

# Sustainable Development Goals Diagnostics

## An Application of Network Theory and Complexity Measures to Set Country Priorities

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## Abstract

The United Nations 2030 Agenda and the Sustainable Development Goals are comprehensive and holistic in nature, as they include 17 goals and 169 targets covering economic, social, and environmental dimensions of development. In this context, policy makers face the challenge of translating the global agenda into feasible yet ambitious development plans and policies. This paper presents a methodology that can assist policy makers in prioritizing the targets of the Sustainable Development Goals within their development plans, given elements of path dependency among the goals. The method used is based on the notion that existing patterns of development outcomes can reveal information about the commonalities in countries' unobservable Sustainable Development Goal delivery mechanisms. The ease with which capacities can be used between Sustainable

Development Goals depends on their degree of commonality, conceptualized in the proximity between them. Related to this, the paper introduces Sustainable Development Goal centrality as a measure of connectedness. In addition, it defines a country's Sustainable Development Goals density to indicate how close an "unsuccessful" Sustainable Development Goals is to those Sustainable Development Goals in which a country is performing well. The paper concludes that countries should prioritize the Sustainable Development Goals that are within reach (high density) and/or offer higher scope for success through redeployment of existing capacities (high centrality). It applies the method to show how this can help countries prioritize implementation of the Sustainable Development Goals.

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# Sustainable Development Goals Diagnostics: An Application of Network Theory and Complexity Measures to Set Country Priorities

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## 1. Introduction

The UN 2030 Agenda and the Sustainable Development Goals (SDGs) are comprehensive and holistic in nature, as they include 17 goals and 169 targets covering economic, social, and environmental dimensions of development. The highly ambitious agenda stresses that all individuals shall collectively benefit from the fruits of development and that no one shall be left behind. In this context, policy makers face the challenge of translating the global agenda into feasible yet ambitious development plans and policies. Hence, there is a need to develop methodologies that can assist during different steps in this process: from data measurement and benchmarking, to prioritization of targets and monitoring of progress. Tailored to their individual national development plans and under the auspices of the global agenda, these methods should be transparent and replicable.

This paper presents a methodology that can assist policy makers to prioritize targets related to their SDG development plans. The methodology uses extensively a global database on SDG progress constructed mainly with data from the United Nations and the World Bank. The methodology proposes a set of metrics that indicate the probability of becoming an over-achiever in a particular SDG indicator, a probability that is *conditional* on progress on the rest of the SDGs.

The method is based on the notion that existing patterns of development outcomes can reveal information about the commonalities that exist in the *unobservable* SDG-delivery mechanisms that exist within countries. It is natural to think that countries have a diversity of *capacities* in the form of skills, culture, infrastructure, roads, natural resources, technology, institutions, systems of government, religion, etc. In addition, through a process of collective action, countries' SDG-delivery mechanisms are (intentionally and non-intentionally) created, and their effectiveness is reflected in the achievement of *observable* development outcomes.

The approach used in this paper is largely based on the basic notions of economic complexity (Hartmann, Guevara, Jara-Figueroa, Aristaran, & Hidalgo, 2015; Hausmann et al., 2013; Hausmann & Klinger, 2006; Hidalgo, Klinger, Barabasi, & Hausmann, 2007). Our hypothesis is that if a set of positive development outcomes are observed frequently co-existing across countries, then there are strong commonalities in the mechanisms of SDG-delivery that make possible these positive development outcomes. For instance, secondary and primary completion rates are two indicators that are strongly correlated – and it can clearly be seen that the first indicator is conditional on the later and that *some* (but not all) of the capacities used to over-perform in primary completion can be re-used for completion in secondary education. *Our hypothesis simply implies that the probability of succeeding in an SDG target can be estimated conditionally on the observed progress on all other targets.* To assess this hypothesis, we built measures of SDG progress at the detailed indicator level, largely based on the methodology of Gable, Lofgren, & Osorio-Rodarte, (2015), and propose a set of metrics based on network theory and economic complexity to test our hypothesis. Examples of questions that will be addressed are as followed:

- How are the SDGs interconnected?
- What is the probability of over-performing in a particular SDG, given progress in others?
- Does achievement in some targets tend to promote progress on others?

The paper begins in Section 2 by assessing recent efforts to create similar SDG-related benchmark and scorecard tools. Section 3 discusses the compiled SDG data, its coverage, and caveats, and presents our methodological framework, which includes a metrics

## 2. Existing tools for SDG benchmarking

derived from network theory and economic complexity. Section 4 presents an application to a country-specific case. Section 5 concludes with areas for further development and research.

## 2. Existing tools for SDG benchmarking

Several initiatives to define measurement standards, identify statistical gaps, collect cross-country comparable data, and monitor progress in SDGs have been launched. Some of these recent efforts are highlighted below.

- The Overseas Development Institute (ODI) produced scorecards to illustrate long-term projections for the achievement of the 2030 Agenda (Nicolai, Hoy, Berliner, & Aedy, 2015). Each scorecard classifies the effort needed in three groups: (i) Reform – if there is a need for better targeted solutions to accelerate progress; (ii) Revolution – significant action and innovation required; and (iii) Reversal – complete and total revision is compulsory. The scorecards produce a more complete and sharper understanding of the global challenge; however, they rely heavily on regional aggregates, thus limiting the application at the country level.
- The SDG Index and Dashboards (Sachs, Schmidt-Traub, Duran-Delacre, & Teksoz, 2017) address country-level objectives by ranking countries based on their overall SDG achievements. Presently, 39 indicators, equally weighted, are included in the index. An additional SDG Dashboard proposal was constructed as a tool to visually present data for each country and goal. Its purpose is to highlight one’s most pressing constraints to identify priorities in which an evaluation of policy is urgent. The initiative started with data for OECD countries.
- Le Blanc’s (2015) study explores the extent to which the structure of the proposed goals and associated targets necessitate better integration across sectors through the analysis of the target statements. This study constructs a network built on the interpretation of the wording for targets as it has been stipulated in each goal. As such, the resulting network can be thought of as a “political mapping,” i.e., a reflection of the consensus among stakeholders as far as how they perceive the connection between the SDGs.
- The Country Development Diagnostics Framework (Gable et al., 2015) is used to examine country-specific progress conducive to the achievement of the SDGs. The analysis relies on cross-country data; however, the outcomes are specific to each country considering its capacity level, proxied by income per capita. The framework is implemented as follows:
  - *Benchmarking recent outcomes* for SDG target indicators inclusive of the factors (including policies) that influence them – how well is a country doing compared to other countries at similar levels of per-capita incomes?
  - *Projecting 2030 outcomes* for selected indicators (when the association between GNI per capita and indicators is deemed sufficiently strong) – under current trends and given expected growth, what are likely achievements for SDG indicators by 2030?
  - *Assessing options for accelerated progress* – what can a country do to increase financial space destined to fulfill the SDG agenda?

