Mapping the Sustainable Development: a network-based approach for achieving the SDGs

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Introduction

In September 2015, the '2030 Agenda' received unanimous ratification from all 193 United Nations (UN) Member States. This global action plan sets forth an ambitious mission to eradicate poverty, advance healthcare and education, reduce inequalities, promote economic growth, address climate change, and safeguard the planet's natural resources. In contrast to its predecessor, the sector-focused Millennium Development Goals, the '2030 Agenda' emphasizes the intricate interplay among economic, environmental, and social factors that underpin sustainable development.

Structured as a network of 169 targets, indivisible and integrated within 17 thematic goals known as the Sustainable Development Goals (SDGs), this ambitious plan necessitates a coordinated endeavor involving governments, corporations, civil society entities, and academic institutions. The aim is to create synergies among these goals and expedite global progress. Within this context, policymakers confront the formidable challenge of translating the lofty ideals of the 2030 Agenda into actionable development plans and policies.

While the academic literature has thoroughly examined the determinants of individual targets, a crucial gap exists in comprehending the broader relationships that interlace these targets, thereby potentially hindering progress across most of the goals. This study endeavors to streamline the complexity of the Agenda, thereby contributing to the development of practical implementation mechanisms. To achieve this objective, we adapt the "economic complexity" methodology pioneered by Hidalgo and Hausman (2011). Our adaptation serves to map the intricate interactions between the SDGs, establish a roadmap for attaining these targets and goals through prioritization, and leverage these interconnections to amplify the scale and pace of progress.

Drawing inspiration from Hirschman's developmental ethos, our approach facilitates the ranking of national projects based on their potential positive externalities on other targets. This ranking relies on a combination of local competences and the opportunities each new investment unfolds. Given the resource and capability constraints confronting most countries, the identification of priority targets becomes an imperative task.

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Methods

Adaptation of the economic complexity method to the 2030 Agenda. The economic complexity methodology was developed to reduce a vast universe of variables (products) into a smaller set of basic elements (capabilities), uncovering potential evolutionary trajectories (specialization patterns) that can be used to not only forecast growth but also inform policymaking strategies. Numerous studies have harnessed the power of this methodology and its associated indicators to scrutinize development from diverse vantage points, including applications with international trade data (Hausmann et al., 2014), labor employment (Gao et al., 2021; Chávez, Mosqueda & Gómes-Zaldívar, 2017), patents (Balland et al., 2019; Li & Rigby, 2023), among others.

Furthermore, extensive literature has established strong correlations between these complexity measures and crucial economic, environmental, and social facets. These include economic growth (Hidalgo, 2021), environmental considerations (Romero and Gramkow, 2021; Lapatinas et al., 2021; Can & Gozgor, 2017), human development (Ferraz et al., 2022), income inequalities (Hartman et al., 2017), and overall well-being (Napolitano et al., 2020). In essence, this evidence underscores that economic growth, trade dynamics, resilience, income distribution, environmental sustainability, and technological advancements can all be perceived as visible outcomes of intricate systemic interactions illuminated by the complexity paradigm (Balland et al., 2022). The nexus between these socioeconomic and environmental phenomena and the Economic Complexity Index (ECI) is not surprising, as economic complexity effectively provides a high-resolution portrayal of the technological and productive landscape of an economy. This encompasses an array of factors, ranging from technological capabilities and implicit knowledge to institutional structures and educational foundations.

Ultimately, the applicability of this method in various domains hinges on two essential conditions: (i) the availability of disaggregated and comparable data across entities (e.g., countries or regions), and (ii) the presumption of shared determinants among the elements under investigation. Both these prerequisites are inherently met within the realm of the Sustainable Development Goals (SDGs). Since 2017, when a statistical commission was created to coordinate the production of data worldwide, substantial international efforts have been devoted to compiling comprehensive and comparable datasets, encompassing national and subnational levels. Today, multiple platforms serve as repositories for both official and unofficial information concerning a wide array of developmental objectives and targets.

The second condition is equally fulfilled, as the SDGs and their associated targets, by design, exhibit extensive interconnectedness and mutual dependencies, sharing numerous underlying determinants. For instance, the achievement of adequate access to sanitation and hygiene (target 6.2) or the reduction of the population living below the poverty line (target 1.1), and even the lowering of homicide rates (target 16.1), undeniably influence health-related targets and indicators (SDG 3). These, in turn, have repercussions on economic (SDG 8 and SDG 9) and educational (SDG 4) targets and indicators, among others. Such shared determinants encompass health risk factors that pertain to various sectors (e.g., water and sanitation, air quality, and nutrition), as well as indirect determinants like income, education, gender dynamics, and peace and security. Analogous interdependencies can be identified across most other SDGs and their respective targets, rendering the SDG framework an ideal landscape for the application of network-based methodologies.

