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of two limit behaviours of the 28 top and the 28 bottom performing countries according to the SDG Index (or degree), i.e., of classes 1 and 6, whose spectra are almost entirely out of phase. These dynamics are more evident within Goals of environmental performances and exploitation, from Goal 12 to 15. As the spectra clearly show, the first 28 best countries in degree (class 1 in light blue) are poorly engaging toward the achievement of SDG 12 and 13. In particular, Norway is the relative worst performer in Climate Action, a Goal in which the country performs almost −60% with respect to its SDG Index. Instead, there are many low-degree countries (class 6 in violet) whose relative performances in Climate Action are higher, with the Central African Republic (CAF) recording +60% of performance with respect to its SDG Index. Even if less accentuated, the spectra of top and bottom degree countries are also out of phase in SDG 17, the one invoking partnership. In this Goal, countries nearer to fulfil most of the Agenda are actually the worst relative performers (e.g., Latvia—LVA). Other examples of this out of phase behaviour of the countries in class 1 and 6 figure in correspondence of Goals 1, 2, 7 and 14 (Zero Poverty, Zero Hunger, Clean Energy and Life below Water, respectively). Drops of performances occur for top-degree countries in Goals 2 and 14, while for bottom-degree countries in Goals 1 and 7. For example, Singapore attainment of SDG 14 is −60% with respect to its average performance in sustainable development. Yemen stands as an exception of such a pattern since, in Goal 1, this country performs 40% better than its average value (although this value may be a consequence of the assumptions on the data, see "Materials and methods" section).

The spectra depict the complexity of the variety of approaches toward sustainable development, in which the specific ty of countries' characteristics has its role in determining the attainment of the Goals. Therefore, we argue that analyses designed to consider and embed this complexity can shed new light on the state of the art in sustainable development. The introduction of network theory is a fi st step toward this direction, and it allows us to define novel aggregate scores based on a data-driven definition of the weights w_g in Eq. (2). In particular, the introduction of network-comprehensive centrality measures may help explore different dimensions of the SDG topic (and consequently, countries' status), and it allows one to defi e bottom-up weighting approaches naturally.

A data-driven weighting of countries. A fi st revision of the degree centrality in bipartite networks consists in weighting the connection of the node proportionally to the centrality value of the node at the other edge. Therefore, countries connected to more central SDGs obtain a higher scoring value, and *vice-versa*. According to this rationale, to defi e the aggregate score S_c in Eq. (2) entails setting $w_g = v_g$, where v_g is the centrality value for Goal g and thus solving the system of coupled equations

$$\begin{cases} S_c \propto \sum_g P_{cg} v_g, \\ v_g \propto \sum_c P_{cg} S_c. \end{cases} \tag{3}$$

Mathematically, the solution of this system is obtained by computing the so-called 'singular vectors' of the matrix **P** which determine the eigen-centrality vectors for countries and Goals, respectively[42] (see "Materials and methods" section). While the degree is a local measure of centrality, the eigenvector is a global one, as it considers for the computation of the scores all possible links and strengths in the network[39–41]. However, as shown in Figure S1, the eigenvector centrality brings no further information in terms of rankings than the one by the degree centrality (99.9% in both Pearson's and Spearman's correlation measures, see Figure S1). This lack of added value is due to the intrinsic correlation that the degree and eigenvector centrality show when the spectral gap–i.e., the delta between the first and second largest singular value of the incidence matrix (see "Materials and methods" section)–is large[41]. For this particular bipartite network, the second largest singular value is roughly one fourth of the principal singular value, implying high correlation between the degree and eigenvector centrality[43] (see "Materials and methods" section). Therefore, in the countries-SDGs network, the use of non-uniform weights as in Eq. (3) is almost ineffective in changing the point of view about the state of sustainable development, and other rationales about countries inter-plays with Goals must be introduced to remove the degree-bias that characterizes the eigenvector centrality[43].