### 3. Methodological framework

#### Constructing a global SDG database

In March 2016, the United Nations Statistical Commission's Interagency and Expert Group on SDG Indicators (IAEG-SDGs) agreed on 231 SDG indicators to monitor and evaluate progress on the 17 goals and 169 targets of the 2030 Agenda. Each indicator can contain several data series, for instance if it is disaggregated by gender, location, or age. Recognizing that the level of methodological consistency and coverage differs significantly among the SDG indicators, a *ier* classification was designed to monitor progress on both the methodological aspects and cross-country coverage. In this classification, approximately 45 percent of the indicators are classified within *Tier I*, having both an adequate methodology for measurement and sufficient coverage across countries. About a quarter of all indicators are classified as *Tier II*, indicating that the methodology is adequate, but coverage across countries is limited. Lastly, around 30 percent of indicators are categorized as *Tier III*. These indicators lack both an adequate methodology and consistent coverage across countries.<sup>2</sup>

Despite the immense challenges posed by limited SDG global coverage, for the purpose of this study, IAEG-SDG data,<sup>3</sup> the World Bank's SDG database (WB-SDGs), and additional external data have been merged, producing a database inclusive of the majority of Tier 1 indicators that can be organized by SDG goal or indicator. To maximize coverage, the most recent observation per SDG has been selected by country and series, within the latest 10 years. Also, some variables originally expressed in absolute values have been transformed into relative units of measurement to make them meaningful, for instance dividing them by a country's population or GDP. Additionally, each observation is matched with the corresponding GNI per capita value for the country/year in question.<sup>4</sup> Table 1 presents summary statistics of the database in question.

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<sup>2</sup> The distribution of data coverage might play a crucial role in the results presented in this paper; but it is hard to quantify the importance of unknown data. Arguably, the current distribution of data coverage reflects the evolving interests of the development community and policy makers. Under this argument, it is not totally surprising that coverage is biased towards the indicators included in the original MDGs, since most countries established the MDGs as benchmarks for progress.

<sup>3</sup> The SDG Goals data is from the UN's Sustainable Development Goals Indicator website, August 17, 2016: <http://unstats.un.org/sdgs/>

<sup>4</sup> Data can be found at: [https://www.researchgate.net/publication/315497169\\_Compiled\\_UN\\_SDG\\_Global\\_Database\\_update\\_March\\_22\\_2017](https://www.researchgate.net/publication/315497169_Compiled_UN_SDG_Global_Database_update_March_22_2017)

### 3. Methodological framework

**Table 1 Summary of series organized by SDG**

Categories	Countries	Indicators	Coverage, %
<i>Indicators organized by SDG goal</i>			
SDG Goal 01: No Poverty	132	30	33.2
SDG Goal 02: Zero Hunger	133	18	34.9
SDG Goal 03: Good Health and Well-Being	134	51	60.8
SDG Goal 04: Quality Education	133	92	16.3
SDG Goal 05: Gender Equality	133	32	21.2
SDG Goal 06: Clean Water and Sanitation	133	52	45.1
SDG Goal 07: Affordable and Clean Energy	134	5	66.2
SDG Goal 08: Decent Work and Economic Growth	133	127	12.9
SDG Goal 09: Industry, Innovation and Infrastructure	134	22	50.0
SDG Goal 10: Reduced Inequalities	133	5	27.0
SDG Goal 11: Sustainable Cities and Communities	134	12	41.5
SDG Goal 12: Responsible Consumption and Production	133	10	63.9
SDG Goal 14: Life Below Water	95	3	47.6
SDG Goal 15: Life on Land	134	17	60.8
SDG Goal 16: Peace, Justice and Strong Institutions	133	19	29.1
SDG Goal 17: Partnership for the Goals	134	53	34.9

Source: Authors' calculations

### Construction of metrics derived from network theory

The construction of the network of SDG indicators is based on two ideas:

- (i) The probability of a country to perform above expectations in a given SDG indicator is conditioned by the probability of performing above expectations in other SDG indicators; and
- (ii) SDG indicators that have similar SDG-delivery mechanisms are more likely to be jointly observed across countries.

Hence, achievements in the SDGs mirrors the underlying similarities in SDG-delivery mechanisms across countries.

#### Concept 1: Performance in SDG indicators

The performance measure is based on the World Bank's Country Development Diagnostics Framework (CDDF) (Gable et al., 2015), though with a few changes. This paper incorporates a similar classification that measures progress on SDGs considering a country's current level of capacities, proxied by GNI per capita. For any combination of country and SDG-series, a country can be classified as an over-performer if the SDG-series is statistically *better* than what is expected given the country's capacities.

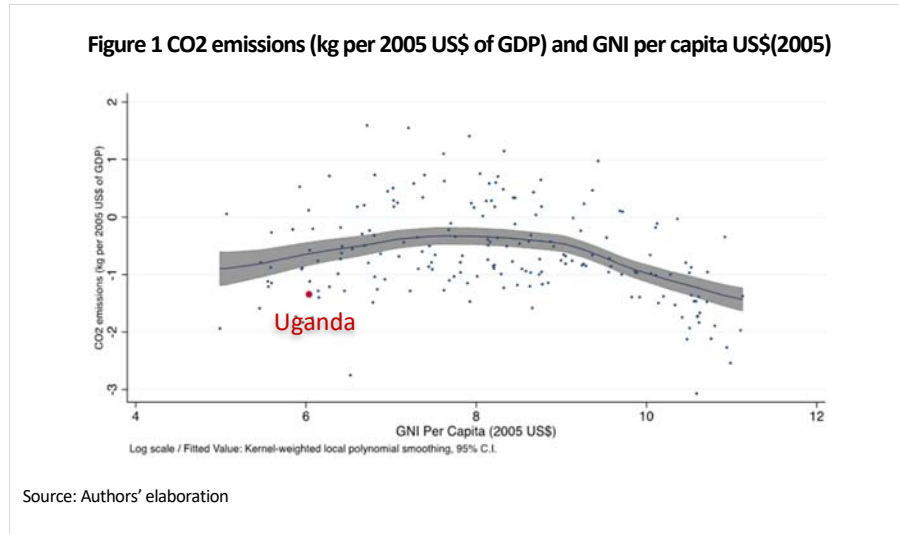
Formally, a country  $c$  has a revealed comparative advantage in the SDG-series  $i$  if the value of the SDG-series is above the 95% confidence interval of the mean:

$$RCA(i, c) = \begin{cases} 1, & x_{i,c} > Z_{\alpha=0.05} + E(x_{i,c}) \\ 0, & otherwise \end{cases}$$