From economic complexity to the sustainable development complexity. The original economic complexity methodology employs export data of hundreds of goods from different countries into the calculation of the Economic Complexity Index (ECI) of countries and the Product Complexity Index (PCI) of goods (Balassa, 1965). The country competitiveness in the production of each good is defined using a Revealed Comparative Advantage (RCA) indicator: RCA=1 in the production of good *p* when the country's export share of this good is greater than the worldwide share, otherwise RCA=0. Based on the binary matrix of RCAs of each country in each product, the diversification of an economy is calculated as the number of goods with RCA, while the ubiquity of each good is calculated as the number of countries with RCA in that good. Iterations between these two indicators for countries and goods yield the ECI and the PCI, respectively.

The economic complexity measures the amount of productive knowledge available in each economy and required to produce each product. Since, by definition, more complex goods require large amounts of productive knowledge for their competitive production, one should expect that these capabilities are less diffused. Thus, more complex countries are usually highly diversified and produce goods with low ubiquity. Similarly, more complex goods are those of low ubiquity produced by highly diversified countries.

This approach can be immediately transposed to understand the capacity of each country to achieve the SDGs as stablished in the 2030 Agenda. In the case of SDGs, since it is not possible to calculate an analogue for the RCA in each SDG, a different strategy must be used to stablish each country' outstanding performance (OP) in each target. Since the level of indicators and targets for SDGs vary considerably with the degree of development of the country, the cut-off criterion for OP has to be based on the comparison of the country's indicator with the countries in its GDP per captain quartile, where 1 represents the 25% lowest and 4 the 25% highest. OP=1 for country *c* in target *i* if the indicator is within the *h*-th percentile of income group *j* with best results. OP=0 if the indicator is among the worst 100-*h*. For example, knowing that the number of physicians per capita in Brazil is among the highest in upper-middle-income countries, the OP for the Brazilian indicator 3.c.1d assumes the value of one. On the other hand, since the number of homicides in the country is significantly higher than that of the top 25% in its income group, the Brazilian OP in indicator 16.1.1 assumed the value of zero. Formally:

$$OP_{ic} = \begin{cases} 1, \text{ if } x_{ic} \geq \vec{x}_{ihj} \\ 0, \text{ otherwise} \end{cases} \quad (1)$$

where x_{ic} is the value found for indicator *i* in country *c*, and $\vec{x}_{ihj}$ represents the minimum (maximum) value to be in the *h*-th percentile with the best results for indicator *i* in income group *j*.

OP is the basis for the sustainable complexity indicators. The definition of an adequate cut-off criterion is essential for the relationship between the indicators to be accurately estimated. Three different cuts were explored for OP (*h* levels): (i) 10%, (ii) 25%, and (iii) 50%. Criterion (i), the most restrictive, proved to be relevant to understanding the strongest relationships between indicators in each income group, but has the disadvantage of excluding statistically significant information from the network analysis. Criterion (iii) has the disadvantage of maintaining relationships that are very weak, making the network and complexity indicators less informative. The results presented in this paper are for criterion (ii), which manages to preserve the weaker but significant relationships, and at the same time does not prove to be excessively loose.

Using the binary matrix of OP in each country and SDG, it is possible to transpose the economic complexity methodology to calculate the Country Sustainable Complexity Index (CSCI) and the Sustainable Target Complexity Index (STCI). Formally:

$$\textit{Sustainable Target Ubiquity} = k_{i,0} = \sum_c OP_{ic} \quad (2)$$

$$\textit{Country Sustainable Diversification} = k_{c,0} = \sum_i OP_{ic} \quad (3)$$

$$k_{c,N} = (1/k_{c,0}) \sum_i OP_{ic} k_{i,N-1} \quad (4)$$

$$k_{i,N} = (1/k_{i,0}) \sum_c OP_{ic} k_{c,N-1} \quad (5)$$

where *N* denotes the number of iterations.

At each iteration more information is added to the indicators. The indexes are given by the Nth iteration in (4) and (5), respectively, which minimized the variation of targets and countries in the sustainable complexity rankings for this dataset.

From complexity measures to the development policies. The complexity methodology also allows the potential analysis of specialization trajectories and the measurement of their impact on production chains through other indicators. Hausmann et al. (2011), for example, proposed the Density Index (DI) to measure the ease of competitive production of a given good by a country as a function of the competitive production of nearby goods, which serves as a proxy for the internalized capabilities. This measure also reflects the amount of new productive knowledge that a region needs to acquire to manufacture and export a given product with comparative advantage. That is, the lower the DI, the more capabilities will have to be acquired and the longer/costly the RCA acquisition process will be in that product. In this way, the products that the country exports without RCA but that have a high DI appear as products with high potential to gain competitiveness.

