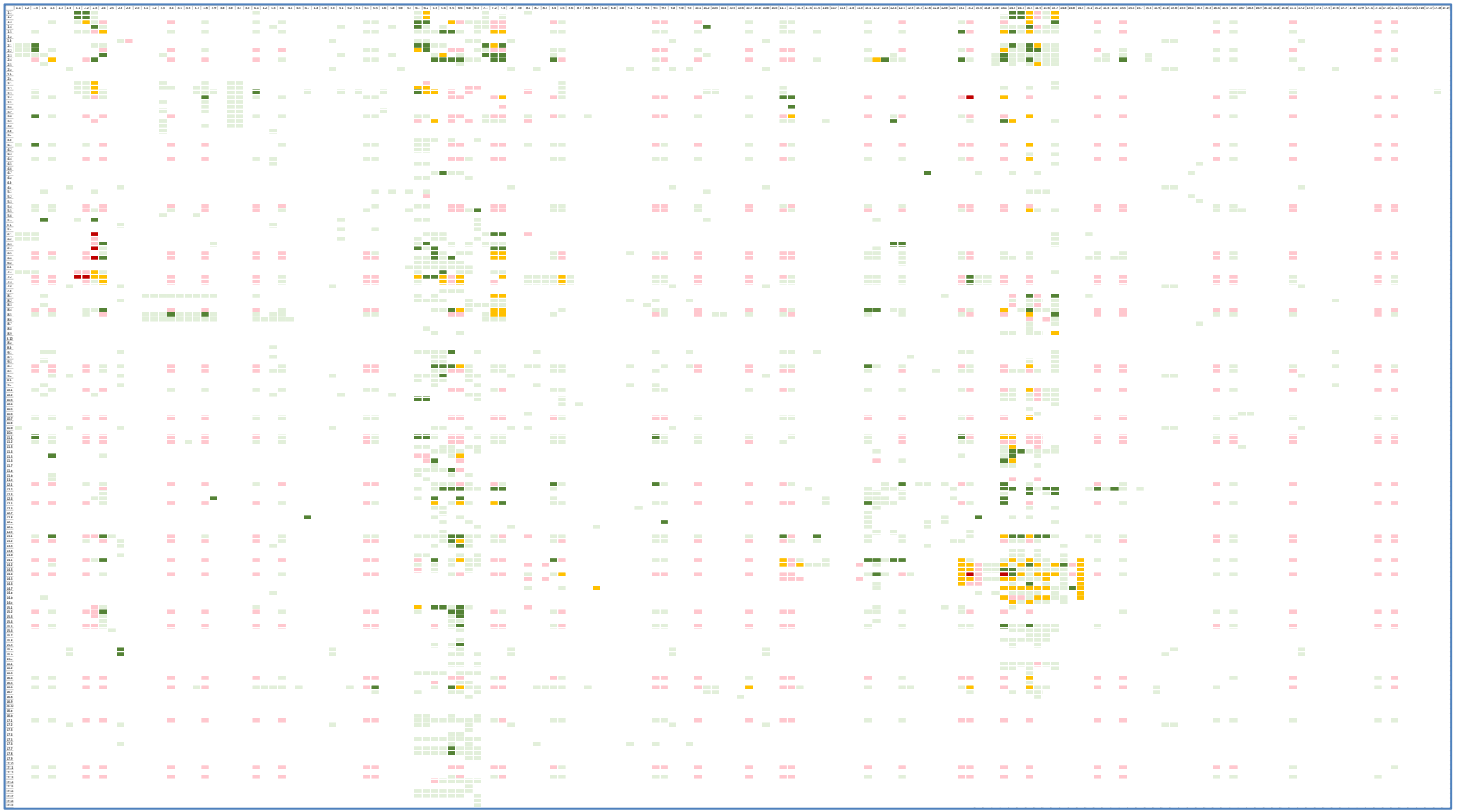
Source: *Author's elaboration.*

These results should be read considering some caveats: the analysed literature is just in English; the sample size of publication is limited as few publications provide concrete analysis on inter-linkages; the subjectivity of the results because most of the authors use a qualitative approach based on expert judgment; the fact that publications to the subject are only now forthcoming makes this analysis an ongoing study. Nevertheless, this dashboard represents a preliminary tool to adopt a systemic approach dealing with inter-linkages. It is exploratory rather than prescriptive. It allows the identification of gaps in terms of knowledge and calls for a contextualization of the analysis.

In our opinion, any method which proposes a sort of panacea to deal with the inter-linkages misleads the 2030 Agenda process based on inclusiveness and context dependence. In fact, the nature of any inter-linkage often depends on the context of the respective country, the level of development, geographical scale and other characteristics and specific policies which might determine if a given inter-linkage constitutes a trade-off or a synergy.

[9] The knowSDGs platform offers more tools to visualize the results of our analysis such as the network The network tool is one of the more effective instruments to visualize connections and to capture intuitively the systemic approach of the SDGs framework.. We have built a network with green lines indicating synergies and red lines indicating trade-offs. In the Annex A more examples are available at country level with the size of nodes of connections being related to the relevance of that specific connection More details at http://knowsdgs.jrc.ec.europa.eu/interlinkages/info

Figure 7: Dashboard on Inter-linkages calculated in R based on entries from literature review.