The CDDF uses log-on-log linear regressions on low- and middle-income countries to estimate the expected value of the formula above. Our approach differs in the following ways: *i*) we include high-income countries in the sample, and *ii*) kernel-weighted local polynomial estimators are used instead of the constant elasticity assumption, due to the varying relationship especially at higher levels of GNI per capita. Figure 1 illustrates the approach with a cross-country scatter plot of an SDG-series, CO<sub>2</sub> emissions (kg per 2005

### 3. Methodological framework

US\$ of GDP) relative to GNI per capita. The fitted line represents expected levels of CO<sub>2</sub> per output for countries at different levels of GNI per capita. Countries outside the shaded area are significantly over- or underperforming relative to their GNI per capita. Hence, in this example where more emissions mean an inferior result, Uganda is overperforming in terms of CO<sub>2</sub> levels – i.e., Uganda is an over-achiever in this SDG-series compared to its peers.



### Concept 2: Proximity

The ease with which capacities can be used between SDGs depends on their degree of commonality, conceptualized in the proximity between them. For example, the commonalities between the indicators “number of physicians, per 1,000 people” and “malnutrition, prevalence in children under 5 years old” are expected to be larger than between “number of physicians, per 1,000 people” and “the share of protected marine areas”. Therefore, countries that are already well ahead of others, at a similar level of capacities as far as SDG attainment, are those that have acquired better SDG-delivery mechanisms.

Proximity between two SDG-indicators A and B is defined as the minimum of two conditional probabilities: the conditional probability of finding A given B; and the probability of finding B given A; since conditional probabilities are not symmetrical.

**Table 2 SDG Matrix of Proximities**

goal	goaldescription	goal01	goal02	goal03	goal04	goal05	goal06	goal07	goal08	goal09	goal10	goal11	goal12	goal13	goal14	goal15	goal16	goal17
1	No poverty		0.39	0.44	0.36	0.39	0.50	0.47	0.41	0.46	0.45	0.35	0.36	0.25	0.25	0.37	0.45	0.38
2	Zero hunger	0.39		0.46	0.36	0.39	0.52	0.49	0.44	0.47	0.41	0.39	0.45	0.32	0.32	0.42	0.44	0.42
3	Good health and well-being	0.44	0.46		0.41	0.42	0.59	0.54	0.51	0.54	0.46	0.41	0.54	0.38	0.39	0.47	0.50	0.48
4	Quality education	0.35	0.36	0.41		0.36	0.52	0.48	0.42	0.48	0.42	0.34	0.39	0.31	0.38	0.39	0.41	0.38
5	Gender equality	0.39	0.39	0.42	0.36		0.50	0.46	0.43	0.48	0.45	0.33	0.40	0.29	0.34	0.39	0.43	0.38
6	Clean water and sanitation	0.50	0.52	0.59	0.52	0.50		0.65	0.57	0.64	0.58	0.47	0.58	0.43	0.51	0.55	0.57	0.55
7	Affordable and clean energy	0.47	0.49	0.54	0.48	0.46	0.65		0.59	0.60	0.54	0.42	0.52	0.39	0.47	0.51	0.52	0.55
8	Decent work and economic growth	0.41	0.44	0.51	0.42	0.43	0.57	0.53		0.55	0.48	0.39	0.54	0.38	0.39	0.50	0.48	0.48
9	Industry, innovation, and infrastructure	0.46	0.47	0.54	0.48	0.48	0.64	0.60	0.55		0.56	0.41	0.53	0.40	0.50	0.52	0.53	0.55
10	Reduced inequalities	0.45	0.41	0.46	0.42	0.45	0.58	0.54	0.48	0.56		0.37	0.41	0.31	0.39	0.46	0.47	0.48
11	Sustainable cities and communities	0.35	0.39	0.41	0.34	0.33	0.47	0.42	0.39	0.41	0.37		0.39	0.41	0.27	0.38	0.37	0.37
12	Responsible consumption and production	0.36	0.45	0.54	0.39	0.40	0.56	0.52	0.54	0.53	0.41	0.39		0.41	0.37	0.50	0.48	0.48
13	Climate action	0.25	0.32	0.38	0.31	0.29	0.43	0.39	0.38	0.40	0.31	0.41	0.41		0.30	0.37	0.33	0.38
14	Life below water	0.25	0.32	0.39	0.38	0.34	0.51	0.47	0.39	0.50	0.39	0.27	0.37	0.30		0.42	0.37	0.37
15	Life on Land	0.37	0.42	0.47	0.39	0.39	0.55	0.51	0.50	0.52	0.46	0.38	0.50	0.37	0.42		0.44	0.48
16	Peace and justice strong institutions	0.45	0.44	0.50	0.41	0.43	0.57	0.52	0.48	0.53	0.47	0.37	0.48	0.33	0.37	0.44		0.45
17	Partnership for the goals	0.39	0.42	0.46	0.39	0.38	0.53	0.51	0.48	0.50	0.45	0.37	0.48	0.35	0.32	0.48	0.45	

Source: Authors' calculations



### 3. Methodological framework

#### Concept 3: Centrality

Another important concept is an SDG's "centrality." Centrality of an SDG is the sum of all their SDG pair-wise proximities; as such, it is used as a measure of connectedness. High centrality indicates that the SDG has a multitude of SDGs in its proximity, i.e., if a country is successful in that SDG, it is likely that it will be successful in many others. It should be noted given that we have yet to introduce country-specific concepts, an SDG's centrality is singular across all countries. It is expected that *central SDGs*, meaning those that appear to be better connected with the rest of the network; are fundamental to redeploy and scale up SDG-delivery mechanisms and thereby be successful in achieving the overall SDG agenda.

Table 3 presents the top 20 and the bottom 20 SDGs, ranked according to centrality. Not surprisingly, different measures of access to electricity are among the most connected SDGs, implying that if a country has successfully provided access to electricity, it is likely that success will ensue in other SDGs as well. As further indicated by Table 3, the groups of SDGs that exhibit high centrality are improved water and sanitation facilities, internet connectivity, school enrollment, and immunization. The least connected, however, appear to be far more diverse. This is also expected since if an SDG-series has limited connection to the other SDGs, it implies that the former has very unique, non-transferable, requirements for its SDG-delivery. For example, as seen in Table 3, having a nondiscrimination clause mentioning gender within a constitution may not be strongly related to the other SDGs because the SDG-delivery mechanism, changing the law, cannot be redeployed to other development outcomes, i.e., reduce mortality.