In the context of the SDGs, this measure shows how far is a country from RCA acquisition (outstanding performance) on a specific indicator. The DI is calculated as the quotient between the sum of the proximities (q) of the indicators that the country present RCA and the sum of the proximities between all the indicators of the network in relation to the indicator i. Formally, the distance (Equation 9) is given by the sum of the proximities of i of all the i' indicators for which the country does not have RCA, normalized by the centrality of the indicator. If the country shows an outstanding performance in most of the indicators connected to indicator i, the distance will be short, close to 0. But, if the country displays RCA in only a few related indicators, the distance will be close to 1, indicating that the internalized capacities are still far from those necessary for a high performance in the indicator.

$$ID_{ic} = \frac{\sum_{i'} OP_{ci} q_{ii'}}{\sum_{i'} q_{ii'}} \quad (6)$$

Analyzing the hypothetical gain generated by displaying OP in each indicator is also important. The ST opportunity gain (OG), proposed by Hausmann et al. (2013), measures the production potential of progressively more complex goods generated by the acquisition of RCA in a given industry. Formally:

$$OG_{ic} = \frac{\sum_{i'}(1-OP_{ci'})OP_{ii'}STCI_{i'}}{\sum_{i''} OP_{i''i'}} - (1 - DI_{ci})STCI_i \quad (7)$$

where STCI is the Sustainable target complexity index and DI is the Distance Index, which measures how far each product exported with RCA is from products that the country does not export with RCA:

$$DI_{ic} = \frac{\sum_{i'}(1-OP_{ci'})q_{ii'}}{\sum_{i'} q_{ii'}} \quad (8)$$

Therefore, distance and density give us an idea of how far each indicator is from a country's mix of indicators with RCA. Opportunity gain quantifies the contribution of a new product in terms of opening doors to increasingly complex products. At the end of the day, a trade-off is placed between the "low hanging fruits" and high returns from diversification through greater investment in new capabilities. The evaluation by only one of the dimensions can lead to non-optimal strategies. Each of these metrics generates information to be evaluated when choosing which of the goals a country should focus on to obtain the maximum return.

The sustainable development goals space. The SDG Space is a representation analogous to the Product Space (Hausman et al., 2014) based on the notion that the probability of a country achieving an outstanding performance (OP) in a certain SDG target for its income group is conditioned by the OPs in other SDG targets. As SDG targets are interrelated, the probability of meeting a target should be conditional on the satisfaction of other targets, so that the SDG Space can be constructed by measuring such probabilities from international data. Following the economic complexity literature (Hidalgo et al., 2007), groups of targets on similar themes require similar capabilities to achieve an OP. From the OP vector of countries and targets it is possible to generate the matrix of OP co-occurrence probability in each pair of targets, i.e., the probability of a country presenting OP in target i given that it has an OP in target i', both relative to its income group. The proximity between two targets in the SDG Space is formally given by the minimum probability between ii' and i'i:

$$\varphi_{i,i'} = \min\{P(OP_i|OP_{i'}), P(OP_{i'}|OP_i)\} \quad (9)$$

Taken together, these 9 indicators not only provide a picture of a region's current conditions, but also of its future possibilities. From the global map, the trajectories of any country/region can be compared to the others and the potential gains with the prioritization of specific themes measured, allowing the optimal application of the scarce resources of the economy and serving as a reference for public policies of development.

Data. To construct the SDG Space and its associated complexity indicators, an extensive dataset was compiled from two primary sources: the Sustainable Development Goals platform of the United Nations' Department of Economic and Social Affairs (UNDesa) and the World Bank. Additionally, GDP per capita data and projections up to the year 2019 were sourced from the International Monetary Fund (IMF). This comprehensive database comprised an impressive 1.5 million rows of data, encompassing information pertaining to the 17 SDGs across 266 countries and regions, spanning the years from 2015 to 2019. In total, a staggering 1817 individual indicators were subject to evaluation.

Given the inherently unbalanced nature of the dataset—both in terms of temporal coverage and the number of countries represented—it became necessary to implement a series of meticulous data selection and validation strategies. These strategies were as follows:

i. Selection of Indicators: Priority was granted to indicators that exhibited the highest degree of coverage across countries and years, particularly those that closely aligned with the official SDG indicators.

ii. Synthesis Indicators: To encapsulate the essence of 19 official indicators, for which numerous sub-indicators were available, synthesis indicators were devised.

iii. Data Consistency: The series underwent rigorous scrutiny for both inter-country and intra-country consistency, ensuring the reliability and coherence of the data.

Following the application of these data processing techniques, the initial dataset comprising 613 indicators was refined. A total of 57 indicators were subsequently excluded: 29 due to their lack of comparable series for at least 10 countries, and 28 because they were non-conclusive indicators that didn't readily translate into a clear target. The latter category was characterized by indicators whose level and/or variation could signify either positive or negative developments depending on other variables within a country's context.

After this meticulous curation process, the final dataset included only those countries for which GDP per capita data/projections were available for the period spanning 2015 to 2022, and which had a minimum of 100 indicators in their dataset. This stringent selection procedure yielded a robust sample covering a total of 187 countries.