The use of the centrality metrics defi ed within the fi ld of Economic Complexity (EC)[44–49] can help in the characterization of more complex inter-plays between countries and Goals. Based on the data regarding the export baskets of countries, EC aims at determining the stage of innovation and competition countries fi d themselves at[44]. EC methods update the simplest proxy of innovation, i.e., the degree of countries in the bipartite system of trade, blamed for not considering the sophistication of the traded products[48]. In fact, the idea upon which EC theory is constructed is that, in a looping system, if a product is only exported by few countries, this item is more knowledge-intensive than other items exported by many other countries. (In EC, the word 'knowledge' intends knowledge of production, resources, human and capital investments, eventually[50].) Th s fact determines higher EC scores of more knowledge-intensive goods.

In a similar manner, we can adapt the EC theory and methods to the network of countries and SDGs, therefore introducing new reasoning about how countries act in sustainable development. In tailoring the EC framework to the SDGs one, we assume that, if within a Goal only a few countries record near to optimal performance values, this Goal is more knowledge-intensive than the others, thus resulting in a higher EC score. Countries recording such optimal performances are those in more favourable conditions to attain the Goals. In fact, here, we translate 'knowledge' into policy and intervention designs and implementations; awareness and preparedness to face the challenges, all well-known factors for affecting countries performances in sustainable development[3,18,26,51–53].

In this work, we adopt the *GENeralized Economic comPlexitY* framework, said GENEPY, which has been shown to reconcile the contrasting methodologies on economic complexity, and it is also a reliable method for processing non-binary incidence matrices as the one of the countries-SDGs bipartite system[48]. For the sake of clarity, in the following, the adaptation of the GENEPY framework to the context of the Agenda 2030 is defined as SDGs-GENEPY. To the best of our knowledge, Cho et al.[38] is the only existing example in literature proposing to adapt EC methodologies and centrality metrics to score countries performances within the Agenda 2030.

Centrality measure	Aggregate score	Weighting value
Degree	$S_c = \sum_g P_{cg}$	$w_g = 1$
Eigenvector	$S_c \propto \sum_g P_{cg} v_g$	$w_g = v_g$
SDGs-GENEPY	$S_c \propto \sum_g P_{cg} Y_g / k'_g$	$w_g = Y_g / k'_g$

Table 1. Weighting approaches through different centrality metrics. In the formulas: S_c is the aggregate score for country c, generally defi ed according to Eq. (2); P_{cg} is the value of countries' performances in Goal g; w_g is the weighting value defi ed in Eq. (2); v_g is the centrality score for SDGs according to the eigenvector centrality, Eq. (3); Y_g is the centrality score for SDGs according to the SDGs-GENEPY framework, Eq. (4), and $k'_g = \sum_c P_{cg}/k_c$ is the adjusted Goals' degree (see "Materials and methods" section).

However, our work differs from that one in both methodology (the *Method of Reflection* from Hidalgo et al.[44] is used, instead), and data, since that work is limited to the Asian Region.

The SDGs-GENEPY rationale defi es two related centrality properties, S_c for countries and Y_g for SDGs, defined through the following system

$$\begin{cases} S_c \propto \frac{1}{k_c} \sum_g P_{cg} \frac{Y_g}{k'_g}, \\ Y_g \propto \frac{1}{k'_g} \sum_c P_{cg} \frac{S_c}{k_c}, \end{cases} \tag{4}$$

in which $k_c = \sum_g P_{cg}$ is the degree of the countries, therefore the sum of all Goals' performances (i.e., the value of the aggregate score supposing $w_g = 1$ for all SDGs). The term $k'_g = \sum_c P_{cg}/k_c$, that we defi e as 'adjusted Goal's degree', is the degree of Goal g accounting for the relative performances of countries within it (relative performances of countries can either be computed as the subtraction of the average performances, as in Fig. 2, or using the ratio P_{cg}/k_c, and the same results and observations hold, see Figure S3). Therefore, to evaluate the aggregate score of countries' statuses S_c according to the SDGs-GENEPY requires computing the Y_g values and it entails assuming, in Eq. (2), $w_g = Y_g/k'_g$. Notice that, similarly to the eigenvector centrality, the metrics provided by the SDGs-GENEPY framework are also global ones since they account for the overall structure of the network[48] (see "Materials and methods" section). Nevertheless, although the mathematical structure of Eq. (4) is formally an eigenvector one (see "Materials and methods" section), the resulting S_c centrality metrics is no longer degree-dominated due to the division of the S_c values by the degree k_c. A *toy model* to exemplify the difference of perspective offered by the SDGs-GENEPY approach is given in Section S1 in the Supporting Information.

