SDGs Indicators as an Input-output System

A Novel Approach to Utilize Interlinkages between SDGs Indicators for Impact Assessment and Projections

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A Novel Approach to Utilize Interlinkages between SDGs Indicators for Impact Assessment and Projections

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Contents

Introduction

The Sustainable Development Goals (SDGs) focus on economic and social development. There is a vast amount of research aimed at mapping the relationships between the SDGs, using network methods or correlation analysis. However, systematically identifying, characterizing and addressing interactions between sustainable development policy issues remains a challenge. The vast majority of traditional approaches of univariate modelling in network and correlation data analyses have proven relatively reliable and robust in indicating SDG interconnectedness. Nonetheless, they provide little or no information about conditional relations among different SDG indicators; in other words, on the direct impact of one SDG indicator on other indicators considering all other targets. The present paper proposes a novel approach to SDGs interlinkages, motivated by the well-known input-output methodology for the projections of SDG indicators and impact assessment. Using panel regression analyses, we produce a full interlinkages matrix showing the conditional strength and breadth of interconnectedness between all SDG targets and indicators. The proposed method is twofold. Firstly, all regressions are based on the review of the literature on how indicators are interrelated. Secondly, we maximize the number of observations and the joint significance of our estimates. Accordingly, these regressions yield elasticities estimated by the underlying data-driven process. Furthermore, we show how such a framework can be used for translating commonly used economic indicators, such as GDP and unemployment, into the projected changes of SDGs indicators, by considering the entire grid of interlinkages. Moreover, this framework can be utilized in a variety of different applications. For example, it can be linked to the computational general equilibrium (CGE) model or used to project the impact of policies on SDGs indicators, given that the influence on exogenous variables is known. Similarly, it can be applied to interlinked SDG costing minimization strategies, once target values and the costs of reaching individual costs are known.

We focus our analysis on the interlinkages of all 17 SDGs, and their related targets and indicators, across the 2030 Agenda for Sustainable Development, using available SDG global data corresponding to 179 countries. To analyse and validate the panel regression analyses results, we first demonstrate the robustness of our panel regression approach in identifying indicator relationships (i.e. consistent results that maximize the sample size and joint significance). Moreover, in a forthcoming paper we demonstrate the coherency of the results by comparing them with regression analyses that utilize simultaneous equation methods (SEM). We further demonstrate why vector autoregressive methods (VAR) are not applicable, and how SEM estimate for a given set of SDG targets are consistent with those estimated via simple panel data methods.

1. Interlinkages and factors affecting the SDGs: literature review

The first studies that tried to understand the SDGs through the lens of networks appeared in the development literature a decade ago. We use the classification suggested by Ospina-Forero and others (2019), which classifies them into the following two groups: subjective studies that rely on qualitative information (e.g., the conceptual description of the variables); and statistical ones that make use of panel and time series data (countries through time).

The most popular quantitative tool used to analyse interlinkages between SDGs is network analysis. In this method, the correlation between different indicators or a priori information of potential linkages is used to map the SDGs over a graph, which is in turn used to calculate some centrality measures, so as to assess the importance of one indicator over another. Such exercises were pioneered by Le Blanc (2015), who shows how the SDGs are unevenly connected, with some Goals connected to many other Goals through multiple targets, while other Goals are weakly connected to the rest of the system.

Zhou and Moinuddin (2017) use national time-series data for 51 indicators to create a correlation matrix of SDG targets for each country. Their approach uses social network analysis (SNA) techniques, which rely on an array of centrality measure techniques. Their estimates provide relevant knowledge supporting national priority setting for SDG planning and implementation. Yet, their methodology has the drawback of relying on short-time series data, thus not allowing for conclusive results on the strength and depth of these associations.

A multidimensional view of development requires well-defined procedures to quantify and operationalize networks of interdependencies between different goals (or their indicators). Following this idea, several studies have attempted to measure such networks through different methods, for example, subjective criteria from expert advice, text mining applied to official documents and names of development indicators, and proximity measures between indicators that are relevant for a given country (Ospina-Forero and others, 2019).

Using these subjective methodologies, the Joint Research Centre (JRC, 2019) reviewed 220 literature sources on SDG relations and their respective interconnectedness and proposed a scale to classify these relationships. They screened the literature to see how different researchers assess the interlinkages. and produced a categorization into 5 categories as follows: for synergies (+1), strong synergies (>+2), trade-offs (-1), strong trade-offs (>-2) and ambiguity (0). The *strength* of the interlinkage is based purely on the number of entries in the interlinkages database based on literature – if more than one paper indicates that there is either trade-off or synergy, then the interlinkage is classified as “strong”. If there is only one observation on given link, the score is equal to one (or minus one in case of a trade-off), and if there is no consensus, the authors indicate ambiguous relationship. The report classified 73 per cent of the interactions as synergies, however the level of the disagreement among queried literature was around 50 per cent (JRC, 2019).[1]

Another study by the International Council for Science evaluated the relationships between the four SDG targets. These interlinkages were identified using a simple dynamical model that investigates the combined outcomes of direct efforts at tackling each Goal and the indirect effects on progress due to network effects (Dawes, 2019). The study proposes unequal, targeted reallocation of direct efforts to achieve these goals. The report included detailed analysis of four SDGs and their interactions with other goals: SDG 2: Zero Hunger, SDG 3: Good Health and Well-being, SDG 7: Affordable and Clean Energy, and SDG 14: Life below Water. The scale ranges from +3, which applies when one goal or target is very reinforcing of others, to -3, which applies when goals and targets conflict with each other. A score of 0 indicates neutral interaction. Their findings suggest there are 238 positive, 66 negative and 12 neutral associations (Griggs and others, 2017). The association of these 5 SDGs with the other goals (1, 4, 5, 6, 8, 9, 10, 11, 12, 13, and 15) were analysed in order to attain the policy integration. In the study the relations to SDGs 16 and 17 have been neglected as these goals are considered as preconditions for the achievement of the other goals (Tosun, 2017).