SDG	Goal Description	Indicators	Maximum Number of Countries per Indicator	Minimum Number of Countries per Indicator	Number of Countries	Average Coverage
1	No Poverty	49	186	8	79	0.42
2	Zero Hunger	9	161	24	80	0.50
3	Good Health and Well-Being	84	187	38	163	0.87
4	Quality Education	137	172	7	60	0.35
5	Gender Equality	33	185	10	39	0.21
6	Clean Watter and Sanitation	26	186	24	86	0.46
7	Affordable and Clean Energy	6	187	183	186	0.99
8	Decent Work and Economic Growth	70	187	19	65	0.35
9	Industry, Innovation and Infrastructure	17	187	39	143	0.76
10	Reduced Inequalities	25	190	88	136	0.71
11	Sustainable Cities and Communities	22	185	37	93	0.50
12	Responsible Consumption and Production	10	185	26	116	0.63
13	Cimate Action	13	181	37	89	0.49
14	Life Below Water	4	142	99	121	0.85
15	Life on Land	12	187	121	163	0.87
16	Peace, Justice and Strong Institutions	29	129	4	49	0.38
17	Partnerships for the Goals	45	185	31	124	0.67

Table 1. Summary of series in the final sample by SDG

Table 3 highlights the number of indicators by SDG and country coverage of indicators. It is possible to note that some topics still have very low international coverage, such as Education (SDG 4), Gender Equality (SDG 5) and Justice and Peace (SDG 16). Some themes have relatively few indicators, such as Ending Hunger (SDG 2), Access to Sustainable Energy (SDG 7) and Preservation of aquatic life (SDG 14). These limitations, however, do not seem to compromise the study, given the high coverage for central indicators in the different themes.

Results

Country Sustainable Complexity Index (CSCI) and Sustainable Target Complexity Index (STCI). Tables 2 and 3 present the top and bottom countries and SDG indicators in the complexity ranking over the period 2015-2019. It is possible to note that, as countries are evaluated from their peers in terms of GDP per capita, there are representatives of all groups between the most and least complex in the ranking, keeping due proportions, since rich countries that are not very sustainably complex should achieve only an intermediate region in the ranking.

Country	Income group	Average GDPpc (2015-2020) USD2017	Normalized complexity indicator
	More complex		
Denmark	High income	45565.17	1
Netherlands	High income	48719.73	1.00
Finland	High income	40209.61	0.96
Latvia	Upper-middle	24734.98	0.95
Greece	Upper-middle	25305.89	0.94
Croatia	Upper-middle	22093.85	0.93
Austria	High income	45341.58	0.91
Germany	High income	45469.58	0.91
Luxembourg	High income	94399.47	0.90
	Least complex		
Angola	Lower-middle	6488.20	0.090
Aruba	High income	34643.63	0.081
San Marino	High income	52923.08	0.053
Gabon	Upper-middle	16637.82	0.047
Puerto Rico	High income	35267.70	0.047
Congo	Lower-middle	6479.03	0.047
Timor-Leste	Lower-middle	4972.88	0.032
Central African Republic	Low income	678.56	0.006
Equatorial Guinea	Upper-middle	24039.54	0

Source: own elaboration

Table 2. CSCI: Top and bottom countries

The most complex targets include indicators of violence, work and education. It is also interesting to note the presence of indicators of educational inequality by gender, existence of assistance benefits for the poor population and proportion of small industries in total industry among the most complex targets. At the other end, among the least complex targets there is a much greater variety of themes (illustrated by the SDGs to which the indicators are linked). In both lists the jumps in the ranking occur due to the repetition of indicators in subgroups of those already presented, e.g. the first two indicators meet the target of indicator 16.1.3, while the 9 in the sequence are of the target of indicator 8.8.1. As in the case of economic complexity, complex sustainable targets are achieved only by sustainable complex countries.

Indicator	Description	Rank
	More complex	
16.1.3	Proportion of the population subjected to physical violence in the last 12 months, by gender (%)	1

8.8.1b	Non-fatal occupational injuries among employees, by gender and migrant status (per 100,000 employees)	3
8.8.1a	Fatal accidents at work among employees, by gender and migrant status (per 100,000 employees)	6
4.4.1	Proportion of young people and adults with information and communication technology (ICT) skills	12
4.5.1	Gender parity index for participation rate in formal and non-formal education and training (ratio)	17
4.3.1	Participation rate in formal and non-formal education and training, by gender (%)	18
4.5.1	Language Test Parity Index for Mathematics Achievement by Education Level (Ratio)	27
1.3.1	[ILO] Proportion of poor population receiving cash benefit from social assistance, by sex (%)	34
9.3.1	Proportion of small scale industries in total industry added value (%)	38
	Least complex	
10.a.1	Proportion of tariff lines applied to imports with zero tariff (%)	527
16.6.1	Primary government expenditures as a proportion of the original approved budget (%)	529
8.7.1	Proportion of children engaged in economic activity and household chores, by sex and age (%)	530
3.4.1	Number of deaths attributed to non-communicable diseases, by type of disease and sex (number)	544
17.15.1	Proportion of results indicators drawn from country-led results frameworks (%)	549
9.3.2	Proportion of small industries with a loan or line of credit (%)	550
17.12.1	Average tariff applied by developed countries, by type of product (%)	551
8.7.1	Proportion of children engaged in economic activity and household chores, by sex and age (%)	554
5.3.1	Proportion of women aged 20 to 24 married or in a stable union before age 15 (%)	555