A resume of the different weighting strategies for the Sustainable Development Goals that we adopted in this work is given in Table 1.

A picture of global responses in sustainable development. Applying the economic complexity theory to the bipartite network of countries and SDGs provides useful insights about how countries are currently responding to the call for actions toward a more equitable, just, and sustainable future. We exemplify these results through the application of the SDGs-GENEPY framework on the data from the 2020 Dashboard by Sachs et al.[26] (see "Materials and methods" section). Let us start from the results obtained from the computation of the SDGs-GENEPY values for Goals and, consequently, the weights Y_g/k'_g. In Fig. 3, the weighting values Y_g/k'_g are shown. The top-weighted Goal is SDG 9 pertaining to innovation, followed by Zero Hunger and Reduced Inequalities, SDG 2 and 10, respectively. Climate Action (SDG 13) is the least weighted, preceded by SDGs 12 and 4, pertaining to sustainable consumption and education, respectively. The wide differences among the weights demonstrate that the SDGs-GENEPY framework is able to capture the contrasting performances among the top and bottom-ranked countries shown in Fig 2. In fact, this weighting of Goals refl cts the poor performances by (generally) high performing countries in some SDGs (e.g., Norway in SDG 13, as will be further detailed; see, also Section S1 in SI). Moreover, these results provide one more piece of evidence that the SDGs are not equally integrated into national strategies worldwide. Consequently, the SDGs-GENEPY weighting values of less prioritised Goals are lower than that of more prioritised ones.

Such a weighting approach determines the ranking of countries according to SDGs-GENEPY score, which differs from the one by the degree centrality (see Section S1). In Fig. 4, we map countries' rankings according to the SDGs-GENEPY index and the degree value (panels (a) and (b), respectively); panel (c) resumes the differences between the two by scattering the ranking values, with countries colour-coded according to Regions, as defi ed in the 2020 Dashboard[26] (see "Materials and methods" section). As the Figure shows, although the two rankings are mostly aligned (Pearson's correlation coefficient 0.81), significant differences arise. As most remarkable examples, we cite here: Singapore (SGP), which jumps from the lower half of the chart to the top of it, moving from position 93 in degree to position 4 in the SDGs-GENEPY S_c; and South Africa (ZAF), moving from 110 in degree to 49 in the SDGs-GENEPY score. Other examples include Chile (CHL), moving from the 28-th position in degree to the 51-th in the SDGs-GENEPY score, and Cuba (CUB), which downgrades from the 56-th place in degree to the 126-th in SDGs-GENEPY S_c.

To explain the reasons behind these variations, we refer to Norway as a relevant example: Norway is among the absolute top performers within SDG 9 (having the largest weighting value Y_g/k'_g), together with South Korea and Singapore. Most countries perform poorly within this Goal–only 50% of the countries is above the 40% of Goal achievement –, as also represented in Fig. 2. Consequently, the SDGs-GENEPY framework assigns a higher