Each single column and each single row correspond to one of the 169 targets of the SDGs framework. Most of the interaction are synergies (73%). There are numerous targets (2.c, 3.1, 3.2, 3.5, 3.6, 3.a, 5.b, 5.c, 8.6, 8.7, 8.10, 8.a, 8.b, 9.6, 10.4, 10.5, 10.6, 10.a, 10.b, 11.3, 11.4, 11.7, 11.a, 11.b, 11.c, 15.4, 15.6, 15.7, 16.3, 16.7, 16.8, 16.9, 16.10, 16.a, 16.b, 17.3, 17.4, 17.5, 17.7, 17.8, 17.9, 17.10, 17.14, 17.15, 17.16, 17.17, 17.18, 17.19) whose potential inter-linkages with other targets or goals have not been addressed yet in the reviewed literature. The level of disagreement (orange cells) is also very high (around the 50% for the SDG7, SDG 8, SDG 14 and SDG 15).

https://public.tableau.com/profile/steve.borchardt#!/vizhome/Dashboards_115/Story1

5 Inter-linkages: in EU regulations and legislation

Sustainable development is fully integrated into the policies of the European Union which in the Article 3.3 of the Lisbon Treaty[10] states that "The Union shall [….] work for the sustainable development of Europe […]. Over time, different strategies for sustainable development have influenced the EU policy. From the first Sustainable Development Strategy adopted in 2001 till 2016 and the adoption of the Communication (COM(2016)739), Next steps for a sustainable European future European action for sustainability[11], EU has taken on a role of frontrunner in pursuing the goal of sustainability in the international policy arena". The Communication (COM(2016)739) lays out the European Commission's strategic approach towards the implementation of the 2030 Agenda. Moreover, on the 13 September 2017, President Juncker announced that the Commission will prepare a reflection paper "Towards a sustainable Europe by 2030" as a follow-up to the UN SDGs, including the Paris Agreement on Climate Change. The current EU approach consists of four work streams:

(1) integrating sustainable development into the European policy framework and Commission priorities;

(2) developing a vision and the focus of sectorial policies for the period after 2020, in order to prepare for the long-term implementation of the SDGs;

(3) Measuring progress: monitoring, reporting and reviewing progress towards the Sustainable Development Goals, and

(4) sharing responsibility by involving stakeholders.

The first work stream brings the commitment to mainstream the SDGs into EU policies and initiatives and the integration of sustainable development into every thematic and sectoral policy of the European Union. In 2017, a mapping of the EU activities into the space of the Sustainable Development Goals (SDGs) and targets, has been undertaken in order to gain a comprehensive understanding of how those activities cover respective objectives.

This section explains the approach taken for the mapping and discusses some issues encountered on the way. This stocktaking exercise enables the identification of synergies by adopting a policy oriented approach/perspective. A second dashboard is then designed to identify EU policy nodes.

5.1. The ad-hoc method mapping SDGs into EU policies

The preliminary mapping by the EU Commission published as per Staff working Document related to the EU communication (COM(2016) 739 final) identifies links between each SDG and the EU's high level policy initiatives. In 2017 that mapping has been extended by carrying out an internal stocktaking exercise. The process has involved scientists from the Joint Research Center and policy analysists from all the EC Departments for a total of 200 experts.

The ad hoc method developed by the JRC was based on the following steps:

Step 1: Identifying relevant policies. The Management Plan 2016 and the Strategic Plan 2016-2020 of each single Department were analysed in order to identify the key policy initiatives ("Communication", "Directive", "Regulation" and "Decision").

Step 2: Identifying the actual policy document. The policy document relating to the references extracted under Step 1 were identified based on EUR-LEX search'[12]

[10] http://www.lisbon-treaty.org/wcm/the-lisbon-treaty/treaty-on-european-union-and-comments/title-1-common-provisions/4-article-3.html

[11] https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52016DC0739&from=IT

[12] https://eur-lex.europa.eu/homepage.html?locale=it

Step 3: Coding the purpose and content of the policy document. The purpose of the policy document was identified by reading the document. A keyword search was used to understand how often certain terms, which might seem relevant, were used in the document.

Step 4/5: Coding the SDGs and mapping the policies. The SDGs and their targets have been scanned and the identified policies have been linked with the SDGs and targets according to the codes applied.

Step 6: Setting up a database. A database has been created to present policy under the respective goal, indicating the mapping to the respective targets or the goal level.

This first coding and mapping procedure was quite ad hoc. This might result in idiosyncratic bias and omissions in the initial coding of the policy documents and the SDGs and the resulting mapping. The data bias was then reviewed by the policy analysts of each single EC Department. During this iterative review process, which also included bilateral meetings, the collection of policy document information has been used by each EC Department to integrate legal information and indicate the policies, programs and instruments related to the respective legal documents.

Many EC departments have indicated a considerable number of policies that were related to more than one goal. There is the possibility that some policies only have a very limited or indirect relation to a goal they are mapped to. This sort of indeterminacy is due to the fact that the mapping of a given policy or instrument to a goal or target is based on argumentation and interpretation.

The current final database includes 1,119 European policies which relate to the SDGs. In July 2017 the database was made publicly available at *https://ec.europa.eu/sustainable-development/about_en*[13]. The number of policies and instruments relating to a given SDG does not indicate the importance of the respective SDG for EU, but it already provides a picture of the degree in which sustainable development is permeating Europe's action. It is clear that the sustainable development is fully integrated into EU policies.

5.2 EU policy nodes: synergies in EU legislation

As many EU policies affect more than one single target or Goal, we can define synergies based on the number of policies in common between two targets. Adopting this policy oriented perspective, we have designed a dashboard on EU policy nodes in terms of synergies relevant for SDGs implementation on the basis of the described mapping exercise. In particular, we designed a four-color dashboard by attributing to target combinations one out of 4 nuances that translate the number of policies in common between two specific targets (table 5)[14].

Table 5: Classes and related colours of the Dashboard on EU policy nodes.