In a similar vein, Nerini and others (2019), using a consensus-based expert elicitation method appraised the status of scientific evidence concerning relationships between one set of 58 commitments on climate change and their effects on each of the 169 Targets of the 2030 Agenda.[2] The report concluded that that action to achieve 72 targets across 16 Goals could be undermined by climate change. Specifically, climate change will affect the achievability of goals relating to material and physical wellbeing such as prosperity and welfare, poverty eradication and employment, food, energy and water availability and health. Moreover, climate change also undermines efforts to achieve justice and equality across the world.

The importance of expert knowledge in the interpretation of SDG interrelations is undisputable. In Cook (2019), an analytical decision framework was adopted to assess and rank SDG targets on the basis of their “urgency”, “systemic impact” and “policy gap”. Moreover, a benchmarking of indicators, the benefits of system and network analyses of linkages between targets, and the policy coordination and the mapping of shortcomings is also discussed (Allen and others, 2019a).

Several applications show the benefits of these type analyses. In the case of Iceland, Cook and others (2019) examines the tourism sector based on the knowledge of four theme-based focus groups made up of expert participants. A total of 32 goal synergies and 11 trade-offs have been identified. In yet another example, Blomstedt and others (2018), show how the links between SDGs can be used to guide multisectoral partnerships on child health. Understanding these interlinkages of health in the development of health systems and public wellbeing have provided crucial information for public policy formulation. The role of the evidence-based decision making has been identified as a key message in these examples.

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1 Dashboard presenting visualizations of the findings is available at https://knowsdgs.jrc.ec.europa.eu/interlinkages-visualization.

2 The process involved an expert-driven search for published studies in academic and peer reviewed grey literature’ (e.g. reports published by international organizations).

While the depth of discussion of SDGs and its relationships varies, the contribution of academic papers and the media has been thoroughly examined using network analysis. For example, Yeh and others (2019), uses network analysis, and find that SDG 3 and SDG 10 shared the highest attention in the media and in academia, while some apparent gaps happened to SDG 5. Moreover, SDG 3-10 were identified as leaders in terms of pairs of interlinkages; more prominently, SDG 8 and SDG 5 have strong connections with several SDGs for the academia and the media, respectively. The SDG-2-6-7 combination or "water-energy-food" nexus was found to be the most frequent combination of three SDGs in the academia. Importantly, SDG 3 was recognized as the unifying theme when seeking to acquire evidence-based knowledge for integrated implementation of the SDGs.

To produce subnational analysis, Kunčič (2018) examines a classification system for grouping the Arab countries together based on characteristics most relevant to sustainable development goals (SDGs). His results show that countries move often from a better to a worse group or vice versa, implying that different and SDG-specific sub regional groups should be used for work on each individual SDG. Examining the overlap of cluster memberships by countries through a network perspective further identifies the most tightly knit country groups. The implications of findings are relevant for informative monitoring of SDGs on the sub regional level, as well as policy recommendation sharing for and between similar countries, and enhancing peer learning capacity.

In the case for SDG 14, the integration of literary knowledge and expert opinions has been shown. Singh and others (2018), use an integrated approach to demonstrate that SDG 14 targets are strongly linked to all other SDG targets, and in particular, that two of these targets (out of seven in total) are most closely related to the overall SDGs. This study highlights the importance of the oceans in achieving sustainable development. The rapid assessment framework can be applied to other SDGs to comprehensively map out the subset of targets that are also pivotal in achieving sustainable development.

In the case of SDG 7, Nerini and others (2018), identify 113 targets requiring actions to change energy systems, and published evidence on 143 synergies and 65 trade-offs, required to achieve SDG 7. Their study displays compelling evidence of the need to better organize, connect and extend this evidence, to help all actors across sectors work together to achieve sustainable development.

Zelinka and Amadei (2019) adapt the Nilsson and others (2016) evaluation system (indivisible, reinforcing, enabling, neutral, constraining, counteracting, cancelling), and produce a double-causality matrix of 17 goals, which can be used to prioritize SDGs (based on the priority indices). In this approach SDG 16, SDG 12 and SDG 17 got the highest priority scores. Relationships can be translated into system dynamics models, which allows the understanding of the relationships between goals. Integrated consideration of the global interconnected system model and planetary boundaries shows that while the global safety margin continues to decline, the SDG agenda is unlikely to materialize by 2030 (Randers and others, 2019). These research highlights the importance of analysing temporal changes in the SDG system. The role of interventions is critical for mapping the system behaviour, that can be studied using scenario analysis. For example, Allen and others (2019b), show that for Australia, the Sustainability Transition scenario results in 70 per cent rapid and balanced progress towards SDG targets by 2030.

Barbier and Burgess (2019), estimate the possible trade-offs and complementarities in attaining the various SDGs, using an analytical model to estimate the welfare effects of progress in attaining one SDG while accounting for interactions in achieving other SDGs. Their paper assesses quantitatively progress in the SDGs over 2000-2016 at the global level and for low-income countries. Using a representative indicator for each goal, they estimate the welfare changes for improvements in No Poverty (SDG 1) net of any welfare gains and losses in attaining each of the remaining 16 goals. Their results suggest that the net gain of poverty reduction is doubling globally, but not at the same pace for lower income countries. Such an analysis helps policy makers prioritize improvements towards one goal or set of goals and show explicitly the net gains and losses for achieving one goal while impacting others.

More recently, The SDG interaction networks have been estimated using global time series data of SDGs for countries with different income levels. Lusseau and Mancini (2019) used global time series of SDG indicators for countries with different income levels indicating that the trade-offs arising from these SDG interactions are a key hurdle for SDG implementation. Their estimates suggest limiting climate change, reducing inequalities and responsible consumption are key hurdles to achieving 2030 goals across countries. Focusing on poverty alleviation and reducing inequalities will have compound positive effects on all SDGs.

Time series analyses of SDG indicators and targets also provide important insights on how these different goals are interlinked. Sebestyen and others (2019), develop a network-based model to study interlinked ecological, economic, environmental and social problems to highlight the synergies between policies, plans, and programs in environmental strategic planning. They propose a methodology for the data-driven verification and extension of expert knowledge concerning the interconnectedness of the sustainable development goals and their related targets. They develop a multilayer network model based on the time-series indicators of the World Bank open data over the last 55 years. Their results illustrate an objective and data-driven view of the correlated variables. Moreover, their methodology allows for the estimation of causal relationships.

