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Policy and political challenges for a better world: The United States and China pathways towards the 2030 Agenda

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ABSTRACT

The Agenda 2030 poses critical elements regarding the transition towards a more sustainable development. This paper aims at exploring and comparing the path of sustainable development within the United States and China at the subnational level. An index of Integrated Sustainable Development is introduced to measure local sustainable development on an internationally-comparable scale. This Index is computed both at the national and subnational level and the resulting scores are compared within and across the two countries, also through the adoption of convergence and cluster analysis, allowing to answer four questions: Are the US and China moving towards a sustainable development agenda? Are the current achievements uniformly distributed within the two countries? Are states/provinces converging towards a more uniform level of sustainable development? Do the existing differences and analogies between states and provinces give rise to common clusters across the two countries? The results lead to one robust conclusion: while the US can claim a better result in the national and subnational rankings of sustainable development, China exhibits a more balanced achievement in terms of synergies across Goals and spatial distribution. Nonetheless, both countries are characterized by subnational disparities and scarce achievements of Planet-related Goals. Policy recommendations are discussed accordingly.

1. Introduction

The Agenda 2030, launched in 2015, provides a common ground to evaluate the sustainability of world development and its multidimensional achievements. This implies also that the accomplishment of the Agenda's 17 Sustainable Development Goals (SDGs)[1] should become a must for all countries, addressing the environmental and social problems which have emerged in the Anthropocene (Fleurbaey et al., 2018) and strictly related to the concepts of sustainable human development (United Nations Development Programme, 2020) and of human security (United Nations Development Programme, 2022). In this context, given their economic, demographic and political magnitude, the United States and China are the two major players in the international arena as, with their actions, they can significantly influence the sustainability of the world development process. What occurs in the two countries, indeed, has the potential to have huge impacts on the rest of the world.[2] While the United States has been a major player since the beginning of the last Century, China has gained the spotlight by recording, over the last four consecutive decades, impressive economic growth and by becoming the so called 'fabric of the world', impacting consumption and production processes as well as trade dynamics worldwide.

As the rest of the international community, both countries, nowadays, are called to face the challenges posed by the Agenda 2030. If European Union, another big player in the international arena, has

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[1] Indeed, the 2030 Agenda lists 17 Sustainable Development Goals (SDGs), which in turn comprise 169 Targets, as prominent dimensions to achieve sustainable development. The goals are meant to have a universal meaning, so that their importance is not biased towards the needs of the developed (nor developing) countries.

[2] Meaningful are the cases of the financial crisis in 2008 and of the Covid-19 pandemic, emerged respectively in the United States and China and rapidly spread internationally.

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already taken a clear route towards sustainable development (the European Green Deal and the Next Generation EU are clear signals in this direction), four relevant questions turn out to be particularly relevant for the United States and China. Are these countries moving towards a sustainable development agenda and achieving the SDGs? Are the current achievements uniformly distributed within the two countries? Are states/provinces converging towards a more uniform level of sustainable development? Do the existing differences and analogies between states and provinces give rise to common clusters across the two countries?

The paper aims at answering these four questions through the *adoption of a comparative perspective* applied *at the subnational level*, where US states and Chinese provinces are compared within and across the two countries. The first result of the paper is a comparison between the United States and China in terms of sustainable development and SDGs achievements. The second result is the investigation of how the level of sustainable development and its changes over time are distributed within the two countries. The third result assesses whether there is within-country spatial convergence in terms of sustainable development, i.e. whether backward states and provinces are evolving faster than the advanced ones. The fourth result is the clustering of states and provinces across the two countries to point out differences and commonalities.

Differently from monetary aspects, multidimensional sustainable development cannot be easily transferred from one area to another, requiring capabilities and grassroot level initiatives, so that the localization of SDGs program *at the subnational level* is crucial for the achievement of the 2030 Agenda. The need of approaching the topic at the subnational level emerges also because, according to the literature, both countries' development has scored environmental problems and increasing inequalities with an unbalanced territorial transformation showing strong disparities among states and provinces. China, in particular, has recorded critical environmental problems, strong unbalances between different provinces and rising disparities among the population (Biggeri and Bortolotti, 2020). In parallel, while some US states have larger GDP than many countries in the world and significant resources and infrastructure, some other states are left significantly behind. We then expect to observe similar unbalances also in terms of sustainable development. Moreover, for the sake of market freedom, the United States showed a reluctant approach in engaging into several important conventions such as the ILO Convention against child labour (Basu and Van, 1998) or the environmental agreements established in the Kyoto Protocol and in the Paris Climate Change Conference. As a consequence, these issues have not been incorporated in a strong national strategy and have been managed differently by each US state resulting in heterogeneous outcomes.