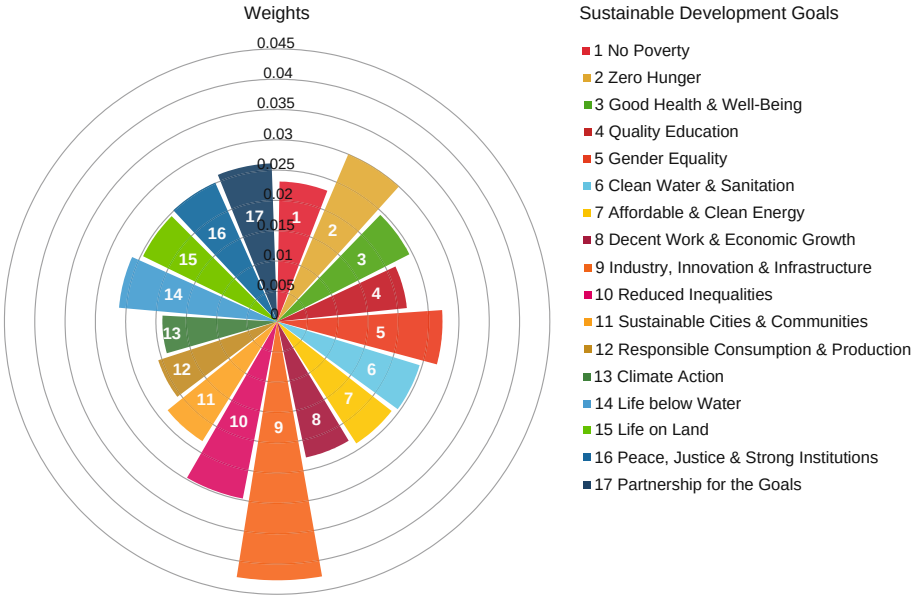

Figure 3. The SDGs-GENEPY weights of the Sustainable Development Goals. The radial bar chart plots the SDGs-GENEPY weights Y_g/k'_g for all Goals (see "Results" section, Eqs. (4), and "Materials and methods" section). Conversely from the original SDGs circle (in which all Goals are equally distributed on a *doughnut plot*[11]), the present radial bar plot remarks that–although Goals are all equal in principle–there exists a difference of importance according to the proposed data-based approach. The figu e has been generated using Excel 2016.

weight to countries that are better performers in this Goal. Also, Norway fi ures as the best absolute performer in Goal 10 and reaches good performances in Goal 2, thus explaining the upgrading of the North-European country from the sixth to the first position in the SDGs-GENEPY S_c ranking. Another relevant example is represented by the case of Singapore, a nation that, due to its outstanding performances in more knowledge-intensive SDGs, has reached the third position in SDGs-GENEPY. In contrast, Norway and Singapore are among the worst relative performers in SDGs 13 and 12, respectively (see Fig. 2). Still, their low performances in these SDGs are comparatively less relevant within the SDGs-GENEPY framework due to the lower weight values assigned to these two Goals.

Discussion

Defini g aggregate scores in sustainable development is a recurrent problem, which needs to be addressed to track the path toward achieving the Goals within the Agenda 2030. Many strategies can be pursued for their computation (see, e.g.,[25,26]); nevertheless, the complexity of the Agenda 2030 should not be neglected when defi ing aggregate scores. In light of this complexity, in this work, we have introduced a novel perspective on sustainable development in which we addressed–within a network science framework–the need for ranking countries for their status concerning the Agenda. In particular, we show that the countries-SDGs system can be structured as a bipartite network and that, by using the centrality tools, different weighting approaches naturally emerge for the computation of aggregate scores to rank countries.

Thanks to this network representation of the system, we show that the SDG Index identifi d by Sachs et al.[26]–which, in line with the Agenda's principles, considers equal weights for all Goals corresponds to measure the degree of countries. In network science, the degree centrality measures the local behaviour of the node, and it does not account for the complex interconnections of the system[41]. A fi st step toward the use of global metrics to account for the network structure is the use of the eigenvector centrality. However, we have demonstrated that the degree and eigenvector centrality in this countries-SDGs system substantially carry the same information. Besides the formal reasoning about the spectral gap, the strong correlation between the two centrality metrics is due to the fact that countries' performances in SDGs are mutually correlated (see Figure S4). This fact highlights that countries set in similar development conditions (*sensu*, Baldwin et al.[54]) tend to emulate each other performances[55], and it explains why, when ranked for their degree, nearby ranking-positioned countries show similar behavioural patterns (see Fig. 2 and Figure S4). Nevertheless, heterogeneity of countries' performances beyond their average value (or equivalently, the degree) is clear from Fig. 2. Th s phenomenon suggests the need for more subtle metrics able to unravel the complexity of the system, a need we address through the *GENeralized Economic comPlexitY* framework (SDGs-GENEPY)[48].