Pradhan and others (2018) use another data-driven approach, to identify synergies and trade-offs across SDG using official SDG data from 227 countries. They classify a significant positive correlation between the pairs of indicators as a synergy, while a significant negative correlation is classified as a trade-off. They in turn rank synergies and trade-offs between SDGs pairs on global and country scales in order to identify the most frequent SDG interactions. For a given SDG, positive correlations between indicator pairs were found to outweigh the negative ones in most countries. Among SDGs the positive and negative correlations between indicator pairs allowed for the identification of particular global patterns. More precisely, SDG 1 (No poverty) was found to have a synergetic relationship with most of the other goals, whereas SDG 12 (Responsible consumption and production) is the goal most commonly associated with trade-offs. They conclude that attainment of the SDG agenda will greatly depend on whether the identified synergies among the goals can be leveraged.

These papers highlight the importance of a multidisciplinary approach and the under-representation of governmental and human development related goals (Van Soest and others, 2019). The simulations of combined SDG policies-based analysis help to understand the causal relationships across multiple SDG policies; while the qualitative and semiquantitative methods complement the results of simulation-based studies (Pedercini and others, 2019). Indeed, the interconnectedness of these goals requires cross-sectoral processes to achieve policy coherence in the successful implementation the 2030 Agenda (Breuer and others, 2019). These interactions depend on key factors such as geographical context, resource endowments, time horizons and governance (Nilsson and others, 2018). Moreover, these interactions vary greatly country by country, and rely on specific goals, urging for greater international cooperation (Scherer, 2018).

A study by the Institute for Global Environmental Strategies (IGES) showcases this multidisciplinary approach analysing nine countries through the theme of energy (IGES, 2017), The results highlight that contextual dependencies need to be considered, possible ways forward for both policymaking and the scientific community (McCollum, 2018). The need for evidence-based and science-based approaches to SDG implementation is clearly emphasized by a community of experts and policymakers now facing the challenge of implementing SDGs in a simultaneous, coherent and integrated manner (Allen and others, 2019b).

Thus far, the literature has found compelling evidence of the importance of understanding the interlinkages across indicators and targets of the SDG agenda, as well as highlighting the importance of taking multidisciplinary approaches to better comprehend how to guide the policy dialogue. Yet, the efforts have fallen short, as different network analyses summarized in this section, have only recognized the assessment of interlinkages in isolation, not allow for quantitative assessment clearly depicting how a unit change in one indicator will affect others. This paper adds to the literature as it proposes a novel approach to SDGs interlinkages motivated by the well-known input output methodology for the projections of SDG indicators and impact assessment. Using panel regression analyses, we produce a full conditional interlinkages matrix showing the strength and breadth of interconnectedness between all SDG targets and indicators. Furthermore, we show how such framework can be used for translating the commonly used economic indicators such as GDP and unemployment onto the projected changes of SDGs indicators, by considering the entire grid of interlinkages. In the next sections we present in detail availability of data and the modelling methodology.

2. Data and coverage

The main challenge we faced in this paper is accessing a comprehensive dataset for all SDG targets and indicators that allows for the estimation of a full interlinkages' matrix showing the strength and breadth of interconnectedness between all SDG targets and indicators. We started the analyses using data from the Global SDG Indicators Database. This database provides access to data compiled through the United Nations System in preparation for the Secretary-General's annual report on "Progress towards the Sustainable Development Goals". The version released on 14 October 2020 contains over 1.4 million observations. However, this is not the number of unique observations, as several indicators and their data are repeated.[3] The Global SDG Indicators Database is updated quarterly – in March, June/July, September and December. However, and despite the efforts carried out by the United Nations, national governments, this data set still has major gaps. We started our analyses by understanding the comprehensiveness of these data, as well as the potential data gaps that can be supplemented using other reliable sources.

The United Nations Statistical Commission requested the Inter-Agency and Expert Group on Sustainable Development Goal Indicators (IAEG-SDG) in its resolution 48/101 (I) "to develop detailed guidelines of how custodian agencies and countries can work together to contribute to the data flows necessary to have harmonized statistics" for global SDG data reporting. While General Assembly resolution A/RES/70/1 clearly states that "national ownership is key to achieving sustainable development" and therefore "the global review will be primarily based on national official data sources", other data sources might be necessary in order to close gaps or even validate and adjust existing data.

While the National Statistics Offices are the custodian agencies of the SDGs, agencies such as UNDP, UNICEF and the World Bank have partnered with national governments working closely to support the reporting of these indicators. At the 7th Meeting of the Inter-Agency and Expert Group on SDG Indicators (IAEG-SDGs) in April 2018, UNDP, UNICEF and World Bank jointly proposed to enable and facilitate the reporting of SDG a number of indicators, within an expanded scope of their role as partner agencies, without assuming custodianship of the indicator. Furthermore, the responsible international agency has been requested to indicate whether the national data were adjusted, estimated, modelled or are the result of global monitoring, for each value of an indicator.

We complement the data from the United Nations Global Database using data from several custodian agencies. These new sources increased the number of available indicators by 30 per cent. Moreover, we identified longer time series for a large number of indicators.

The following are the most relevant data sources used:

[3] For the complete list of the indicators that are repeated in the indicator framework please see https://unstats.un.org/sdgs/indicators/indicators-list/.