Table 3. STCI: Top and bottom indicators

One of the most important applications of the concept of complexity is in its use for forecasting future income, given the method's ability to synthesize the structural elements that make up the country's economy. As a summary indicator of the country's level of development in socioeconomic and environmental issues, CSCI is expected to present a strong correlation with GDP per capita. Simple regression of the normalized indicator (0-1) on the logarithm of GDP per capita resulted in a statistically significant coefficient of 0.11 at 0.01%, as indicated in Figure 1. This means that a 1% increase in GDP per capita is associated with an increase close to 0.1% in CSCI. This relationship allows projecting the country's CSCI based on the static relationship between these variables, allowing the creation of a base scenario for CSCI if public policies aimed at achieving specific goals are not conducted.

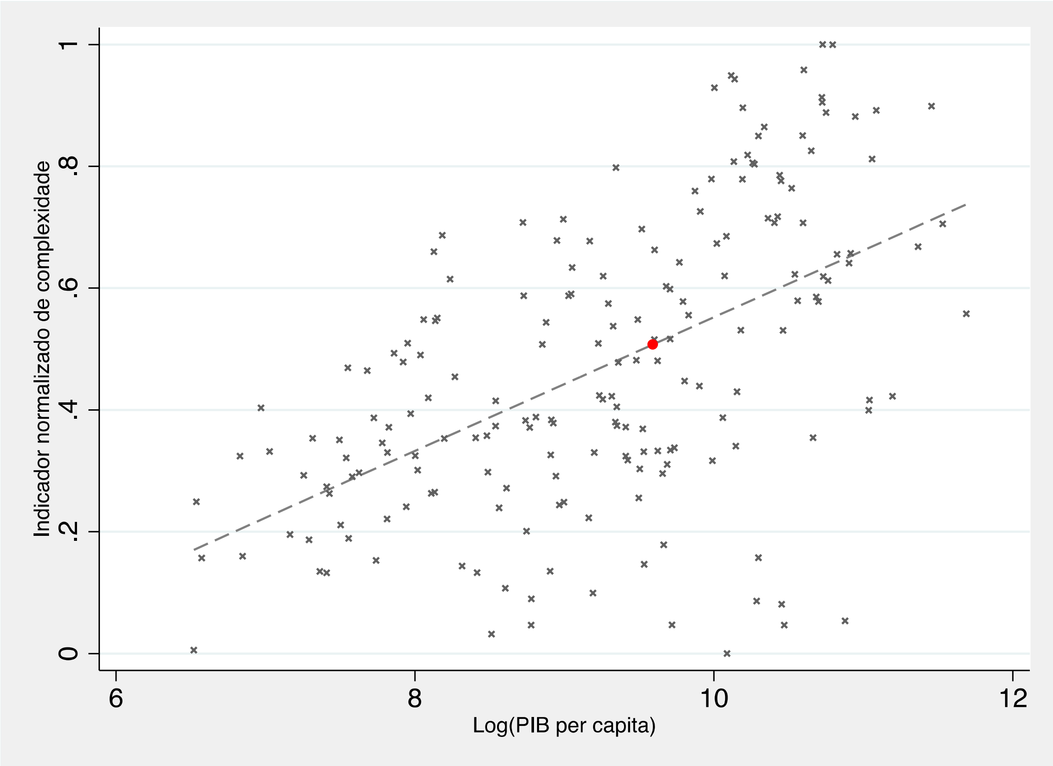

Figure 1. Correlations between CSCI and GDP per capita
Note: Brazil is highlighted

The SDG Space. Table 4 illustrates the average proximities between the indicators that make up each SDG. The colours are on a scale where dark orange indicates closer proximity. A series of interesting aspects emerge from the analysis of the figure: (i) the SDGs of sustainable consumption and production (SDG 12), aquatic life (SDG 14) and energy (SDG 7) are those that have the most cohesive indicators internally, ie, with a higher degree of proximity between the indicators themselves, above 0.5, as can be seen in the diagonal of the matrix; (ii) at the other end, the economic (SDG 8), justice (SDG 16) and gender equality (SDG 5) indicators are the least internally cohesive, an indication that these have greater dispersion in the network, being determinant and determined by a multitude of aspects that are not within the SDG itself.