The SDGs-GENEPY approach we propose for the creation of one aggregate score brings two main positive advancements. Firstly, the weights $w_g = Y_g/k'_g$ are self-emerging from the data, and they account for the relative performances of countries as measured by term k'_g, thus providing a data-driven embedding of the synergies and trade-offs across the SDGs. Secondly, the division of the SDGs-GENEPY S_c values for the degree of countries k_c–intrinsic of the computation of the index–removes the undesired degree-bias which is known

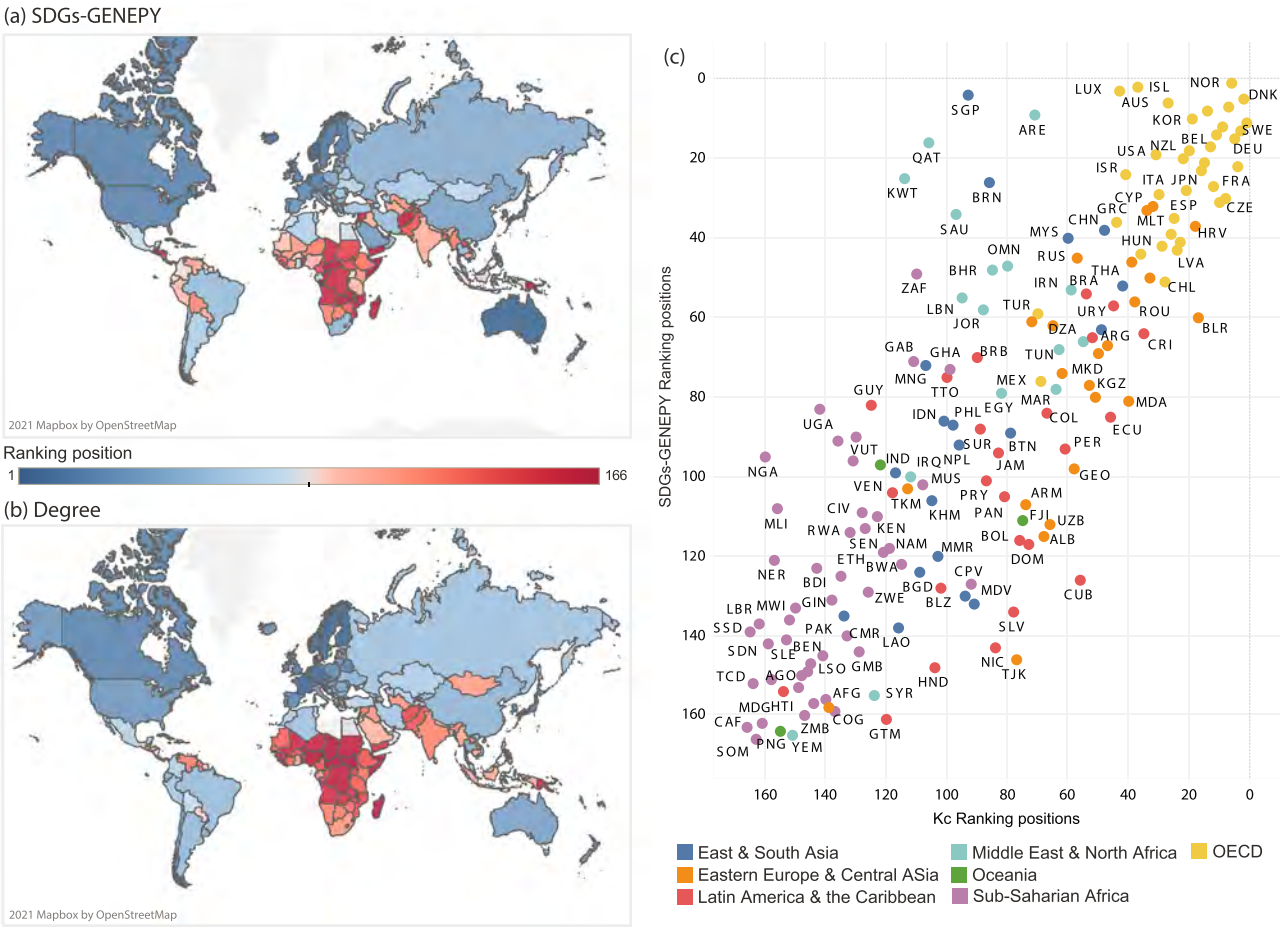

Figure 4. Countries rankings according to the degree and SDGs-GENEPY values. In panel (**a**), countries are coloured according to the ranking position computed by the SDGs-GENEPY score. Panel (**b**) shows the ranking position computed by the degree or, equivalently, the SDG Index[26]. The ranking position is defi ed in both maps according to descending score (1 = best performer, 166 = worst performer). In panel (**c**), we scatter the values of the two rankings: on the x-axis is the degree ranking, on the y-axis, the SDGs-GENEPY one. Countries are colour-coded according to their Region as specifi d in the legend, in accordance with the regional division in the 2020 Dashboard[26]. Countries lying along the diagonal share the same ranking position both in SDGs-GENEPY and SDG Index. The figu e has been generated using Tableau 2020.3, [https://www.tableau.com/]; in panels (**a**) and (**b**), underlying maps are provided by OpenStreetMap, [https://www.openstreetmap.org].

to affect eigenvector-based centrality measures[43], thus providing useful insights about the countries' status in sustainable development. These characteristics of the SDGs-GENEPY framework can be interpreted in light of some further considerations concerning the Agenda 2030. The adjusted degree values k'_g are determined by the relative performance values P_{cg}/k_c. In particular, the term k'_g is larger if, in a given Goal g, there are many large performance values P_{cg} recorded in countries at low degree k_c values. Considering that the weights w_g are inversely proportional to the adjusted degree, it follows that heavier (in the sense of weights) Goals are also those that top-performing countries favour to the detriment of other Goals (see SI, Section S1). The fact of having found Climate Action and Innovation as, respectively, the lowest and greatest weighted Goals, witnesses such result, since the $w_g = Y_g/k'_g$ values are mainly determined by the relative performances of high-income and sustainable-outperforming countries, such as Norway (see Fig. 2).