White	No policy in common
Light Green	1-2 policies in common
Medium Green	3-4 policies in common
Dark Green	more than 4 policies in common

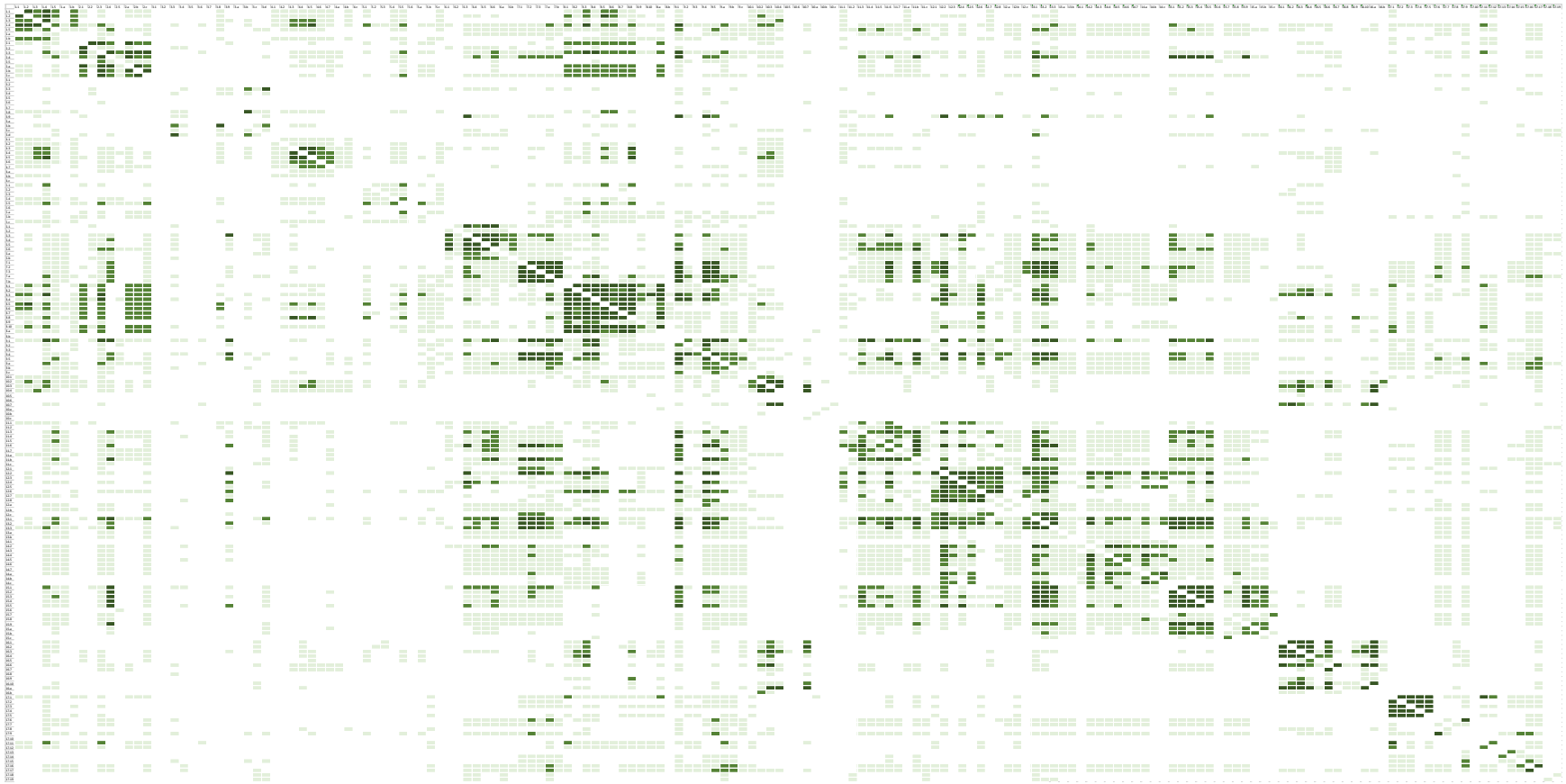
Source: *Author's elaboration.*

[13] For those readers interested in knowing the list of policies per each single target we recommend to visit that website. Making an assessment of the impact of these policies already in place according to the achievement of the SDGs in 2030 was not the objective of the stocktaking exercise neither of this chapter.

[14] It is important to underline that "no policy in common" does not mean "no policy".

Figure 8 shows the dashboard, which allows the identification of policy priority areas where the EU added value is maximised. It also provides a clear policy message: the EU has already set up a system of synergetic actions which can be exploited for the achievement of the SDGs, as the ”policy nodes” of synergies already in place in the EU could be the levers to define effective policy actions in terms of identification of priority areas and more effective budget allocation.

Figure 8: EU policy nodes in the SDGs context. Synergies based on EU legislation.



This dashboard indicates synergies defined on the basis of number of policies in common between two targets. White cells indicate no policy in common. *Each single column and each single row correspond to one of the 169 targets of the SDGs framework.* *https://public.tableau.com/profile/steve.borchardt#!/vizhome/Dashboards_115/Story1*

Source: *Author's elaboration.*

6 Science policy interface: an example of interaction

This chapter provides an example on how the green and blue blocks of the science-policy interface supporting the SDGs policy coherence (figure 1) could operate. The example is a case study applied in the European Union context.

The two proposed dashboards, in combination with more analytical tools such as those to identify gaps and integrated assessment models (green blocks of Figure 1), can offer a knowledge base to adopt a systemic and holistic approach and to identify all action levers for an overall policy coherence with sustainable development. Information from the two proposed dashboards (the one based on the literature - Figure 7 - and the one on the EU policy nodes - Figure 8) are integrated with information on monitoring progress towards the SDGs in the EU context as assessed by EUROSTAT (ESTAT, 2018).

In particular, EUROSTAT analyses the trends of the most recent five years of available data and proposes a sort of score of each single Goal in the EU (Figure 9). On the basis of this score, the Goal 10 seems to be the one which accounts for the lowest results in the EU. Consequently, we could consider the SDG 10 as the Goal which calls for more attention in the EU. The two Dashboards with more specific information on Goal 10 could then help policy makers in identifying operational strategies. Figure 10 combines information from the dashboard on inter-linkages based on the literature with information form the dashboard on synergies based on EU legislation.