SDG	Goal Description	Centrality (ranking)	SDG 1	SDG 2	SDG 3	SDG 4	SDG 5	SDG 6	SDG 7	SDG 8	SDG 9	SDG 10	SDG 11	SDG 12	SDG 13	SDG 14	SDG 15	SDG 16	SDG 17
1	end poverty	8	0.35	0.28	0.26	0.27	0.17	0.28	0.36	0.23	0.25	0.24	0.23	0.31	0.27	0.32	0.23	0.24	0.25
2	end the hunger	14		0.41	0.24	0.25	0.19	0.27	0.31	0.22	0.24	0.25	0.23	0.26	0.23	0.24	0.23	0.24	0.23
3	Ensuring a healthy life	5			0.32	0.27	0.21	0.26	0.30	0.23	0.24	0.26	0.27	0.28	0.27	0.25	0.24	0.24	0.25
4	quality education	4				0.31	0.18	0.28	0.34	0.24	0.24	0.26	0.29	0.33	0.25	0.29	0.25	0.26	0.26
5	Gender equality	17					0.27	0.17	0.25	0.16	0.23	0.22	0.16	0.27	0.13	0.31	0.24	0.19	0.21
6	Sustainable management of water and sanitation	6						0.36	0.35	0.22	0.25	0.26	0.27	0.32	0.25	0.30	0.24	0.25	0.25
7	Access to sustainable energy	1							0.64	0.27	0.26	0.30	0.28	0.40	0.32	0.35	0.26	0.31	0.30
8	Sustainable economic growth and employment	16								0.27	0.23	0.22	0.22	0.26	0.22	0.23	0.23	0.21	0.23
9	Industry, innovation and resilient infrastructure	13									0.36	0.24	0.23	0.27	0.23	0.27	0.23	0.25	0.23
10	Reduction of inequalities	9										0.35	0.26	0.29	0.22	0.29	0.26	0.23	0.26
11	Sustainable cities and communities	7											0.42	0.30	0.31	0.29	0.26	0.25	0.25
12	Sustainable consumption and production	2												0.53	0.27	0.41	0.29	0.30	0.31
13	climate action	11													0.45	0.24	0.24	0.25	0.24
14	Preservation of aquatic life	3														0.64	0.32	0.23	0.24
15	Preservation of Earth	12															0.41	0.21	0.25
16	Strong institutions for peace and justice	15																0.28	0.24
17	Partnerships to achieve goals	10																	0.33

Table 4. SDG proximity matrix: target averages in each goal
Note: Proximity of each SDG with itself is not equal to one because the figures are the average proximities between targets in each SDG.

The *Centrality* of each SDG can be defined as the sum of the proximity of SDG pairs. A high centrality indicates that the SDG has a multitude of SDGs in close proximity. This means that if a country succeeds in achieving OP in this SDG, it is likely to succeed in many others, given the multiple capabilities needed to do so. The most central SDGs are also those that showed greater internal cohesion of its indicators, illustrated by the dark colours. The centrality of the SDGs indicates that the countries that manage to achieve OP in the indicators of Sustainable Energy (SDG 7), Sustainable Consumption and Production (SDG 12), Preservation of Underwater Life (SDG 14) and in Education Quality (SDG 4), in that order, are those that also perform best on all other SDGs. In the opposite end, a low centrality indicates that the capacities necessary for the acquisition of OP in the SDG are not shared with other goals, so that there is a greater probability of a country presenting an OP in the indicators of this SDG without presenting a good performance in the indicators from other SDGs.

Figure 2 is the SDG Space generated from the conditional probability matrix between targets. As in the Product Space, targets that require similar capabilities tend to cluster together. Furthermore, more complex targets tend to occupy positions more towards the centre of the network, while the opposite applies to less complex targets. The Fig. presents two different representations, the first (A) includes all indicators in the sample and their connections. The second (B) only shows the principal indicators in each target, as defined by the most aggregative indicator in the topic. The colors in the latter represent the SDGs to illustrate how the themes (goals) are interconnected.