Table 4 ranks the 17 goals by their average centrality, based on the centrality of the underlying SDG-series for each goal. The goal with the highest average centrality is SDG 7: Affordable and Clean Energy, followed by SDG 6: Clean Water and Sanitation, SDG 9: Industry, Innovation and Infrastructure, and SDG 3: Good Health and Well-being. The values underscore that on average, fulfillment in these SDG areas yields a higher probability of success that will also be exhibited in other SDG areas. This metric implies that SDG-delivery mechanisms put in place to over-perform in the indicators within SDG 1: No Poverty and SDG 13: Climate Action are indeed very specific and cannot easily be redeployed to achieve targets in other goals.

### 3. Methodological framework

**Table 3 SDG Centrality – Top and bottom 20**

**Top-20**

Rank	indicatorname	path
1	Access to electricity, urban (% of urban population)	258,6
2	Urban Proportion of population using improved drinking water sources	257,1
3	Improved water source, urban (% of urban population with access)	256,8
4	Proportion of population using improved drinking water sources	256,5
5	Proportion of population with access to electricity	256,2
6	Improved water source (% of population with access)	256,1
7	Access to electricity (% of population)	255,5
8	Immunization, measles (% of children ages 12-23 months)	255,4
9	Immunization, DPT (% of children ages 12-23 months)	255,2
10	Access to electricity, rural (% of rural population)	254,5
11	Proportion of population covered by a 2G mobile network	254,2
12	Urban Proportion of population using improved sanitation facilities	253,5
13	Improved sanitation facilities, urban (% of urban population with access)	253,4
14	Rural Proportion of population using improved drinking water sources	252,9
15	Improved water source, rural (% of rural population with access)	252,9
16	Proportion of population using improved sanitation facilities	252,3
17	Fixed broadband subscriptions (per 100 people)	252,0
18	Improved sanitation facilities (% of population with access)	251,7
19	Internet users (per 100 people)	251,3
20	Rural Proportion of population using improved sanitation facilities	251,2

**Bottom-20**

404	Male Proportion of teachers in upper secondary education who have received at le	159,9
405	Male Time spent on unpaid domestic and care work	158,7
406	Employment in agriculture, male (% of male employment)	155,1
407	Malaria incidence per 1,000 population	154,8
408	Number of local breeds classified as being not-at-risk of extinction	152,4
409	Theoretical duration of secondary education (years)	151,1
410	Proportion of local breeds classified as being not-at-risk of extinction	151,0
411	Alcohol per capita consumption (aged 15 years and older) within a calendar year	149,5
412	Fixed Internet broadband Subscriptions per 100 inhabitants	134,5
413	Proportion of children aged 1-14 years who experienced any physical punishment a	130,0
414	Annual freshwater withdrawals, agriculture (% of total freshwater withdrawal)	129,2
415	Gender parity index for achievement in reading by the end of primary	128,1
416	Gender parity index of teachers in upper secondary education who are trained	126,2
417	Gender parity index of teachers in primary education who are trained	125,7
418	Proportion of local breeds classified as being at unknown level of risk of extin	115,3
419	PM2.5 air pollution, population exposed to levels exceeding WHO guideline value (% of total)	114,0
420	Gender parity index of teachers in lower secondary education who are trained	106,9
421	National and local disaster risk reduction strategies	78,2

Source: Authors' calculations

**Table 4 Ranking of centrality, by SDG**

goal	goal description	average path
7	Affordable and clean energy	235,1
6	Clean water and sanitation	224,6
9	Industry, innovation, and infrastructure	220,7
3	Good health and well-being	213,0
17	Partnership for the goals	211,8
15	Life on Land	209,9
8	Decent work and economic growth	209,7
16	Peace and justice strong institutions	205,4
4	Quality education	200,8
14	Life below water	199,4
12	Responsible consumption and production	196,6
2	Zero hunger	195,5
5	Gender equality	193,3
10	Reduced inequalities	190,6
11	Sustainable cities and communities	187,1
1	No poverty	182,0
13	Climate action	150,0

Source: Authors' calculations

#### 4. Prioritizing SDGs

##### Concept 4: A country's SDG density

Density in a given SDG is a country- and SDG-specific concept. In the context of the SDG network and for a particular SDG, the ease for a country of becoming an over-performer depends on: (i) the other SDGs in which the country is over-performing; and (ii) the proximity from the target SDG to each of the others on which the country is over-performing. Formally, the density for a country  $c$  in SDG  $j$ , on which it is under-performing, is the sum of proximities between SDG  $j$  and all other successful SDGs, scaled by the sum of all proximities leading to SDG  $j$  (i.e., scaled by its centrality):

$$density_{cj} = \frac{\sum_i \phi_{ij} x_{ci}}{\sum_i \phi_{ij}}$$

where  $x_{ci} = \begin{cases} 1 & \text{if } RCA_{ci} \geq 1 \\ 0 & \text{otherwise.} \end{cases}$  and  $\phi_{ij}$  denotes the proximity between SDGs  $i$  and  $j$ . The density of any SDG lies between 0 and 1. The higher the density of a non-successful SDG, the closer its required capacities are to the country's existing ones. Hence, density is defined on the basis of the proximities of the SDG to other SDGs in which the country is successful.

In sum, countries should prioritize SDGs that:

- Are within reach (high density, reflecting that the country has most of the capacities)
- Offer higher scope for further diversification (high centrality, reflecting that if the country is capable of producing this SDG it will very likely be capable of producing others).