In fact, evidence of the validity of such analysis can be found in Norway's development strategies, among the most relevant examples in this study. Norway is currently diversifying its industrial sector by enhancing investments in the Research and Development area, so to face the reduction in prices of crude oil[56,57] (see, also, the Climate Action Tracker, [https://climateactiontracker.org/countries/norway/]). Norway is one of the worldwide leader exporters of crude oil[58], a fact that puts under the spotlight the country's shared responsibility in Climate Action and the permanent presence of trade-offs between economic and environmental issues at the world level[59]. Therefore, in the SDGs-GENEPY indexing approach, the heterogeneity of countries and contrasting policy implementations are naturally embedded through the data and brought up by the algorithm, determining the weights of SDGs. Th s hierarchy testifies the shared global responsibility in sustainable development and the intrinsic compromise among political willingness, opportunities and capacities to move toward sustainable development[26,60,61]. Th s compromise is even more evident in countries with more favourable conditions to fulfil

the Agenda, resulting in higher 'knowledge' (i.e., policy and intervention designs and implementations; awareness and preparedness to face the challenges[3,18,26,51–53]).

In light of these considerations, we can interpret the SDGs-GENEPY ranking of countries as a picture of shared responsibilities, where it emerges the possibility for nations to act as role-models and promote the achievement of global sustainable development. In light of the emulation phenomena among countries[55], we argue that identifying role-model countries is rather relevant, and it can pave the way to a new strategy for boosting sustainable development in the next decade. In particular, our ranking can be used as an '*ex post*' and complementary tool to the Rapid Integrated Assessment–RIA–analysis[2] which the United Nations conduct to monitor the willingness of countries in integrating the Goals within their national strategies. In this sense, our analysis would effectively provide insights about the implementation of such plans, also providing a tool for comparing the efforts across countries. Moreover, such an approach can be suitably adapted to the sub-national level by using regional data on sustainability performance, thus revealing crucial features of countries' regional effici cy in sustainable development.