A – SDG space: all nodes

B – SDG space: main nodes

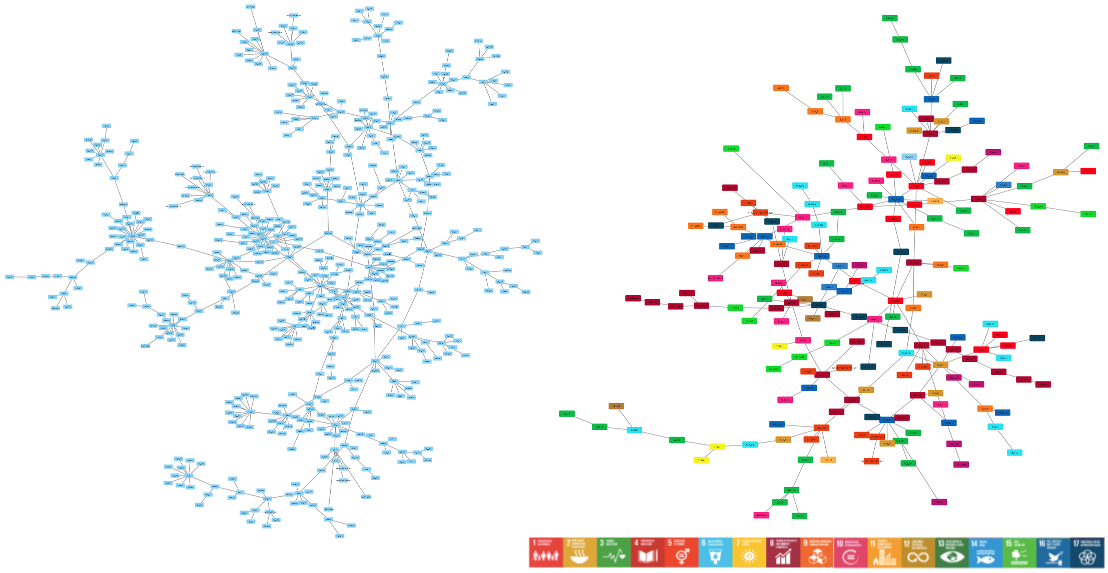

Figure 2. The SDG Space: all nodes (indicators) and the reduced space, with only the main nodes (key indicators in each target).

Notes: Only the active links with $\varphi_{i,i'} > 0.55$ are represented.

The applications of the *SDG Space* are manifold. Most importantly, it provides a map that allows the identification of the most prominent strategy for achieving OP in other SDGs, based on the proximities to the targets in which the country has an OP. Hence, the network can be used to guide the coordination of actions on different SDGs for their successful implementation in different countries.

While the outcome of the proximity matrix and centrality measure for each SDG is universal and creates the *SDG Space*, the level of density for each target differs across countries as countries succeed in different parts of the network. If a country succeeds in a dense part of the network, it means that its current capabilities can be used to diversify its SDG implementation focus. If it's 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 to the 2030 Agenda, which means that a leap to a high-centrality SDG might be advisable, even if proximity is currently low.

Discussion

Using complexity indicators to establish priority targets. Once local capabilities and the degree of difficulty in reaching new goals have been mapped using the OP index and the *SDG Space*, the second challenge is to choose what targets to prioritize. On the one hand, the STCI and the ST opportunity gain indicators signal which indicators and related targets increase the CSCI. On the other hand, the degree of difficulty in achieving OP in new goals depends on the existing capabilities that can be used to achieve each goal, as measured by the *Density* indicator.

The balance between the opportunity offered by improving the results in a new target and the feasibility of acquiring OP in this target. This balance will be more difficult in regions with low-density *SDG Space* and with targets with OP located in the periphery of the network. In these cases, policies should assume the risk of improving new targets and prioritize the ones that increase the opportunity for subsequent improvements in other targets. As for regions that have a *SDG Space* of targets with high density, but with low STCI, the path to diversification can be more conservative, prioritizing targets that are closer to the ones with OP. Finally, regions that have a more interconnected *SDG Space* and that has OP in complex targets can reconcile bold and conservative policies, since the risks for diversification are lower.

Using these principles, it is possible to devise a rule to rank the most promising targets to be focused by public policies in each country or region. In this paper two dimensions are considered: (i) current capabilities, which captures the costs of seeking OP in each target; and (ii) the potential gains, which is the benefit to be obtained by achieving OP in each target. Dimension (i) is measured by the level of OP and the *Density* indicator, generated from the OP matrix, that shows how far a country's existing capabilities is from the required to achieve OP in each target. Dimension (ii) is measured by *Centrality*, which indicates the number of connections each target presents, since the final objective of the 2030 Agenda is reaching OP in all targets of the *SDG Space*.

The case of Brazil. Figure 3 illustrates Brazil's SDG Space for the period spanning 2015 to 2019. The green diamonds on the graph represent the indicators in which the country demonstrates Outstanding Performance (OP). A noteworthy observation from the figure is that the majority of the targets Brazil is currently meeting are situated at the periphery of the network. This observation aligns with the earlier explanation that the capabilities required to excel in these indicators have limited applicability in acquiring RCA in other, more central goals. Furthermore, a closer examination reveals that nearly all of the green indicators are subsidiary within their respective clusters. This implies that even when considering shorter distances within the network, Brazil may encounter challenges in attaining targets in other indicators. Such challenges are alleviated when the country possesses RCA in central nodes. These observed gaps in the network underscore the immense challenges Brazil faces in the pursuit of the SDGs.