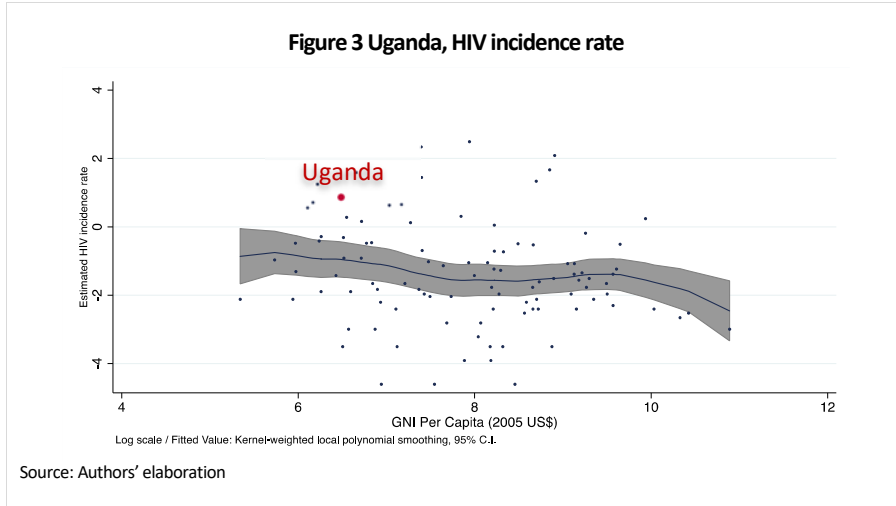
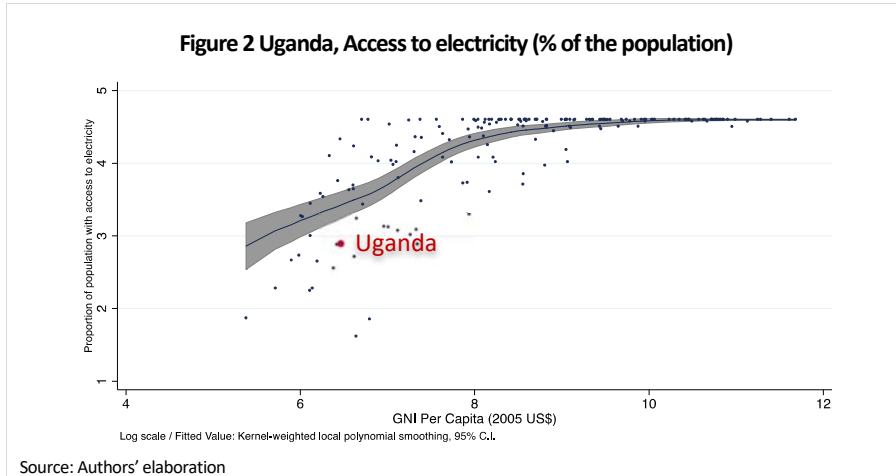
Hence, it may come down to a trade-off between "low-hanging fruit" (due to the position of the country in the network) and high diversification return through a larger investment in new capacities.

#### 4. Prioritizing SDGs

While the result of the proximity matrix and the centrality measure for each SDG is universal and creates the basic SDG network, the level of density for each SDG differs among countries since countries are successful in different parts of the network. If a country is successful in a dense part of the network, it means its current capacities can be used to diversify its SDG focus of implementation. If it is in a sparse part of the network, the opportunity set is limited. In both cases, a long-term view is needed to ensure sustainable improvements on the SDG agenda, which means a jump to a high centrality SDG may be advisable even if the proximity is currently low. The country then must invest in new capacities that in the future will pay off in more diversity options. Using the example of Uganda, this section illustrates how these concepts can be used to assess policy options.

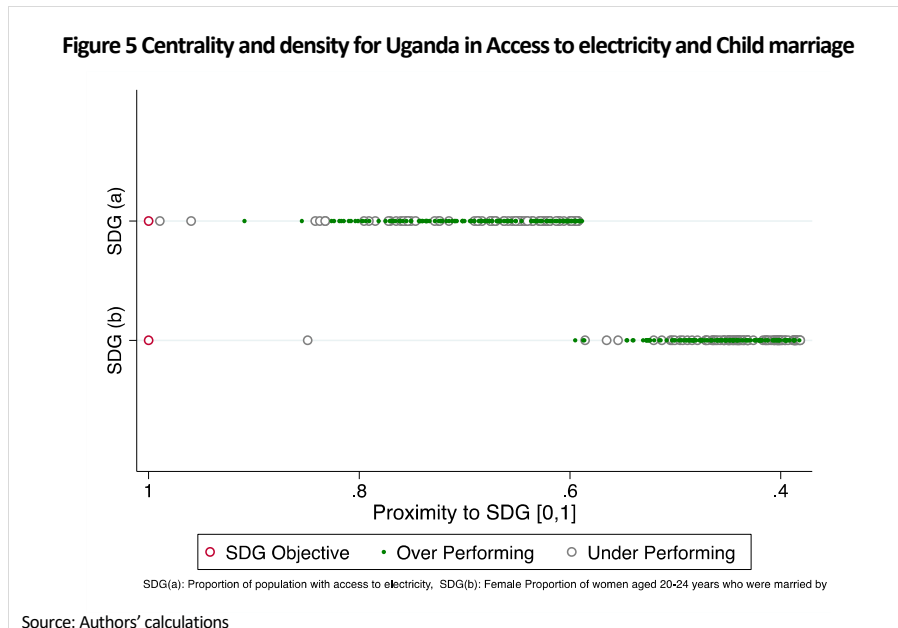
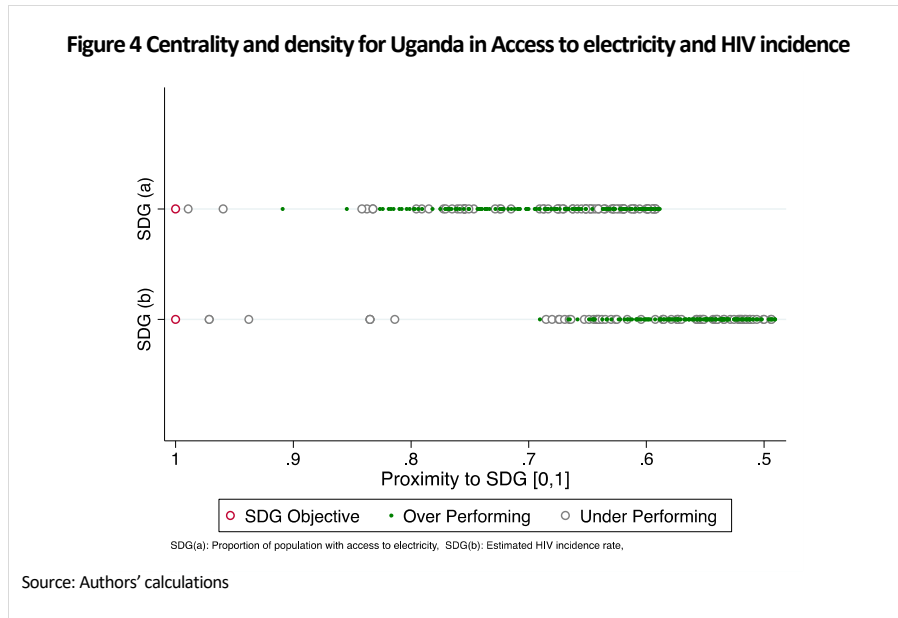
Figure 2 and Figure 3 show two SDGs for which Uganda is currently underperforming, that is for which Uganda is currently unsuccessful compared to what is expected for a typical country at Uganda's income per capita level. Which one should Uganda prioritize? There are of course a number of factors to take into account to answer that question, but among those would be: (i) the easiness of success given current capacities (density), and (ii) the potential for further improvement it creates (centrality).