The *adoption of* a *comparative perspective* is conversely based on the increasing attention that the comparison between these two countries is receiving, with economists investigating the timing of China's economic overtaking of the US (Japan Center for Economic Research Asian Research Team (JCER), 2021) while political scientists focusing on their capacity to appear a reference model for global development (Caria, 2022). However, the standard way to compare the two countries not only focuses at the national level but also uses GDP and strictly economic measures as unique benchmarks. Conversely, there is no evidence on the comparison of the two development processes at the subnational level in terms of SDGs achievements. The quantitative approach proposed here, based on the SDGs paradigm, fills the gap by maintaining the objectivity and comparability of monetary analyses but broadening the focus on an aspect, sustainable development, which is nowadays internationally recognized as crucial for the future of humanity.

In order to make these analyses possible, we introduce a comparable composite indicator of Integrated Sustainable Development (ISD) at US state level and China's provincial level. This index embraces the integrated nature of the 17 Sustainable Development Goals (SDGs) of the Agenda 2030 and uses the Multidimensional Synthesis of Indicators (MSI) aggregation method (Mauro et al., 2018) that penalizes heterogeneity across SDGs' outcomes. The dataset at the state (for the United States) and at the provincial level (for China) is compiled for two years, 2016 and 2019, and is based on official statistics. Variables are grouped according to the UN's 17 Sustainable Development Goal (SDG) domains and are rescaled and transformed to be comparable at the subnational level among the two countries.

The rest of the paper is structured as follows. The second section summarizes the most recent policies implemented by the United States and China towards the achievements of the Agenda 2030, at both the national and subnational level. The third section presents the sources of data and the methodology adopted to compute the ISD Index, and the tools used to analyze its trends. The fourth section describes the four sub-sets of results. In the Appendix, the robustness of the results is checked by adopting a different aggregation method to measure local sustainable development based on Principal Component Analysis (PCA) and geometric mean. The fifth section discusses such results, paving the way for the conclusions.

2. SDG implementation in the United States and China

2.1. The United States' strategy for SDG implementation

The US federal government adopted formally the 2030 Agenda for Sustainable Development in 2015, along with all UN Member States. Nonetheless, the SDGs seem to have not yet achieved a prominent position in US politics and public policy and the engagement of the federal and state governments on sustainable development remains generally extremely weak, especially in comparison with other advanced economies (Lynch and Sachs, 2021). In reality, the US engagement in international partnerships to face the global challenges seems to have always been rather discontinuous.

Since the nineties, when environmental issues started to occupy an important position in the international political debate, accession of the United States to international protocols was particularly controversial. For instance, President Bill Clinton (encouraged by vice President Al Gore) signed the Kyoto protocol during the last months of his mandate, but shortly after the election of George W. Bush, the United States withdrew their membership from the Protocol. More recently, after Obama's signing of the Paris Climate Agreement of 2015, President Trump declared the US withdrawal from the convention. The reason for this staggering approach can be found in the constraints that these protocols impose at the national and local level and in the related political interests at stake. The impact of sustainable development policies on private investment decisions, on the costs structure of companies and on the structural adjustment of the whole economy, make the political process in this field particularly tricky in the US (see, e.g., Oates and Portney, 2003).

Nevertheless, in the last decades, policies for sustainable development have been gradually reinforced, especially during the Obama administration. In this respect, the American Recovery and Reinvestment Act (ARRA), signed by President Obama in 2009, played an important role for a sustainable structural change of the US economy. For instance, approximately $90 billion ($60 billion in direct spending and $30 billion as tax credits) were invested in "jump-starting the transition to clean energy" (ERP, 2010, p. 243). In this context, renewable generation of energy was supported with $26.6 billion investment (ERP, 2010, p. 246). In advanced vehicles and fuels, the ARRA invested $6.1 billion (ERP, 2010, p. 246). In order to reduce the national consumption of electrical energy, the government promoted the grid modernization: the investment in this area has been $10.5 billion (ERP, 2010, p. 246). The ARRA also provided a tax credit from $500 to $1500 in 2010 for the renovation of private homes in line with energy efficiency standards (see, e.g., Di Tommaso et al., 2020; Di Tommaso and Schweitzer, 2013; Tassinari, 2019, 2021).