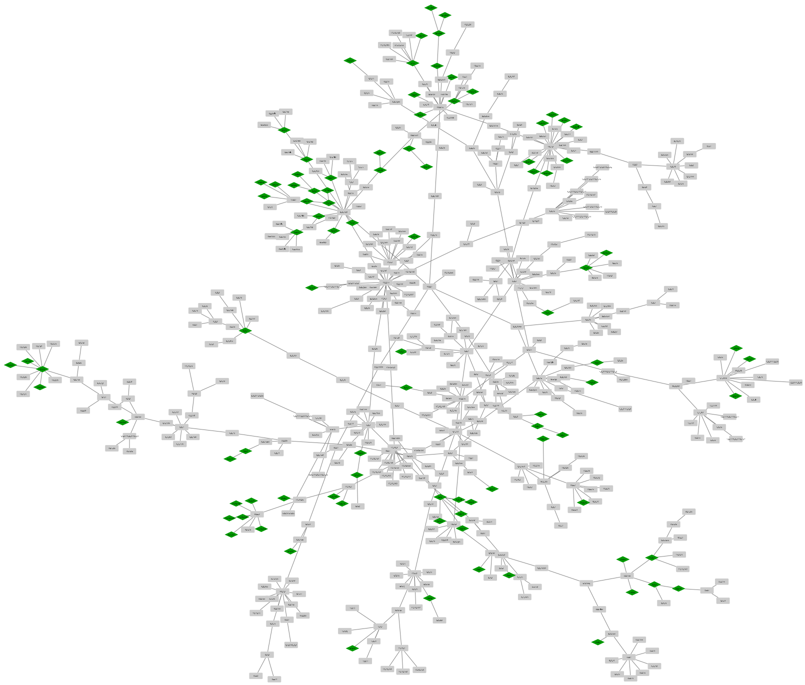

Figure 3. Brazilian SDG space

Table 2 presents a curated set of indicators that are favorably positioned based on the score derived from this straightforward criterion. The results strongly advocate for Brazil's focus on social protection programs aimed at impoverished families and children. These goals exhibit a high degree of centrality, boasting implementation mechanisms in proximity to other objectives and substantial gains in terms of centrality. Additionally, the importance of addressing access to electricity, a highly central indicator in the entire network, is underscored. Given the persistent urban-rural inequality in Brazil, this area also merits special attention.

	Indicators	Complexity	Density	Opportunity	Score
1.3.1c	Mothers with newborns receiving maternity cash benefit	0.743	0.205	2.847	0.773
1.3.1a	Children/families receiving cash benefits for children/families	0.724	0.204	2.715	0.717
7.1.1u	Rural population with access to electricity	0.558	0.187	2.064	0.709
7.1.1r	Urban population with access to electricity	0.565	0.186	2.070	0.699
6.2.1	People practicing open defecation	0.579	0.183	2.118	0.693
5.1.1	Legal frameworks to promote, enforce and monitor gender equality in employment	0.623	0.196	2.352	0.693
4.4.1	Proportion of young people and adults with information and communication technology (ICT) skills	0.800	0.170	2.820	0.685
10.7.2	Migration policies to facilitate orderly, safe, regular and responsible migration and mobility of people	0.437	0.202	1.682	0.677
3.d.1	International Health Regulation (IHR) Capacity	0.452	0.205	1.745	0.676
8.b.1	National strategy for youth employment	0.444	0.199	1.701	0.644
12.4.1	Compliance with the Basel Convention on Hazardous Waste and Other Chemicals	0.470	0.185	1.748	0.639
6.5.2	Proportion of cross-border aquifers with an operational water cooperation agreement	0.653	0.190	2.399	0.632
1.4.1	Population using basic drinking water services	0.543	0.184	1.913	0.609
4.5.1b	Rural/Urban Parity Index for Reading Achievement (Ratio)	0.690	0.201	2.513	0.604
4.5.1a	Low to high socioeconomic parity index for reading outcomes (ratio)	0.705	0.156	2.347	0.593
6.2.1	Population using safely managed sanitation services	0.640	0.176	2.226	0.593
12.c.1	Pre-tax subsidies and fossil fuels (consumption and production) per capita	0.532	0.173	1.838	0.589
2.5.2	Proportion of local breeds classified as endangered as a share of local breeds with a known level of extinction risk	0.475	0.186	1.778	0.586

3.4.1	Death rate attributed to cardiovascular disease, cancer, diabetes, or chronic respiratory disease	0.492	0.180	1.753	0.584
1.3.1	Proportion of population covered by at least one social protection benefit	0.675	0.177	2.327	0.583
8.8.1	occupational injuries	0.681	0.198	2.487	0.579

Table 5. Brazil: Promising targets

Concluding Remarks

in contrast to the sectoral nature of the Millennium Development Goals (MDGs), the 2030 Agenda and its SDGs are best viewed as an intricate network of interconnected objectives and targets. These encompass the economic, social, and environmental dimensions of sustainable development. In this context, there is a pressing need for the development of transparent and reproducible methodologies that can assist in various stages of the implementation process. These stages include organizing databases, selecting suitable indicators, benchmarking internationally, and monitoring goal progress and prioritization.

The application of complex network methodology offers a valuable framework for designing a roadmap to attain these objectives. It equips policymakers with the necessary tools to evaluate each country or region's progress towards these goals and to prioritize them effectively. The results of this study affirm the methodology's promise within the realm of SDGs, as both the SDG Space and complexity indicators align logically with initial assumptions and demonstrate their significant value in guiding policymaking towards the ambitious target of achieving the SDGs by 2030.

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