4. Prioritizing SDGs



In a horizontal line, Figure 4 shows the proximity of other SDGs in relation to the two SDGs in question. SDG (a) is here access to electricity (% of population) and SDG (b) HIV incidence (rate, total population). Each gray circle or green dot represents another SDG and the further away they are from the red circle (representing SDG (a) or SDG (b) with the normalized maximum centrality of 1) the lower the proximity. The green dots represent the SDGs where Uganda is currently successful and the circles where it is not.

4. Prioritizing SDGs

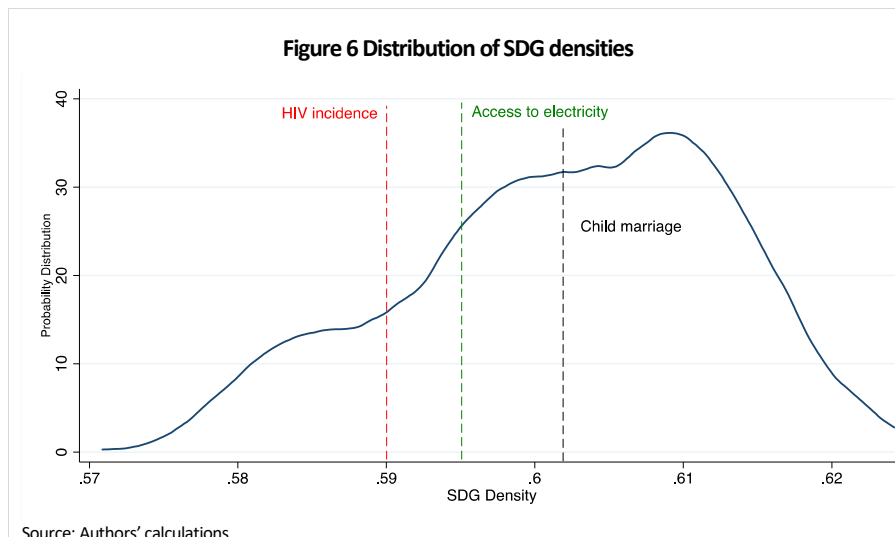


The centrality for a) access to electricity is 255 and for b) HIV incidence is 212. The question is where in the network Uganda is, given its current capacities, i.e., its current successful SDGs. Calculating Uganda's density with regard to each of these SDGs, it turns out that Uganda is somewhat closer in capacities to a) access to electricity, with density 0.594, than b) HIV incidence, 0.590. Hence, the fact that access to electricity has both higher density and centrality, suggests that it should be prioritized over HIV incidence (all else equal and no weights attached to the different goals).

#### 4. Prioritizing SDGs

Figure 5 shows the example of two SDGs where the prioritization is less straightforward; SDG (a) is here access to electricity (% of population) and SDG (b) is child marriages (women married by 15 years old (proportion of women aged 20-24)). Centrality for access to electricity is 256, and for child marriages it is 185. Hence, if you had no country-specific information – access to electricity would stand out as the best choice for overall SDG agenda success. However, calculating the densities for Uganda, which are 0.594 for access to electricity and 0.602 for child marriages, suggests that it would be easier for Uganda to become an over-performer in child marriages than in access to electricity. Hence, in this example, Uganda needs to make a trade-off between a higher probability of success given current capacities (prioritize child marriages) or higher probability of further SDG achievements given a successful outcome (prioritize access to electricity).

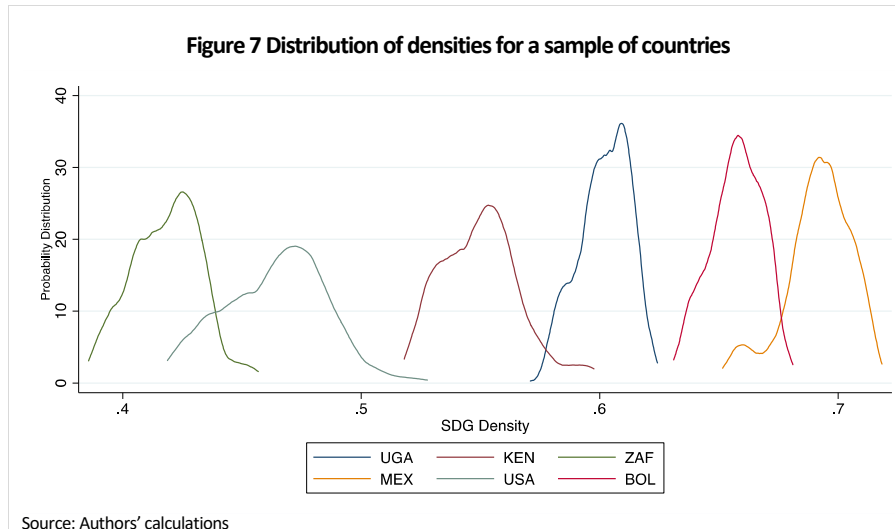
Figure 6 presents the distribution of all the SDG densities for Uganda, with some examples. The successful SDGs would be more common at higher levels of density, and vice versa. If the centrality was the same for each SDG, Uganda should prioritize the not yet successful SDG with the highest Uganda-specific density.



#### Comparing the overall potential in several countries

Graphs of the distribution of SDG densities can also be used for cross-country comparisons. In Figure 7 we see that among the selected countries, Mexico has the highest average density followed by Bolivia, Uganda, Kenya, USA and South Africa. This would suggest that, among these countries and controlling for GNI per capita, Mexico has the highest possibilities of becoming an over-achiever when pursuing the SDG agenda; while South Africa will struggle the most. Mexico is for its income level successful in a number of SDGs already while South Africa is lagging behind countries at a similar GNI per capita level. Certainly, at higher levels of per capita income, like the USA, competition is tougher, and becoming an over-achiever in development outcomes, vis-à-vis, other high-income countries represents a major policy challenge.

#### 4. Prioritizing SDGs



The *shape* of the distribution matters. A narrow probability distribution means that most SDGs have similar levels of density for the country in question. A broad probability distribution means that the density differs significantly between SDGs. Hence, the country has a higher potential to achieve some of the goals, but a lower potential to achieve others, suggesting an SDG network analysis would be very helpful in prioritizing SDG initiatives. With the *average* density in each country, it is possible to rank countries in terms of their potential for SDG *improvement* (not SDG levels achieved). Table 5 presents the top 15 and bottom 15 countries.