- **United Nations Global SDG Indicators Database:** https://unstats.un.org/sdgs/indicators/database/ The context of the Sustainable Development Goals (and its indicators) is based on data from the United Nations Global Database. The database contains indicators for all 17 goals (and 169 targets). The geographical coverage of the database means 315 different geographical units, but the amount of data available varies considerably country by country and non-countries (e.g. regional geographical units) were excluded. Our rule of thumb for including the given indicator in the database was the country coverage greater than 100 and more than average of 5 observations per country. This resulted in selection of 135 indicators. Unfortunately, not all targets could be reflected (though there are indicators for each goal);
- **World Bank Open Data:** 17,000 indicators from the World Bank databases, including: Development Africa Development Indicators; Doing Business; Education Statistics; Enterprise Surveys; Global Development Finance; Gender Statistics; Health Nutrition and Population Statistics; International Development Association – Results Measurement System; World Development Indicators; and the Worldwide Governance Indicators. These indicators include information from over 256 countries and regions, since 1960 (with gaps);
- **IMF open data:** The IMF publishes a range of time series data on IMF lending, exchange rates and other economic and financial indicators. The main source for policy measures was IMF. We used the IMF data on expenditures by function (COFOG), but the country coverage is relatively poor, even if we considered the fact that for some countries there is information at the general government level and for some there is information on indicators for Central Government or Budgetary Central Government level;
- **World Economic Outlook Dataset:** We used WEO (World Economic Outlook) database as a source of data for broad macroeconomic indicators as GDP, GDP *per capita* or GDP *PPP.*
- **UNICEF:** The Progress for Every Child in the SDG Era 2020 dashboard and analysis below measure countries' progress on the 44 child-related SDG indicators using the latest available pre-COVID data;
- **Human Development Report Office Statistical Data (UNDP):** The Human Development Report (HDR) Statistical Annex is regarded as a useful compendium of human development statistics. Traditionally, the HDR carries tables with the Human Development Index (HDI) and other composite indices and their component indicators; as well as several tables with theme-related indices and indicators. The Human Development Report Office (HDRO) is a data user. It does not collect data directly from national statistical systems but uses indicators produced by United Nations entities and affiliates with mandate for data collection, compilation and dissemination. **Such Agencies include the United Nations Department for Economic and Social Affairs (UNDESA), the UNESCO Institute for Statistics (UIS), the United Nations Children's Education Fund (UNICEF) and the World Bank.** For composite indices that account for distributions across population, micro data from international surveys and databases are used (Demographic Health Surveys, Multiple Indicators Cluster Surveys, Luxembourg Income Study database, International Inequality Distribution Database, etc.).

We then proceeded to interpolate the data when observations were found across nonconsecutive years. We use natural cubic spline interpolation to create to replace missing values. This method calculates intermediate data between known values by conceptually drawing a cubic spline between two adjacent known values. Despite our efforts to have long and complete time series on all indicators and targets gaps still remain, as coverage for some indicators and targets is more readily available in some countries relative to others. In the next section we present the modelling approach and how the use of all these data contributes to a better understanding of how SDGs targets and indicators are interlinked.

3. Modelling approach

Our motivation in this paper is to estimate the interlinkages between sustainable development goals targets and indicators, understanding that to achieve a desired level of these goals (target or indicator) or an "output", a series of "inputs" need to be combined. A production function describes the relationships between these inputs and how they interact to produce a given output. For instance, to eradicate poverty, given country need productive economy (measured with GDP *per capita*), good quality of education and healthy labour market (reflected in low unemployment). Therefore, to "produce" reduction in poverty indicators, given country need to put some "inputs" – high GDP *per capita*, decent values of education indicators and low unemployment rate. However, improvements in these areas support also other SDG – e.g. high education expenditures support achievement of literacy goals, and low unemployment rates will in turn influence for example, the number of injuries at work, or will help to reduce informality of the economy. Moreover, reduction of poverty will contribute to the fall in inequalities and should reduce adolescent birth rate.

These relationships closely resemble input-output system – The paper adopts a log-linear regression model formulated sequentially from the Solow's neo-classical growth theory and standard Cobb-Douglas production function.

In this paper, we try to estimate the interlinkages between sustainable development goals into the matrix that will resemble standard input-output matrix for the economy and estimate the values of the coefficients, measuring the strength of the interlinkages conditional on the value of other indicators. Such matrix allows estimating these interlinkages (which are quite well researched in the literature), but also allow exploring issues that can be resolved using the standard input output framework, such as:

- How much do I need to reduce unemployment to reduce poverty by one percentage point and how it will affect other SGGs indicators?
- How much do I need to increase GDP *per capita* to reduce the proportion of people living in slums, considering interlinkages between poverty, unemployment and area of residence?
- How increasing health expenditures affects SDGs indicators, for example those related to poverty?
- How should resources be allocated to achieve the SDG, assuming the individual costs and associated values of targets and indicators is known?

In the standard input-output tables apart from the intermediate inputs, there are also production factors engaged – land, capital, labour etc. In our case, we do not know the amount of capital engaged to achieve each goal. Instead, we use expenditures on different categories as a percentage of GDP and GDP *per capita* to measure *per capita* expenditures on various services. Among these indicators, we included the following measures based on data availability and statistical significance on the interlinkages between indicators and different policy measures:

- GDP per capita (USD);
- Expenditure on environment protection (percentage of GDP);
- Investment (percentage of GDP);
- Population;
- Government expenditures (percentage of GDP);
- Unemployment rate;
- Households consumption (percentage of GDP);
- Expenditure on public order and safety (percentage of GDP);
- Expenditures on military services (percentage of GDP);
- Expenditure on general public services (percentage of GDP);
- Health expenditures (percentage of GDP);
- Expenditure on economic affairs (percentage of GDP);
- Gov't education expenditure (percentage of GDP);
- Expenditure on social protection (percentage of GDP);
- Expenditure on housing and community amenities (percentage of GDP);
- Research and development expenditures (percentage of GDP).

To populate the matrix with elasticity coefficients, we adopted production function approach as a starting point. For this purpose, we used the Cobb-Douglas production function, where the value of given indicator is explained as:

$$x_i = A_i \prod_{j \neq i} x_{,}^{\alpha_{ij}} \prod_{k \in F} f_k^{\beta_{ik}} \quad (1)$$

Where x_i is indicator i, f_k is intervention measure k and α_{ij} and β_{ik} are elasticities. Such production function can be linearized to:

$$\log(x_i) = \sum_{j \neq i} \alpha_{ij} \log(x_j) + \sum_{k \in F} \beta_{ik} \log(f_k) + \gamma_i \quad (2)$$

Therefore elasticities α_{ij} and β_{ik} can be easily organized to matrices, such that we have:

$$logX = AlogX + BlogY \quad (3)$$

Where X is vector containing logged values of SDGs indicators for given country and given year, $A = [\alpha_{ij}]$ is the square matrix containing all pairwise elasticities between different indicators and $B = [\,\beta_{ik} \quad \gamma_i]$ is the matrix with elasticities of indicators to intervention measures (including constant) and Y is the vector containing logged values of all the intervention measures (and 1 to reflect constant). With such approach, the values of X can be calculated as:

$$logX = (I - A)^{-1} BlogY \quad (4)$$

These will show, how the values of indicators X will react to the changes to Y, including interlinkages between SDGs.