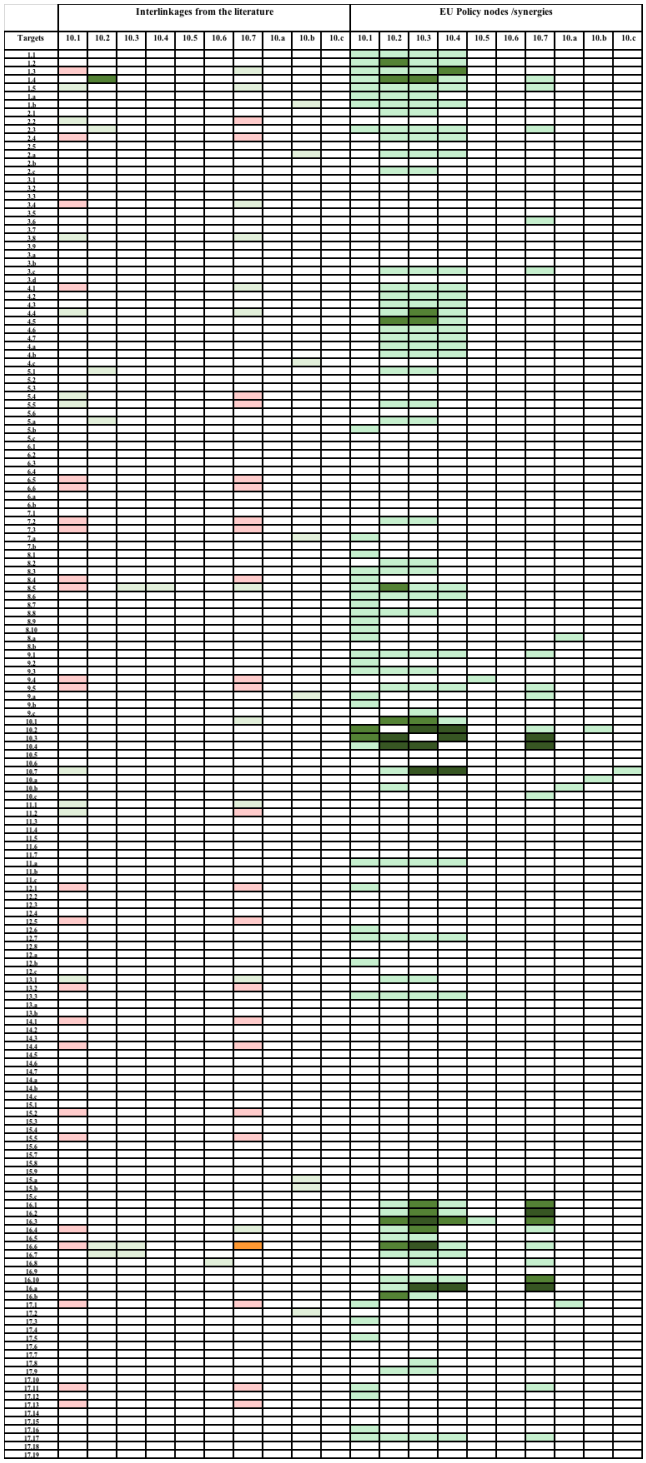
Figure 9: How has the EU progressed towards the SDGs?

Source : ESTAT,2018; page 11.

Analysing the columns related to the inter-linkages from the literature focusing on SDG10 it is evident that the targets 10.1 ("By 2030, progressively achieve and sustain income growth of the bottom 40 per cent of the population at a rate higher than the national average") and the target 10.7 ("Facilitate orderly, safe, regular and responsible migration and mobility of people, including through the implementation of planned and well-managed migration policies") are those with trade-offs.

In terms of EU legislation these two targets have a good coverage but the trade-offs identified by the literature do not have a specific policy coverage.

Figure 10: Inter-linkages form the literature and EU policy nodes- Focus on SDG10.



Source: *Author's elaboration.*

The next step will be up to the policy blocks (figure 1) which will have to identify the strategy to address this specific aspect. It could be (i) exploiting the existing synergies or (ii) designing new specific sectoral policies to minimise trade-offs. An additional focus could be done at national level by analysing the inter-linkages at indicator level for the SDG 10 as the exercise reported in the Annex A. In this way a more detailed focus on indicators and countries could enable the definition of specific actions at national level.

We would stress that the entry point of policy actions does not necessarily have to be Goal 10. In fact, the SDGs implementation cannot be treated in isolation but it should rather be contextualized in the whole EU political context which integrates the SDGs' priorities in a broader context of EU policy priorities.

For example, one of the trade-offs of the target 10.1 is with the target 9.4 ("By 2030, upgrade infrastructure and retrofit industries to make them sustainable, with increased resource-use efficiency and greater adoption of clean and environmentally sound technologies and industrial processes, with all countries taking action in accordance with their respective capabilities").

An industrial policy by involving private sector could be developed rather than a policy specifically designed for target 10.1. This final decision should consider many variables such as the budget allocation and political priorities defined in a democratic and participatory context wider than the SDGs framework. At this stage the integrated assessment based on quantitative models could give more details on the dynamics of the involved variables and interactions and could provide alternative scenarios to select policy. Table 6 gives an example of the models that have been already run for the impact assessment of some of the EU policies classified as relevant for the SDG1. The inclusion of indicators and assumptions coherent with the SDGs frameworks in models could enable the adoption of a sort SDGs impact assessment for new policies.

Table 6: Example of models used for the impact assessment of policies relevant for the SDG1.