**Table 5 Average density in selected countries**

TOP 15		BOTTOM 15	
Country	Average density	Country	Average density
Bulgaria	0,703	Micronesia	0,161
Panama	0,672	Afghanistan	0,159
Ecuador	0,671	Andorra	0,141
Peru	0,663	Tuvalu	0,118
Colombia	0,663	São Tomé and Príncipe	0,116
Chile	0,656	San Marino	0,112
Costa Rica	0,655	Palau	0,099
Mexico	0,641	Marshall Islands	0,092
Argentina	0,641	Faroe Islands	0,085
Vietnam	0,632	Yemen, Rep.	0,081
Madagascar	0,629	Morocco	0,075
Uruguay	0,628	Liechtenstein	0,061
Korea, Rep.	0,627	Greenland	0,058
Germany	0,623	Isle of Man	0,017
Hungary	0,621	Chile	0,008

Source: Authors' calculations

## 5. Conclusion

Another example showcasing the SDG network method compares the number of SDGs in which countries are successful to their density. Mexico and Bolivia are successful with about the same number of SDG indicators included in this study: 282 in Mexico and 271 in Bolivia. Despite this, Mexico's density is significantly higher than for Bolivia. This means Mexico's successes are located in a more dense part of the SDG network, i.e., Mexico is doing well in those SDGs that have a high potential to make the development of other SDGs successful. The implication is that it would be easier for Mexico than for Bolivia to take advantage of its opportunities.

Imagine there is a global or regional SDG problem, or an organization dealing with local problems in several countries, then priorities between countries is on the table. Table 6 shows the example of the SDG indicator "access to electricity", with the corresponding densities for three African countries that are currently underperforming for their income per capita levels. All else equal, investing in Rwanda would entail a higher probability of success since the country is successful in more of the SDGs in the proximity of "access to electricity". Compared to the other countries with a lower density for this particular SDG, Rwanda has an underlying capacity that is more in line with what is needed for improvement of "access to electricity".

Table 6: sample of country densities for "Access to electricity, % of population"

Country	Density for Access to electricity
Rwanda	0.641
Uganda	0.594
Tanzania	0.499

Source: Authors' calculations

## 5. Conclusion

The UN 2030 Agenda and the Sustainable Development Goals (SDG), adopted by the world's leaders in September 2015, are comprehensive and holistic in nature, as they includes 17 goals and 169 targets covering economic, social, and environmental dimensions of development (UN 2015). The ambitious agenda articulates that no one shall be left behind, and that all shall collectively benefit from the fruits of development across all the SDGs. Individual countries now face the tough challenge of translating this agenda into feasible and realistic, yet ambitious, development plans as well as identifying policies that comprehensively reflect their initial conditions and priorities. This study builds on the idea that the SDGs are both products of countries' current capacities, and a contributor to future capacities. Hence there is an element of path dependency, which needs to be taken into account as countries prioritize their SDG policies.

The SDG network is based on the same idea as the product space developed by Hausmann and Klinger (2006) and Hidalgo et al (2007), and combines it with the insights from the Country Development Diagnostics Post-2015 framework (Gable et al, 2015). SDG achievements mirror the underlying structures that possess and combine available input in the country (the underlying capacities). The ease with which an input can be moved between two SDGs depends on their degree of commonality, conceptualized in the proximity between them. Proximity is the conditional probability of two SDG indicators being "successful" together. Successful is defined as a country performing better than expected, or as expected, *for its income per capita level*. Centrality is the sum of an SDG's pair-wise proximities with all other SDG indicators. As such, it is a measure of potential diversity and contribution to success of the overall SDG agenda in the country.

Not surprisingly, different measures of access to electricity are among the most connected SDGs, therefore implying that if a country has successfully provided access to electricity, it is likely that success will ensue in other SDGs as well. As indicated by the pair-wise correlation matrix in Table A.1 in the annex, the groups of SDGs that exhibit



## 5. Conclusion

high centrality are improved water and sanitation facilities, internet connectivity, school enrollment, and immunization. The least connected, however, appear to be far more diverse. However, it is important to note that if an SDG has limited connection to the success of other SDGs, it does not imply that the SDG is irrelevant.

The methodology is then used for country-specific assessment, by introducing the concept of density. Density is defined on the basis of the proximities of the SDG to other SDGs in which the country is successful. Hence, it is a country-specific measure that differs for each SDG indicator. The higher the density of a non-successful SDG, the closer its required capacities are to the country's existing ones, and the easier it will be for the country to turn it into a successful SDG. When comparing two SDG policy options for a country, the country-specific density for each SDG indicator (i.e., its easiness of success), must then be weighted against the cross-country centrality of each SDG indicator (i.e., its connectiveness to other SDGs and hence potential for further improvement). Furthermore, countries can be ranked according to their average density, or their density for a specific SDG in question.

The awareness of country-specific path dependency will be important in order to achieve an efficient and successful prioritization of the SDG agenda in each country. However, it needs to take into account the level of data limitations and be combined with other studies, not least cost benefit analyses and political economy analyses. In addition, this approach assumes that all SDG targets have equal value in themselves, while those values may differ between SDG targets and for each country.

## References

- Amin-Salem, H., M.H. El-Maghrabi, I. Osorio Rodarte, and J. Verbeek (2018). Sustainable development goal diagnostics : the case of the Arab Republic of Egypt (English). Policy Research working paper; no. WPS 8463. Washington, D.C. : World Bank Group. <http://documents.worldbank.org/curated/en/532831528165791465/Sustainable-development-goal-diagnostics-the-case-of-the-Arab-Republic-of-Egypt>
- Gable, S. E., Lofgren, H., & Osorio-Rodarte, I. (2015). *Trajectories for sustainable development goals : framework and country applications*. Washington D.C: World Bank. Retrieved from <https://openknowledge.worldbank.org/handle/10986/23122>
- Hartmann, D., Guevara, M. R., Jara-Figueroa, C., Aristarán, M., & Hidalgo, C. A. (2015). Linking Economic Complexity, Institutions and Income Inequality. *Physics and Society*. Retrieved from <http://arxiv.org/abs/1505.07907>
- Hausmann, R., Hidalgo, C. A., Bustos, S., Coscia, M., Chung, S., Jimenez, J., ... Yildirim, M. A. (2013). *The Atlas of Economic Complexity*. Center for International Development Harvard University. Retrieved from <http://atlas.media.mit.edu/book/>
- Hausmann, R., & Klinger, B. (2006). *Structural Transformation and Patterns of Comparative Advantage in the Product Space*. *CID Working Paper* (Vol. no. 128.). Cambridge, Mass.: Center for International Development at Harvard University. Retrieved from <http://discovery.lib.harvard.edu/?itemid=%7Clibrary/m/aleph%7C010148641>
- Hidalgo, C. A., Klinger, B., Barabasi, A. L., & Hausmann, R. (2007). The product space conditions the development of nations. *Science*, 317(5837), 482–487.
- Le Blanc, D. (2015). Towards Integration at Last? The Sustainable Development Goals as a Network of Targets. *Sustainable Development*, 23(3), 176–187. <https://doi.org/10.1002/sd.1582>
- Nicolai, S., Hoy, C., Berliner, T., & Aedy, T. (2015). *Projecting progress: reaching the SDGs by 2030*. Retrieved from <https://www.odi.org/publications/9895-projecting-progress-reaching-sdgs-2030>
- Sachs, J. D., Schmidt-Traub, G., Duran-Delacre, D., & Teksoz, K. (2017). *SDG Index & Dashboards Report 2017*. New York. Retrieved from <http://www.sdgindex.org>
- World Bank. (2013). *Financing for development post 2015*. Washington, D.C. Retrieved from <http://documents.worldbank.org/curated/en/206701468158366611/Financing-for-development-post-2015>