This concept is very simple, but the most challenging task is to estimate the matrices A and B. Ideally, they should be estimated at country-by-country basis, as these functions may be slightly different in the real world depending on the individual country characteristics. On the other hand, behavioural rules underlying these relationships should be universal and estimation on the full sample should be more robust. Nevertheless, we do not have enough empirical data to estimate such function individually for each country.

To estimate the matrices, we wanted to use as much data as possible and apply panel regression models. However, as the list of indicators as well as intervention measures is quite long, including full list will result in overfitting the model and due to the various coverage for different indicators there may be even too few observations to estimate the model. To avoid this problem, we decided to adopt the following procedure:

1. We started from the potential interlinkages between different SDGs as listed by the United Nations Statistics Division. Also, ESCWA experts defined interlinkages of SDGs to intervention measures. These allowed to create initial list of independent variables for each indicator. The list of potential interlinkages is presented in annex I.
2. We ran standard OLS stepwise regression on the full dataset with quite low significance level for addition to the model (0.1).
3. Such list of automatically selected independent variables was a starting point for further removal of corelated variables to remove collinearity problems. For this reason, the number of indicators for each target was limited to 1. Without this limitation, the number of indicators would have been much larger.[4]
4. Variables were plugged into the random effect panel regression model. The random effect model is used to leverage on heterogeneity across countries.
5. Coefficients from such models were arranged into A and B matrices.

This method is far from perfect, but it allows for quite fast and consistent development of econometric models for all the considered indicators, even if their number is quite large (in our case it was 135 indicators with enough data coverage).

[4] In the extended version of the matrix, there are 583 possible indicators. In this case, however, the decision on the selection of potential independent variables must be made.

4. Results

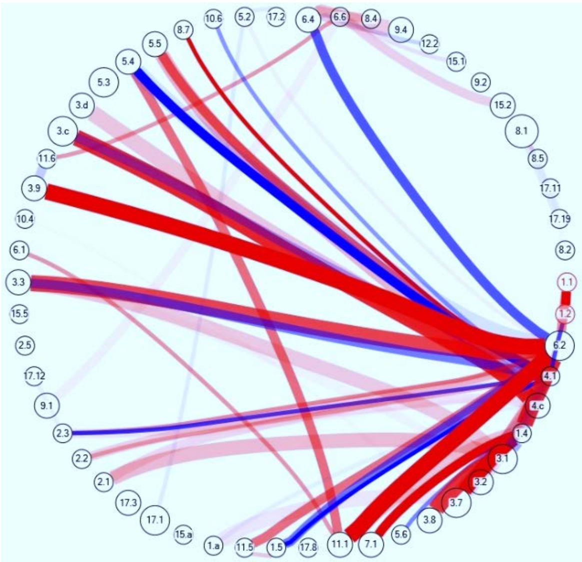
A. Interlinkages matrices

In total, we considered 135 SDGs indicators. We used GLS random effects panel data estimation as implemented in Stata software. As the number of indicators is quite large, presentation of the results is quite challenging task. In this paper, we will show the matrix of interlinkages graphically and the matrix of interlinkages is relegated to annex II. Instead, figure 1 shows the picture of interlinkages. Most of the observed relationships were positive, which means that achievement of given target reinforces achieving other goals. However, in some cases, such, as targets 4.2 and 4.5 or 8.6 versus 4.c, there are trade-offs between SDGs, meaning that increase in one indicator would hinder the achievement of other goals. In most cases, such relationships reflect the trade-off between quantity and quality, but otherwise, these interlinkages should be examined on case-by-case basis.

B. Impact of external variables

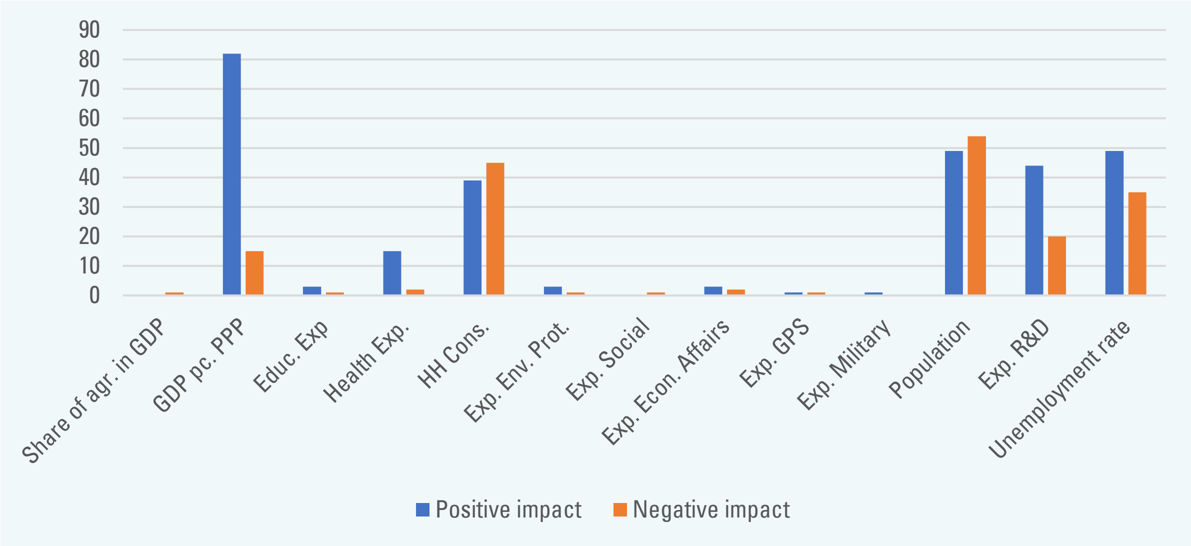
In this model apart from the interlinkages, we aim at the assessment of the impact of other (exogenous) indicators (policy variables) on achieving the SDG targets. Among these indicators, there are several indices that are general (like GDP, unemployment and population) and can have some impacts on most of the indicators and there are some that are target-specific (like outlays on education, health or R&D) that can affect only indicators that are related to specific area. Furthermore, some of the SDGs indicators are, in fact, the outcome of government unilateral and sovereign decision – therefore it would not make sense to formulate any predictions for their values. Nevertheless, they can enter the equations for other indicators as the dependent variables. The matrix of these coefficient is part of annex II.