Example of models relevant for animpact assessment for policy actions related to SDG1
Augmented CGE Model with Representative Household Approach: to evaluate the impacts of economic shocks, policy changes and exogenous events on poverty and inequality.
IMMPA to analyse the impacts of macroeconomic policies on income distribution employment and poverty.
PER to analyse and allocate public-expenditure by promoting economic growth and poverty reduction.
PAMS to analyse the impacts of macroeconomic policies on poverty, employment and income distribution.
PPA used to collect poor people's views regarding poverty analysis and survival strategies.
123 PRSP Model allow to forecast the effects of welfare measures and policies on poverty and inequality.
SimSip Poverty to estimate the impacts of growth on poverty and inequality.
Beneficiary Assessment used to identify and improve the impacts of development strategies.
ESIM to model the impacts related to net trade of agricultural products.
SimSip Poverty to estimate the impacts of growth on poverty and inequality.
EUFASOM model is a dynamic partial equilibrium model for the agricultural, forestry biomass for energy sectors. It simulates land use management under environmental, political and technological changes.
EUCS100 land use/cover maps to evaluate the impacts of different policy alternatives.
G4M used to estimates the impacts of forest activities on biomass and carbon stock.
GLOBIOM is a model used to analyse the competition for land use between agriculture, forestry and bioenergy.
LULUCF to model land use, land use change and forestry.
RURAL-ECMOD to model the regional economic impacts of CAP policy instruments.
GEM is an integrated weather forecasting and data assimilation system.
Augmented CGE Model with Representative Household Approach: to evaluate the impacts of economic shocks, policy changes and exogenous events on poverty and inequality.

7 Conclusions

Policies aimed at achieving SDGs require simultaneous and coordinated transformations in several domains, which could only be reached by adopting a policy coherence approach. In this report, we define policy coherence within the SDGs context as a framework that allows the definition of a single vision and a systemic approach for sectoral policies with sustainable development as a single and shared goal, in order to be mutually supportive. This aspect influences the current debate in the literature on the identification of inter-linkages in the SDGs context.

Sustainability is inherently complex, going beyond traditional policy areas, and often there is not only one "right" or "objective" way to define sustainability paths. For this reason, no single analytical tool could be considered fully able to identify policy strategies to implement SDGs. On the contrary, a systemic approach needs to be adopted in dealing with this aspect in order to identify and manage possible trade-offs and to exploit existing synergies and complementarities that can exist among the different SDGs.

This report offers an operational method to deal with inter-linkages by focusing on the identification of inter-linkages and their integration in a broader framework of a science/policy interface. One of the proposed tools is a dashboard summarizing the main elements of the current literature on inter-linkages. This tool cannot be considered as a panacea tool, but it is a first step to understand the systemic interrelated nature of the SDGs. It allows the identification of gaps in terms of knowledge and calls for a contextualization of the analysis. In fact, the nature of any inter-linkage, often depends on the context of the respective country, the level of development, geographical and other characteristics and specific policies which might determine if a given inter-linkage constitutes a trade-off or a synergy.

The SDGs implementation cannot be treated in isolation, but it should be contextualized in the specific political context which integrate the SDGs priorities in a broader context of policy priorities. Therefore, a second tool is proposed by adopting a new approach based on a policy oriented perspective/approach and which defines synergies as number of policies in common between two targets. This second tool is developed at EU level and it enables the identification of the policy nodes of synergies already in place that could be the levers to define effective policy actions which could benefit of several analytical tools.

Taking into account the priorities of the whole national system the entry point can be one of the Goals with which there are co-benefits rather than tradeoffs. The final decision will have to be taken also considering the budget allocation and political priorities defined in a democratic and participatory context wider than the SDGs framework.

At the end of our analysis we can identify some gaps in terms of knowledge:

a. No specific study is available in the current literature on the analysis of the Trans-boundary and inter-generational effects related to the SDGs implementation. Few papers refer to trans-boundary effects but they present a bit of an environmental (social-ecological) bias. The inter-generational aspects are mainly related to the studies on future well-being.

b. the widely accepted *ceteris paribus* condition, which analyzes the behavior of each system independently, could not be considered as helpful in the SDGs context. More holistic approaches are required as the contextual evaluation of several systems together is fundamental. For this reason, integrated and systemic approaches (quantitative and qualitative methods) are pivotal for an ex- ante and ex- post assessment, but a systemic approach is still missing. Furthermore, the "modeling" community has started to face the SDGs without developing a new specific tool, but trying to adapt already existing models. In many cases there is no effort to adapt the model with the integration of specific indicators set, or hypotheses able to capture the holistic approach of the 2030 Agenda. In most cases

the results of the models are interpreted by applying the SDGs terminology as a reading key in a sort of SDGs washing.

Finally, the SDGs offer an integrated and complex development framework that requires a holistic approach to policymaking and scientists as well. The presence of plurality of frameworks, and possible interpretations in the analysis of inter-linkages preclude a consensus on ideal methods and tools to identify inter-linkages, not even on the basic terminology.

Increasing knowledge sharing and exchange will avoid knowledge gaps and facilitate the identification of trade-offs and the realization of complementarities, thus ultimately supporting successful SDG implementation. Breaking down silos is thus a recommendation that we would address to the policymaking and scientific communities.