In conclusion, we acknowledge the complexity of the system defi ed within the Agenda 2030. In light of such complexity, and for the sake of providing more complete analysis, we address future work to embed models of interaction across the sustainable development sectors (e.g., those related to the complex interaction between water, energy, and food[62] among the many[12,15,16,22,63]). Moreover, the burgeoning literature in the field of SDGs assessments suggests the presence of different ideologies about how to properly measure the status of countries along their sustainable development path. We realise that the understanding of such paths should not be shrunk to a single indicator analysis. Therefore, to fully understand countries' paths toward sustainable development, we suggest using different and complementary mathematical approaches, such as e.g., the computation of both the degree and SDGs-GENEPY rankings. The adoption of more classical methods (such as the degree-like ones) combined with the SDGs-GENEPY would provide a bird's-eye view of the conditions of countries to achieve sustainable development while providing a list of change-making places and actions that can help meet the 2030 deadline.

Materials and methods

Data. Notwithstanding the call for efforts toward the standardisation in the data collection by all National Statistical Systems, NSSs, launched by the Cape Town Global Action Plan in 2017[64], the data accessible at the UN Statistics Division (available at https://unstats.un.org/sdgs/indicators/database/) clearly show that work is still needed to have a comprehensive, homogeneous, and extensive database covering all countries and years under the Agenda 2030 and beyond. For this reason, the input data we are using are taken from the 2020 SDG Index and Dashboard[26], which represent a commendable step forward in data collection, homogenisation and assessment of countries progress in sustainable development. The aim of the Dashboard is to provide yearly rankings of UN countries based on an aggregate score of all Goals' performances. The score is intended to be readable as a percentage of achievement of all the Goals, ranging from 0 to 100; therefore, countries close to 100 are approaching the complete fulfilling of the Agenda's Goals according to the indicators used to compute the score[36]. The score is constructed upon a number of indicators providing quantitative information about countries performances. All listed indicators are normalised according to an optimum and a minimum value of indicator performance to ensure comparability and aggregation of measurements (we refer the reader to[26,36] for further details). Listed indicators are updated every year, accounting for advances in monitoring and research. In order to provide statistical-sound results, we only refer to 2020 data, thus not inferring any possible missing data back in other years' Dashboards. The 2020 dataset constitutes of 115 indicators across the Goals, 30 of which are specifi ally defi ed for the members of the Organization for Economic Co-operation and Development (OECD). The Dashboard only includes countries covering at least 85% of the indicators, totalling 166 out of 193 UN countries. To have OECD-specific indicators entails that, with respect to the same Goal g, the term N_{cg} (from which, in Eq. (1), the value of performance P_{cg} is obtained) differs between OECD and other countries. The Dashboard also introduces Regional scores, assigning countries to 7 different Regions around the world, namely: Sub-Saharan Africa, Middle East and North Africa–MENA–, East and South Asia, Eastern Europe and Central Asia, Latin America and the Caribbean–LAC–, Oceania and OECD group, which we use to colour-code countries in Fig. 4.

In line with the methodology exemplifi d with the SDG Index, we replace countries' missing data with the Regional score in that same Goal[36]. Notice that, as pointed out by the Authors of the Dashboard[65], this assumption might have implications in any analysis.

Eigenvector centrality. Let u_c be the eigencentrality of country c and v_g the eigencentrality of Goal g. By defin tion, the eigencentrality value for country c is its degree weighted by the centrality of all Goals, and *vice-versa*[39]. In this work, the centrality score for countries u_c coincides with the computation of S_c when setting $w_g = v_g$ in Eq. (2). The computation of the eigenvectors of a matrix requires the matrix to be squared. Incidence matrices of bipartite networks, such as the matrix $\mathbf{P}$ in this work, are rectangular, instead. In order to compute the eigenvector centrality of countries and Goals, the matrices $\mathbf{A} = \mathbf{P}\mathbf{P}'$ and $\mathbf{B} = \mathbf{P}'\mathbf{P}$ are introduced, where $\mathbf{P}'$ is the transpose of the matrix $\mathbf{P}$[42,66]. The system in Eqs. (3) can hence be solved in closed form as

$$\begin{cases} \sigma_1^2 \mathbf{u}_1 = \mathbf{A}\mathbf{u}_1, \\ \sigma_1^2 \mathbf{v}_1 = \mathbf{B}\mathbf{v}_1, \end{cases} \tag{5}$$

in which the term σ_1 is the largest singular value of the matrix $\mathbf{P}$[66], or, equivalently, the square root of the largest eigenvalue λ_1 of the matrices $\mathbf{A}$ and $\mathbf{B}$. The vector $\mathbf{u}_1$ and $\mathbf{v}_1$ are the singular vectors of the matrix $\mathbf{P}$ associated to

σ_1 or, equivalently, the eigenvectors of **A** and **B** associated to the largest eigenvalue λ_1[42,66]. Notice that, due to the mutual relationship between eigen- and singular values, the spectral gap can be equivalently measured between the two largest eigenvalues of the matrices **A** and **B** or between the singular values of the matrix **P**.