Figure 1. Graph of interlinkages between different SDGs resulting from interlinkages matrix (sample of all available countries)



Source: Developed by ESCWA.
Note: The width of interlinkages depicts the number of indicators between targets that are interlinked, and the opacity depends on the strength of the strongest interlinkage (the value of the coefficient). Red lines indicate positive interlinkage (synergy), while blue – negative interlinkage (trade-off).

Figure 2. The number of positive and negative interlinkages for exogenous (policy) variables



Source: Developed by ESCWA.

Figure 2 shows the number of positive and negative interlinkages for each of the indicator. In general, high GDP heavily supports achieving SDGs, while the population makes them more difficult to reach, which is in line with expectations. Negative impact fall in unemployment on some indicators may be surprising, but in some cases, high unemployment may support reaching the goals that require a lot of workforce in healthcare or education. Figure 2 also depicts that these *overarching* external indicators supports reaching many targets, while the influence of the remaining *sectoral* variables is relatively narrow.

C. Indicators projection for the Arab countries

Another output of the interlinkages matrix can be the projections of SDGs indicators. As the relationship between SDGs indicators and such variables as GDP, unemployment and population were estimated, external forecasts of these variables can be used to project the value of indicators and assess the progress of countries in reaching the SDGs. Once these projections are ready, one can use methods as described in Nia (2017) for the tracking progress towards SDGs and assessing the achievement of these goals in the *baseline* scenario. This *baseline* scenario can be further used to compare with the scenarios with *policies*, to assess the impact of e.g. increase of expenditures on health on interconnected SDGs targets.

As the number of indicators is quite large (135-583) endogenous variables, depending on the model specification), it is difficult to present them all in one graph. Nevertheless, figure 3 shows the exemplary dashboard, that can be used to present results on whether given target will be achieved or not. These projections can also be presented on interactive charts etc. Full projections of all 135 indicators in the smaller version of the model for the Arab region will be presented in the forthcoming dashboard.

Figure 3. Exemplary dashboard showing whether a given country achieved a Goal by 2000 and 2015, and if the Goal will be achieved in 2030