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List of abbreviations and definitions

CGE	Computable Equilibrium Models
EC	European Commission
EUROSTAT	European Union's Statistical Office
HIV/AIDS	Human Immunodeficiency Virus
ICSU	International Council for Science
IGES	Institute for Global Environmental Strategies
ISTAT	Italian National Institute of Statistics
MDG	Millennium Development Goals
NGO	Non-Governmental Organisation
OECD	Organisation for Economic Cooperation and Development
SDG	Sustainable Development Goals
UN	United Nations
UNEP	United Nations Environmental Program
UNESCAP	United Nations Economic and Social Commission for Asia and the Pacific
UNSC	United Nations Statistical Commission
UNSDSN	United Nations Sustainable Development Solutions Network
VNR	Voluntary National Reports

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Annex A - A Statistical analysis of inter-linkages between SDGs indicators

Background

Despite several qualitative analysis and studies on the strength of relationships among Sustainable Development Goals (SDGs), a significant gap is still nowadays present on empirical and practical investigations. Actually, while in recent years there have been several studies in qualitative analysis, trying to disentangle the main synergies and trade off among goals and targets, from the empirical point of view limited studies on quantitative assessment have been performed[15], evidence is still inadequate and underdeveloped and most should however be done. Identification and quantification of these inter-linkages at national level are often still missing. This provides an example of the results of a statistical analysis which has been carried quantifying inter-linkages in EU 27 Member States by using historical time-series data for two sets of SDGs indicators (ESTAT, 2018[16] and the United Nations -SDG Indicators - Global Database [17]) . More information on the results of the analysis are available the JRC 114558 Report "*Statistical Analysis of inter-linkages among Sustainable Development Goals in EU27*". This annex introduces briefly the method and the result for just one EU Member State (Austria)

Data gaps and methodology

The time sample considered covers yearly data from 2000 to 2016 (17 years).

Considering the time series for the group of EU27 countries, data gaps are remarkable in both databases utilized:

1. in Eurostat database, over a total of 253 indicators, 15 have no data (representing 6% of the total) and 39 (15% of the total) count a maximum of 3 entries per country, over the entire time span considered;
2. UN database counts a total of 542 indicators, but 182 (representing 34% of the total) have no data and for 153 indicators (28% of the total) it is registered a maximum of one entry for the entire EU27 group.

This missing data problem reduce dramatically the amount of data over which it is possible to conduct statistical analysis. Our choice has been to avoid any type of manipulation of data like filling empty cells with some imputation rule, in order to conduct our analysis over the crude data sets provided by institutions and assume the most agnostic approach possible, letting data decide.

Taking into account this constraint of data lacks, it should be noticed that in the end we have been able to work with around 200 indicators in both databases, Eurostat (253 minus 15 minus 39) and UN (542 minus 182 minus 153) data sets. Data series utilized are listed in Table 1 and 2 of the Annex II.

In performing a correlation analysis, we utilized the Spearman coefficient instead of the most common Pearson coefficient. This choice relates to the consideration that the Pearson correlation coefficient give a standardized measure of the linear relationship between

[15] One of the first analysis on the indicator-level time series data corresponding to the associated SDGs targets has been done for nine Asian countries in the IGES (2017) Research Report "*Sustainable development goals interlinkages and network analysis: a practical tool for SDG integration and policy coherence* ".

[16] http://ec.europa.eu/eurostat/web/sdi/indicators

[17] https://unstats.un.org/sdgs/indicators/database/

variables, providing both the direction and the strength of the relationship, but it can be seriously affected by odd extreme observations. Moreover, it rely for its validity on an assumption of normality of data.

Spearman rank correlation[18] is instead a test to measure the degree of association between variables that is not susceptible to serious influence by extreme values and on which valid tests can be based for very general population distributions. Unlike Pearson's correlation, it does not carry any assumptions about the distribution of the data, there is no requirement of normality and hence it is a nonparametric statistic. Briefly, the Spearman rank correlation test is the appropriate correlation analysis when the variables are measured on a scale that is at least ordinal. Its assumptions are that data must be at least ordinal and the scores on one variable must be monotonically related to the other variable.

Spearman's ρ is equivalent to Pearson's linear correlation coefficient applied to the rankings of the columns. The following formula is used to calculate the Spearman rank correlation if all the ranks in each column are distinct:

$$\rho = 1 - \frac{6\sum d_i^2}{n(n^2-1)}$$

ρ= Spearman rank correlation
di= the difference between the ranks of corresponding variables
n= number of observations (length of each column)

Analysis by EU27 country

For each EU27 country, we have obtained the correlation matrix of SDGs indicators for both Eurostat and UN Databases. In this way, inter-linkages are identified at national level.

Eurostat Database

We have classified significant (p-value <0.05) correlations results considering five classes:

3. Strong positive correlation (corr>=0.7)
4. Positive correlation (0.3<=corr<0.7)
5. Absence of correlation (-0.3<=corr<0.3)
6. Negative correlation (-0.7<corr<=-0.3)
7. Strong negative correlation (corr<=-0.7)

The outcome of this correlation analysis in time-series has been synthetized by country through cake graphs. In this representation, we have discarded correlations equal (1) of the principal diagonal and equal (-1), that put on relation respectively same indicators or an indicator and its specular one. We have discarded as well correlations among different specifications of the same indicators (example: correlation score among an indicator expressed in percentage and the same indicator expressed in thousand persons).