## **Annex A: Results using pair-wise correlations**

To investigate the statistical relationship between indicators, targets, and goals a simple pair-wise correlation was first used. Pair-wise correlations indicate the extent of which two variables are moving together; if two variables show a strong correlation, it suggests that the behavior of one variable affects the other. However, it may also indicate the existence of an additional third variable that is affecting the former variables.

To summarize results from pair-wise correlations, the 423 indicators were grouped by SDG goal and average pair-wise correlation are presented in the matrix in Table A.1. In the table, darker colors indicate stronger average correlations. Since our goal is to support country-specific prioritization of the SDGs, it is also important to advise on policy directions given the country's current capacities and resources. This is especially true if the results differ significantly depending on the income per capita level. To further investigate this, we divide the sample into two sub-samples; (i) low- and middle-income countries, and (ii) high-income countries.

In the entire sample and for the sample with only low and middle-income countries, the goals that seem to have the strongest correlation with the other goal's SDG indicators are "poverty reduction," "clean water and sanitation," "affordable and clean energy," "gender equality," "sustainable cities and communities," and "health." Table A.2 presents the average correlation of one specific SDG to all other SDGs. While it goes beyond this study to explain why specific goals are correlated with others, it is worth noticing that indicators with less of a global "public good" and more of a national "public good" character seem to have a stronger pair-wise correlation. They are easier to address for a specific country once the resources are there, and may be hence be more strongly correlated with a third variable; the national income per capita.

The order of the goals, beginning with the strongest correlation to the other goals, alters subsequent to changes in the income level of the sample (see Table A.2). For example, "peace and justice" and "climate action" takes the place of "clean water and sanitation" and "affordable and clean energy," which have less of a variation in a sample of only high-income countries. With that being said, while we cannot compare the strength of the correlations across groups due to the varying sample sizes, we observe that the ranking of goals in terms of how strongly correlated they are to the other goals, changes. We therefore need a method that can (1) assess the implications for specific countries, and (2) control for income level. Consequently, to allow for the ability to advise countries with different capacities on how to prioritize their SDGs, we turn to network analysis in the next section.

While this report focuses on correlations between goals, it is also of great interest to see how the SDG indicators within the same goal are correlated. As observed in Table A.3, the strongest correlation is among the indicators related to SDG 1: No Poverty followed by SDG 7: Affordable Energy, SDG 6: Clean water and Sanitation, and lastly, SDG 3: Good Health and Well-Being. The goals with the least correlated indicators are SDG 10: Reduced Inequalities and SDG 17: Partnership for the Goals. Identifying the reasons that perpetuate these results will not be investigated in this paper, though it should be noted that in some cases, it may indicate a too fragmented goal, which may affect the ability to identify efficient policies.



**Table A.3:** Within goals correlations – whole sample.

goal	goaldescription	within_corr
1	No poverty	64,8
7	Affordable and clean energy	49,4
6	Clean water and sanitation	45,9
3	Good health and well-being	30,1
9	Industry, innovation, and infrastructure	28,2
4	Quality education	28,1
8	Decent work and economic growth	28,0
5	Gender equality	27,9
15	Life on Land	24,4
12	Responsible consumption and production	22,6
2	Zero hunger	22,2
16	Peace and justice strong institutions	20,9
11	Sustainable cities and communities	19,8
17	Partnership for the goals	17,1
10	Reduced inequalities	14,2
13	Climate action	
14	Life below water	

## Annex B: Economic complexity and the development of nations.

The SDG network analysis has borrowed concepts from the economic complexity methodology. This annex explains briefly the main concepts of economic complexity. The process of structural transformation asserts that over time, as economic growth accelerates, a wider range of capacities are created, permitting the production of a larger selection of goods and services. Moreover, an additional feature of structural transformation is an increase in the human capacity to produce more technologically sophisticated goods and services i.e. an increase in the *complexity of the economic system* that fulfills a greater variety of needs. The product space approach articulates that the capacity of knowledge embedded in a society is not dependent on the amount of knowledge each individual possesses, but rather, the *diversity of knowledge* across individuals and a *society's ability to both use and combine such knowledge* through a complex web of interactions (market, institutions, etc.).

The PS approach holds that *the composition of produced goods and services mirrors the underlying structures that possess and combine this knowledge*, and that this composition is not well captured by standard aggregate economic indicators. The ease with which the knowledge embedded in available production inputs can be transferred and recombined is an immense determinate of a producer's ability to offer a larger and more complex set of goods and services (associated with higher productivity levels). The ease with which an input can be moved between two products is dependent on their degree of commonality.

In this context, Hausmann and Klinger (2006) started by proposing a measure of proximity based on observed patterns of diversification across countries. Specifically, they use the concept of *conditional probabilities of co-exporting pairs of products* as the building block in the construction of a square *matrix of proximities* (the "PS map"). They show that *products exported by stagnant countries tend to be isolated, located in the sparsest and less connected parts of the PS map, while products exported by countries with higher long-run GDP growth rates tend to be in the densest part*. Hence, the location of a country's export mix in PS matters for growth.

Hidalgo and Hausmann (2011) embark in the study of the sequential evolution of economies—from the production of less sophisticated to more sophisticated activities. Economic complexity illustrates that economic development is not only a process of continuous improvement in the production of the same goods, but also one that requires structural transformation; that is, the accumulation of the capacities needed to upgrade production (by transferring resources) toward activities associated with higher levels of productivity. Moreover, such shift is the catalyst to fast and sustained growth, further implying that development is a path-dependent process. The only feasible way to traverse it is through significant structural transformation.