The SDGs-GENEPY framework. Th *SDGs-GENeralized Economic comPlexitY* scoring and weighting approach is set in a linear algebra framework. The SDGs-GENEPY framework aims to defi e two properties X_c for countries and Y_g for SDGs, which can account for the EC rationale and so embed the inter-play between countries and Goals. In this rationale, a Goal is more knowledge-intensive if only a few countries–also in more favourable conditions to attain the Goals, see "Results" section and Section S1–record near to optimal performance values. These countries are those with a higher change-making power and more responsible for prioritising certain Goals. Th s fact can be mathematically obtained by defini g the system in Eqs. (4). Similarly to the eigenvector centrality, a closed solution for this system is provided by solving the coupled singular vectors **X** and **Y** associated to the largest singular value σ_1 of the matrix **W** defi ed as

$$W_{cg} = \frac{P_{cg}}{k_c k'_g}.$$

The matrix **W** helps in defini g the EC rationale and in providing a symmetric representation of the bipartite system for which the **X** and **Y** are determined. In fact, the vector **X** for countries is the eigenvector of the largest eigenvalue of the matrix **N** defined as

$$N_{cc^*} = \mathbf{W}\mathbf{W}' = \sum_g \frac{P_{cg}P_{c^*g}}{k_c k_{c^*}(k'_g)^2}; \tag{6}$$

the vector **Y** for SDGs is the eigenvector of the largest eigenvalue of the matrix **Z** defined as

$$Z_{gg^*} = \mathbf{W}'\mathbf{W} = \sum_c \frac{P_{cg}P_{cg^*}}{k_c^2 k'_g k'_{g^*}}. \tag{7}$$

In this work, the centrality score for countries X_c coincides with the computation of SDGs-GENEPY S_c values, when setting $w_g = Y_g/k'_g$ in Eq. (2).

For further details, we refer the readers to Sciarra et al.[48] for a complete description of the algebra beyond the framework. However, some comments are due to the readers to follow along the reasoning behind this work entirely. Thanks to the differences in the input bipartite system, adapting the GENEPY framework to the Agenda 2030 (i.e., the SDGs-GENEPY we introduced in this work) provides a more straightforward mathematical rationale than the one presented in the original work for trade. Building upon the export data, the GENEPY index in[48] is a multidimensional centrality score for economic complexity in which two eigenvectors of the matrix **N** for countries are combined in quadratic form (or, **Z** for SDGs). Without any loss of information, in this work, we limit our analysis to the fi st eigenvectors of the matrices **N** and **Z**, for countries and Goals, respectively. In fact, the eigenvectors associated with smaller eigenvalues bring no relevant added information, and their quadratic terms in the formulation of the SDGs-GENEPY score can be neglected (see Figure S5). Moreover, the diagonal values of the matrices **N** and **Z** are left as computed following Eq. (6) and Eq. (7), respectively (differently from the export case, the diagonal values do not bias the results, see Figure S6). Finally, with respect to the trade case, a further difference is that the incidence matrix of the bipartite network of countries and SDGs defi es non-binary, so weighted, connections among the nodes.

Data availability

The data on countries performances in sustainable development supporting the findings of this study are freely available at [https://www.sdgindex.org/]. Other results are available from the authors upon request.

Code availability

The code for the computation of the GENEPY index is publicly and freely available at [https://zenodo.org/record/3876721].

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Author contributions
C.S. conceived the study, prepared the data and conducted the analysis. C.S., G.C., L.R. and F.L. analysed the data and results. C.S. produced the figu es and wrote the manuscript. C.S., G.C., L.R. and F.L. edited the manuscript. All authors reviewed the manuscript.

Competing interests
The authors declare no competing interests.

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