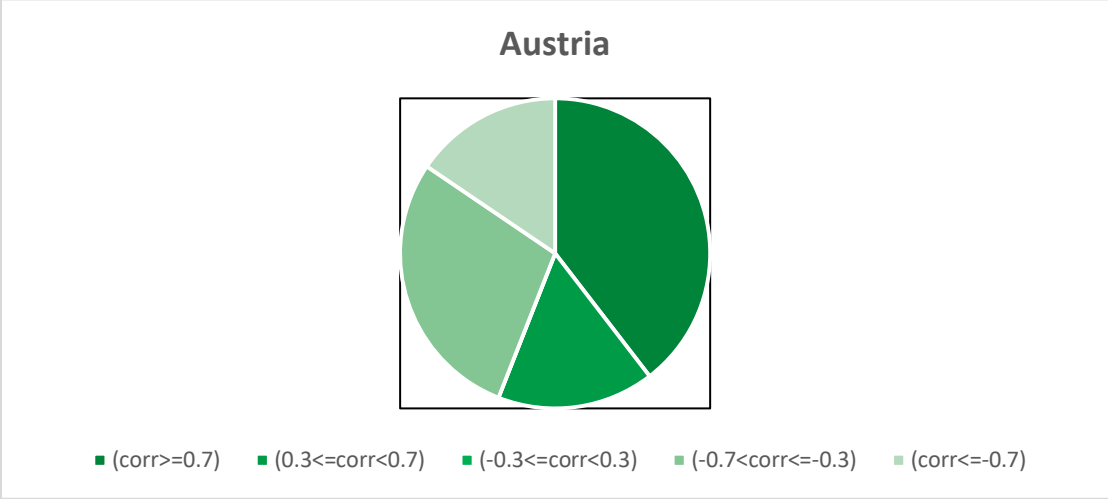
The following section presents results for Austria.

[18] Spearman C., 1904. The proof and measurement of association between two things. American Journal of Psychology 15: 72–101.

Austria

Significant results for Austria are synthetized in figure 1 and show 40% strong positive correlations and 16% positive correlations, while there is 29% of negative correlations and 16% of strong negative correlations. Results do not show significant correlations of value comprised between -0.3 and 0.3, this correlation range is indeed empty.

Fig.1 Spearman correlation analysis for Austria



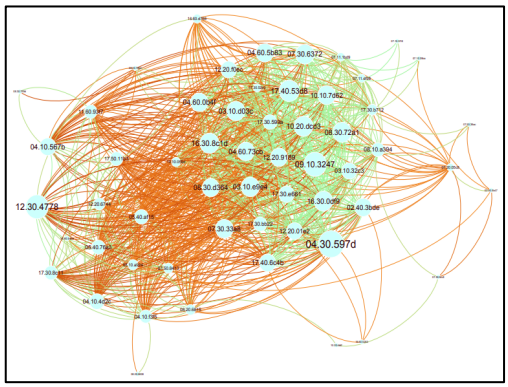
Source: Author's elaboration.

The network analysis performed with correlations results is represented in figure 2a and allows to show positive correlations (in green) and negative ones (in red) among indicators together with central nodes of the network (namely the indicators that are characterized by the major number of connections with other indicators) that corresponds to the biggest balls in the picture. The ball size is relative to the amount of its adjacent connections scaled linearly. On the other side, the node label size is calculated by the amount of its adjacent connections scaled exponentially.

Codes of indicators refer to 8 figures corresponding to 4 official Eurostat codes plus 4 random codes generated by the algorithm utilized to create the network.

Considering the totality of correlations, central node for Austria resulting network is represented by indicator *04.30 Participation in early childhood education.*

Fig.2a Network analysis of Spearman correlations for Austria

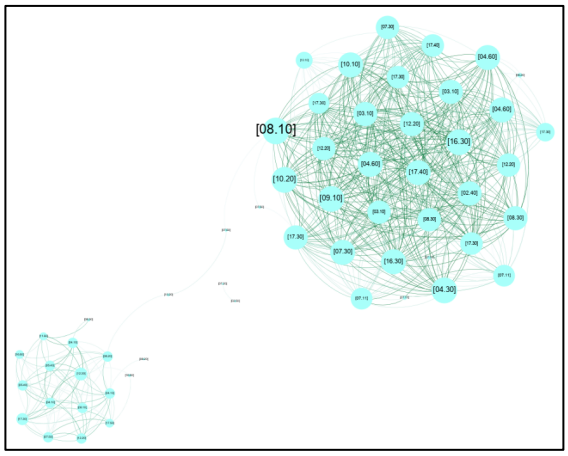


Source: Author's elaboration.

Conversely, considering separately positive correlations network in figure 2b and negative correlations network in figure 2c, results highlight different central nodes:. In these figures codes are corresponding to just the four figures assigned by Eurostat to indicators, to guarantee major clearness of resulting networks.

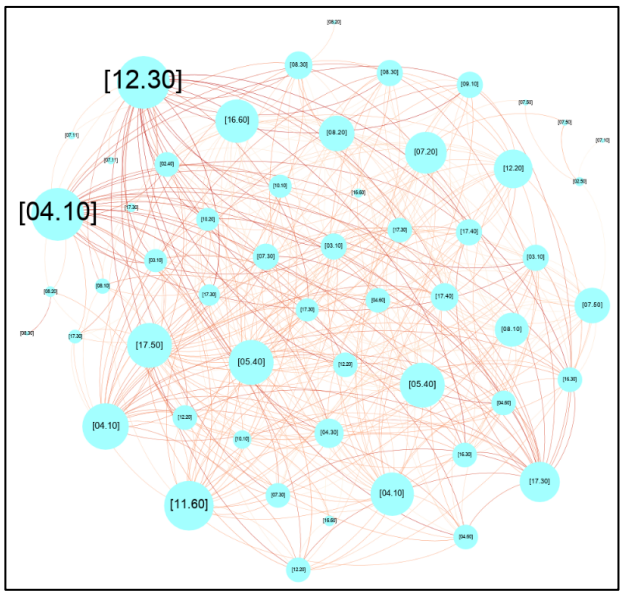
- In the positive correlations network, central node is around indicator *08.10 Real GDP per capita-Chain linked volumes;*
- In the negative correlation network, central nodes are represented by indicators *04.10 Early leavers from education and training by sex; 12.30 Average CO2 emissions per km from new passenger cars* and *11.60 Recycling rate of municipal waste.*

Fig.2b Network analysis of positive Spearman correlations for Austria



Source: *Author's elaboration*

Fig.2c Network analysis of negative Spearman correlations for Austria



Source: *Author's elaboration.*

Overall, results of this exercise of Spearman correlation analysis conducted for all EU27 countries show that indicators are significantly positively (40% strong positive correlation, 16% positive correlation) or negatively (16% strong negative correlation and 29% negative correlation) correlated, and that for every EU27 country the group of uncorrelated indicators is empty.