Goal	arget	ind	SeriesDescription	SeriesCode	Target	Progress	Off Track	2000	2015	2030
1	1.1	1.1.1	Employed population below international poverty line, by sex and age (%)	SI_POV_EMP1	<5	5-20	>20	0.1	0.1	0.0
1	1.1	1.1.1	Proportion of population below international poverty line (%)	SI_POV_DAY1	<5	5-20	>20	3.8	0.2	0.1
1	1.2	1.2.1	Proportion of population living below the national poverty line (%)	SI_POV_NAHC	<5	5-20	>20	5.5	5.5	4.6
1	1.4	1.4.1	Proportion of population using basic drinking water services, by location (%)	SP_ACS_BSRVH2O	>95	95-65	<65	90.1	93.5	94.3
1	1.4	1.4.1	Proportion of population using basic sanitation services, by location (%)	SP_ACS_BSRVSAN	>95	95-65	<65	84.1	87.5	94.2
1	1.5	1.5.1	Number of deaths and missing persons attributed to disasters per 100,000 population	VC_DSR_MTMP	<0.1	0.1-0.5	>0.5			
1	1.5	1.5.3	Score of adoption and implementation of national DRR strategies in line with the Sen	SG_DSR_LGRGSR	>0.55	0.55-0.30	<0.30			
1	1.5	1.5.4	Proportion of local governments that adopt and implement local disaster risk reductio	SG_DSR_SILS	>95	95-65	<65			
1	1.a	1.a.2	Proportion of total government spending on essential services, education (%)	SD_XPD_ESED	>20	20-10	<10	11.4	11.4	11.4
2	2.1	2.1.1	Prevalence of undernourishment (%)	SN_ITK_DEFC	<5	5-20	>20	10.2	4.6	3.8
2	2.2	2.2.1	Proportion of children moderately or severely stunted (%)	SH_STA_STUNT	<5	5-20	>20	23.8	9.9	9.6
2	2.2	2.2.2	Proportion of children moderately or severely overweight (%)	SH_STA_OVRWGT	<5	5-10	<10	14.9	12.2	12.3
2	2.2	2.2.2	Proportion of children moderately or severely wasted (%)	SH_STA_WASTE	<5	5-10	<10	6.4	4.2	4.0
2	2.c	2.c.1	Consumer Food Price Index	AG_FPA_CFPI	<0.5	0.5-1	>1		0.9	1.2
3	3.1	3.1.1	Maternal Mortality Ratio (per 100,000 live births)	SH.STA.MMRT	<70	70-150	>150	164.0	100.0	100.0
3	3.1	3.1.2	Proportion of births attended by skilled health personnel (%)	SH_STA_BRTC	>95	95-65	<65	94.2	97.0	92.5
3	3.2	3.2.1	Infant mortality rate (deaths per 1,000 live births)	SH_DYN_IMRT	<5	5-10	>10	33.3	21.4	19.3
3	3.2	3.2.1	Under-five mortality rate, by sex (deaths per 1,000 live births)	SH_DYN_MORT	<5	5-10	>10	38.9	24.9	22.4
3	3.2	3.2.2	Neonatal mortality rate (deaths per 1,000 live births)	SH_DYN_NMRT	<5	5-10	>10	21.2	15.5	13.4
3	3.3	3.3.1	Number of new HIV infections per 1,000 uninfected population, by sex and age (per 1,	SH_HIV_INCD	<5	5-10	>10	0.0	0.1	0.0
3	3.3	3.3.2	Tuberculosis incidence (per 100,000 population)	SH_TBS_INCID	<5	5-65	>65	72.0	74.0	100.7
3	3.3	3.3.3	Malaria incidence per 1,000 population at risk (per 1,000 population)	SH_STA_MALR	<5	5-65	>65	0.3	0.0	0.0
3	3.4	3.4.1	Mortality rate attributed to cardiovascular disease, cancer, diabetes or chronic respira	SH_DTH_NCOM	<15	15-25	>25	20.4	14.4	13.8
3	3.4	3.4.2	Suicide mortality rate, by sex (deaths per 100,000 population)	SH_STA_SCIDE	<3	3-5	>5	4.0	3.2	3.0
3	3.6	3.6.1	Death rate due to road traffic injuries (per 100,000 population)	SH_STA_TRAF	<10	10-20	>20	24.0	23.8	23.3
3	3.7	3.7.1	Proportion of women of reproductive age (aged 15-49 years) who have their need for	SH_FPL_MTMM	>75	75-65	<65	72.9	77.9	86.2
3	3.7	3.7.2	Adolescent birth rate (per 1,000 women aged 15-19 years)	SP_DYN_ADKL	<10	10-30	>30	4.8	9.7	9.9
3	3.8	3.8.1	Universal health coverage (UHC) service coverage index	SH_ACS_UNHC	>80	80-65	<65	57.0	76.0	78.0
3	3.9	3.9.1	Age-standardized mortality rate attributed to household and ambient air pollution (d	SH_STA_ASAIRP	<20	20-85	>85		43.0	39.3
3	3.9	3.9.2	Mortality rate attributed to unsafe water, unsafe sanitation and lack of hygiene (deat	SH_STA_WASH	<5	5-20	>20		1.9	1.6
3	3.9	3.9.3	Mortality rate attributed to unintentional poisonings, by sex (deaths per 100,000 popu	SH_STA_POISN	<5	5-20	>20	1.2	0.8	0.6
3	3.a	3.a.1	Age-standardized prevalence of current tobacco use among persons aged 15 years and	SH_PRV_SMOK	<15	15-20	>20	16.4	15.6	14.0
3	3.c	3.c.1	Health worker density, by type of occupation (per 10,000 population)	SH_MED_HEAWOR	>30	30-15	<15	2.8	4.6	4.9
3	3.d	3.d.1	International Health Regulations (IHR) capacity, by type of IHR capacity (%)	SH_IHR_CAPS	>95	95-65	<65	100.0	100.0	100.0
3	3.d	3.d.1	International Health Regulations (IHR) capacity, by type of IHR capacity (%)	SH_IHR_CAPS	>95	95-65	<65	100.0	100.0	100.0
4	4.1	4.1.1	Minimum proficiency in mathematics, by education level and sex (%)	SE_MAT_PROF	>90	90-65	<65	57.4	19.0	20.1
4	4.2	4.2.2	Participation rate in organized learning (one year before the official primary entry age	SE_PRE_PARTN	>90	90-65	<65	3.4	100.0	100.0
4	4.4	4.4.1	Proportion of youth and adults with information and communications technology (ICT	SE_ADT_ACTS	>75	75-50	<50			
4	4.5	4.5.1	Gender parity index for achievement in mathematics, by education level (ratio)	SE_GPI_MATACH	>0.95	0.95-0.65	<0.65	0.7	1.2	1.2
4	4.5	4.5.1	Gender parity index for participation rate in organized learning (one year before the c	SE_PRE_GPIPARTN	>0.95	0.95-0.65	<0.65	0.9	1.0	0.9
4	4.5	4.5.1	Gender parity index of trained teachers, by education level (ratio)	SE_GPI_TRATEA	>0.95	0.95-0.65	<0.65			
4	4.5	4.5.1	Language test parity index for achievement in mathematics, by education level (ratio)	SE_LGP_ACHIMA	>0.95	0.95-0.65	<0.65	0.7	1.3	1.2
4	4.5	4.5.1	Low to high socio-economic parity status index for achievement in mathematics, by e	SE_SEP_MATACH	>0.95	0.95-0.65	<0.65		0.5	0.6
4	4.5	4.5.1	Rural to urban parity index for achievement in mathematics, by education level (ratio	SE_URP_MATACH	>0.95	0.95-0.65	<0.65	1.4	0.4	0.4
4	4.a	4.a.1	Schools with access to basic drinking water, by education level (%)	SE_ACC_DWAT	>95	95-65	<65			
4	4.a	4.a.1	Schools with access to the internet for pedagogical purposes, by education level (%)	SE_ACC_INTN	>95	95-65	<65			
4	4.a	4.a.1	Schools with access to access to single-sex basic sanitation, by education level (%)	SE_ACC_SANI	>95	95-65	<65			
4	4.a	4.a.1	Schools with access to computers for pedagogical purposes, by education level (%)	SE_ACC_COMP	>95	95-65	<65			
4	4.a	4.a.1	Schools with access to electricity, by education level (%)	SE_ACC_ELEC	>95	95-65	<65			
4	4.a	4.a.1	Schools with basic handwashing facilities, by education level (%)	SE_ACC_HNWA	>95	95-65	<65			
4	4.c	4.c.1	Proportion of teachers who have received at least the minimum organized teacher tra	SE_TRA_GRDL	>95	95-65	<65	94.2	100.0	68.2
5	5.3	5.3.1	Proportion of women aged 20-24 years who were married or in a union before age 15	SP_DYN_MRBF15	<1	1-10	>10		0.4	0.5
5	5.3	5.3.1	Proportion of women aged 20-24 years who were married or in a union before age 18	SP_DYN_MRBF18	<5	5-20	>20		2.5	2.5
5	5.5	5.5.1	Proportion of elected seats held by women in deliberative bodies of local governmen	SG_GEN_LOCGELS	>30	30-15	<15			
5	5.5	5.5.1	Proportion of seats held by women in national parliaments (% of total number of seat	SG_GEN_PARL	>30	30-15	<15	3.4	31.6	51.1
5	5.5	5.5.2	Proportion of women in managerial positions (%)	IC_GEN_MGTL	>30	30-15	<15	5.2	9.4	12.2
5	5.b	5.b.1	Proportion of individuals who own a mobile telephone, by sex (%)	IT_MOB_OWN	>90	90-20	<20			
6	6.1	6.1.1	Proportion of population using safely managed drinking water services, by urban/rura	SH_H2O_SAFE	>95	95-65	<65			
6	6.2	6.2.1	Proportion of population practicing open defecation, by urban/rural (%)	SH_SAN_DEFECT	<5	5-20	>20	5.9	0.8	3.0
6	6.2	6.2.1	Proportion of population using safely managed sanitation services, by urban/rural (%)	SH_SAN_SAFE	>95	95-65	<65	18.5	17.7	13.1
6	6.2	6.2.1	Proportion of population with basic handwashing facilities on premises, by urban/rur	SH_SAN_HNDWSH	>95	95-65	<65	82.1	83.6	54.7
6	6.3	6.3.1	Proportion of safely treated domestic wastewater flows (%)	EN_WWT_WWDS	>80	80-65	<65		17.7	24.7
6	6.4	6.4.2	Level of water stress: freshwater withdrawal as a proportion of available freshwater r	ER_H2O_STRESS	<25	25-75	>75		100.0	100.0