Furthermore, frequently the indicators representing central nodes in the overall correlation network of a country, are not those central in positive correlations network and negative correlations network.

Correlations based on the United Nations Global Database

Similar exercises of the previous section have been performed with UN database. Here again are shown Spearman correlations by EU 27 country.

Overall, significant correlations found are much lower in number, compared with results coming from Eurostat database. In terms of ranges percentages, the group of indicators significantly uncorrelated is still empty in every country considered.

The network analysis performed with correlations results is as well represented and allows to show positive correlations (in green) and negative ones (in red) among indicators together with central nodes of the network (namely the indicators that are characterized by the major number of connections with other indicators) that corresponds to the biggest balls in the picture. The ball size is relative to the amount of its adjacent connections scaled linearly. On the other side, the node label size is calculated by the amount of its adjacent connections scaled exponentially.

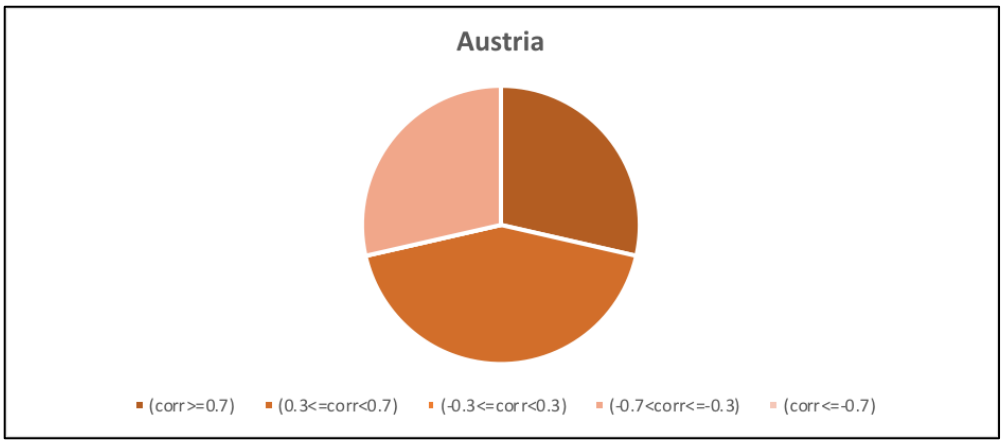
In these networks, the thickness of edges (lines) is related to the value of correlation found: the thinner red lines represent more negative values. On the contrary, the thicker green lines represent the more higher values.

In order to improve the readability of networks, codes of indicators represented refer to four figures corresponding to the truncation of the UN indicators codes of seven figures utilized to classify UN indicators.

Austria

In the case of Austria, 29% of significant correlations are found strongly positive, 43% are found positive and 29% are found negative. The ranges of correlations between -0.3 and 0.3 and lower than -0.7 are empty.

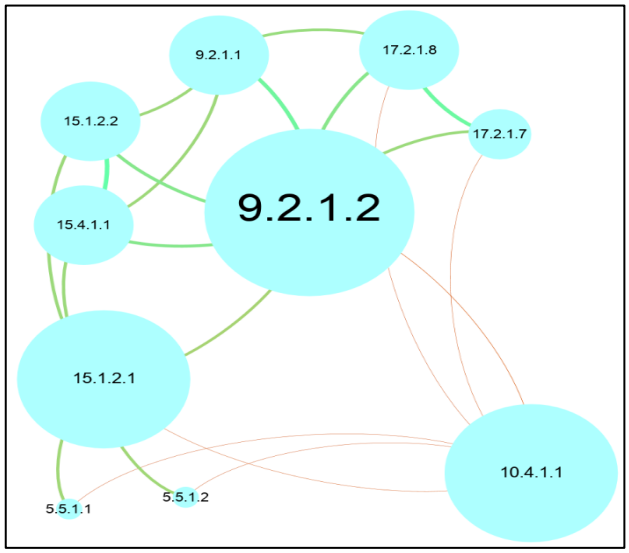
Fig. 56 Spearman correlation analysis for Austria



Source: *Author's elaboration.*

Network analysis conducted on Austria data shows the centrality of the node around indicator *9.2.1.2 Manufacturing value added per capita at constant 2010 United States dollars.*

Fig. 57 Network analysis of Spearman correlations for Austria



Source: *Author's elaboration.*

EU27 overall analysis

In terms of overall results that summarize country-by-country analysis, we have retained significant correlations found considering two guiding principles in order to avoid reaching conclusions from a naïve analysis:

a. significant correlations that are found in 14 countries or more of our database of 27 countries, that means results with high frequency;
b. significant correlations with a standard deviation lower that 0.2, that means low dispersed result values.

These two conditions should be fulfilled together to finally create our results database. We cannot exclude a priori some spurious behavior between indicators, however as the correlation analysis is performed in each EU27 country individually, the existence of a large number of concordant results suggests that the relations are widespread across countries and most likely not appearing by chance.

Concluding remarks

Overall, final results of this analysis count 284 significant correlations among Eurostat SDGs indicators: 220 are positive associations representing possible synergies between SDGs indicators and 64 are negative associations, representing probable trade-offs.

Utilizing UN Global Database indicators, the resulting picture coming from the correlation analysis is very different: only 9 correlations are found significative, all are positive.

This first systematic overview of SDGs interactions for EU27 should of course be compared with evidences coming from qualitative results in all the different goals domains.

A further interesting analysis should consider country-specific conditions and micro-level data in order to investigate more in deep the links highlighted by this first analysis.

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