Source: Developed by ESCWA.

D. Optimization of SDG expenditures

Another use of the interlinkages matrix is the optimization of SDG expenditures, once a detailed cost of reaching a given target and its associated indicators is known. There is a growing interest in activities aimed at estimating the *cost* of achieving the SDGs. The SDG interlinkages matrix is an important policy tool, as it can be used to minimize the total cost of reaching the SDGs. Consequently, equation (4) may be extended to include the unit cost of improving the SDGs:

$$logX = (I - A)^{-1}(BlogY + Cz) \tag{5}$$

where C is the vector of unit costs of improving the indicators by one percent, and z is the total amount invested in reaching a specific goal. Subsequently, the following optimization problem may be solved:

$$\min Z = \sum_{i \in SDG} z_i \tag{6}$$

Subject to:

$$(I - A)^{-1}(BlogY + Cz) \geq \log X_{target} \tag{7}$$

Where X_{target} is the vector of target (desired) values of the SDG outcome target and corresponding indicators. As this is linear optimization problem, it can be solved using any software with linear optimization solver (including Excel). Preliminary results for Egypt suggest that expenditures can be optimized in such way, that total costs can be reduced by 22 per cent from the initial allocation, which is based on the sum of individual costs. Accordingly, these budget savings of 22 per cent are reached by reallocating investments in those SDGs that maximize the synergies and minimize trade-offs, without compromising the final outcome. Results of the optimization technique for selected Arab countries will be presented in the forthcoming paper.

5. Conclusions and direction for future research

This paper presents the overall framework for the estimation of the interlinkages of SDGs and how it can be used for impact analysis or future projections. We estimated 135 separate econometric panel models for each of the SDG indicator, so the number of interlinkages is quite large. Also, we shown, how this matrix can be used:

1. For integrated forecasting of the future developments of SDGs indicators – based on external projections of social and economic quantities, such as GDP, unemployment, population, the future trajectory of SDGs indicators can be forecasted.
2. For impact analysis – policy influence on GDP and unemployment resulting from other kind of modelling (e.g. CGE modelling) can be translated into the impact on SDGs indicators through interlinkages matrix.
3. For costing the achievement of SDGs – as outlays spent on achieving one SDGs will affect also the distance to be achieved for other indices.
4. For optimizing the use of SDG interlinkages, while minimizing the total costs of achieving the SDGs.
5. As a standalone tool, that can be used for the assessment of relative strength between different interlinkages.

There are few main conclusions from the analysis. Firstly, there are lot of both positive and negative interlinkages between SDGs and attempts to cost the achievement of SDGs or to project future developments without considering them is seriously flawed. Secondly, developments of *overarching* indicators, such as GDP *per capita*, unemployment and population shape the projections of many SDGs targets and general economic development is crucial for the fast achievement of the desired values of SDGs indicators. Thirdly, achievement of many SDGs would be difficult and there are very few policy areas in which there are golden bullets to allow for quick achievement of given target.

As the number of interlinkages is huge, it is difficult to analyse them case-by-case. Nevertheless, it would be beneficial for the analysis, to present and describe interlinkages for each goal separately and possibly correcting the matrices presented above. Full understanding of the relationships that we briefly described above (and presented in figure 1) as well as the influence of external policy indicators on reaching SDGs is required for building robust projections that will tell what the countries should do to reach as many SDGs as possible. Furthermore, as these interlinkages are country-specific, it would be beneficial to explore the difference in reaction of countries to different fiscal stimulus, and how efficient are different tools in reaching the SDGs targets, depending on individual characteristics of the country. This should be further explored in future research.

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The interlinkages between different Sustainable Development Goals (SDGs) and their targets and indicators have been well documented in the literature. There is vast amount of research aimed at mapping these relationships using network methods or correlation analysis. While the SDGs are broadly framed as 17 separate elements, they inherently interlink with each other forming an indivisible framework that aims to achieve holistic sustainability from a systemic perspective. The SDGs and their associated targets form a complicated network of interlinkages, so achieving one Goal or target may contribute to achieving other Goals or targets. Moreover, fully understanding these interlinkages can help identify potential synergies and trade-offs.

However, vast gaps still remain, particularly in terms of the comprehensiveness (coverage of all goals and targets), and the quantification of SDG interlinkages beyond network and correlation analyses. These analyses fall short, only summarizing the strength and direction of the relationships between a small set of indicators. Fully recognizing these interlinkages requires the identification of these interactions in a systematic way, to understand the interconnectedness beyond a small number of indicators. The present paper proposes a novel estimation approach, that utilizes panel regression analyses to address these gaps. The estimates produce a full interlinkages matrix showing the strength and breadth of the associations across various SDG targets and indicators. Furthermore, the paper shows how such a framework can be used for translating commonly used economic indicators, such as GDP and unemployment, into projected changes of SDGs indicators, by considering the entire grid of interlinkages among them. Moreover, this framework can be utilized in a variety of different applications. For example, it can be linked to the computational general equilibrium (CGE) model; used to project the impact of policies on SDGs indicators, given that the influence on exogenous variables is known; or applied to optimize SDG expenditures once the individual cost of achieving an SDG is known.

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