The ARRA investments also attempted to mitigate the economic and social disparities exacerbated by the 2008 crisis and to alleviate the conditions of the more disadvantaged groups. First of all, the plan allocated approximately $90 billion of support for individuals directly affected by the recession by financing an extension and expansion of unemployment insurance benefits, subsidies to help the unemployed continue to obtain health insurance, and additional funding for the Supplemental Nutritional Assistance Program (ERP, 2010, p. 54). About $14 billion were allocated to support elderly, veterans and people with disabilities (ERP, 2010, p. 53). Moreover, the "healthcare reform" of 2010 aimed at improving social equity, by making health insurance coverage mandatory for most employers and individuals (see, e.g. Tassinari, 2019).

Despite these actions, the subsequent policies implemented by the Trump administration seem to have firmly counteracted the interventions of the Obama administration for sustainable development (see, e.g., Hejny, 2018; Eilperin and Cameron, 2017). For instance, just a few months after his election, President Trump launched the "Energy Independence" policy, resulting in the withdrawal from the Clean Power Plan launched in 2015 by Obama to promote clean energy production, requiring the U.S. Environmental Protection Agency (EPA) to change the rules and soften its terms on greenhouse gas emissions, not only for existing power plants but also for those to be built. Energy Independence also cancelled rules on the reduction of methane losses in the atmosphere during mining and refining of oil and natural gas (the Obama administration had decided to reduce them of 40% compared to 2012 levels by 2025). Furthermore, Trump's executive order also impacted the estimates of the social cost of emissions: under the new laws, EPA could lower these estimates, for example by considering only the emissions damages to the United States, and not to the whole planet. Finally, Trump's executive order aimed at eliminating the Obama's moratorium on federal land-use concessions for coal mining, which was established to prevent it from being too easy to build new mines.

More generally, the Trump administration seemed oriented towards responding to the short-term corporate interests of traditional industries, including the oil, coal, steel, defence and other traditional sectors (Ferguson et al., 2018). In this regard, policies of the Trump administration focused on significant cuts to corporate income tax, deregulation and strict control over federal spending (Office of Management and Budget, 2018), with the consequence to cut or terminate programs relating to social security, 'health care reform' and environmental protection. Although these actions were partially constrained by opposing forces in the US Congress, the fiscal measures introduced by the Trump administration were oriented towards substantially benefiting the upper classes, given that the public spending cuts were mostly derived from programs assisting individuals with low or middle incomes (see, e.g., Tassinari, 2021). Recently President Joe Biden's proposals for Building Back Better (BBB) could contrast this trend by encouraging new important steps forward the promotion of the SDGs. Indeed, the BBB framework aims to "set the United States on course to meet its climate goals, create millions of good-paying jobs, enable more Americans to join and remain in the labour force, and grow our economy from the bottom up and the middle out". (Statement by the President, October 27th, 2021).

There are, however, important differences in the promotion of SDGs at the state level. Though some states appear particularly virtuous in promoting the SDGs, many others are rather behind in fostering prosperous, inclusive, and sustainable economies, notably the states of the Southern and Appalachian regions (Lynch and Sachs, 2021). This entails a marked heterogeneity of cases and experiences in promoting the SDGs within the United States, that tends to exacerbate social and economic disparities characterizing the country. Even states belonging to the industrial Midwest and Rust Belt, where the Trump administration had most concentrated its industrial and trade policy efforts, seem showing quite weak revival and development performances during recent years. At the same time, there are some "virtuous cases", namely states that seem to promote SDGs with continuity over time, including California, Washington, Colorado, Oregon, New York, Massachusetts, Maine, and Vermont. These are mainly States that have been opposed to Trump in the 2016 election and to his subsequent policies, suing the Administration over a number of interventions critical for environment sustainability, health and immigration.

2.2. China's strategy for SDG implementation

The Chinese government has been highly responsive to the new challenges launched by the Agenda 2030, as they have been promptly integrated in its mid- and long-term development strategies at both the national and local levels (ASEAN and UNDP, 2019). This punctual response was likely favoured by two factors. First of all, since the beginning of the economic reforms in 1978, China's GDP per capita grew at impressive rates and, in parallel, absolute and relative poverty rates dramatically decreased until reaching exceptionally low values (Rolf, 2021). However, the rapid economic growth was accompanied by high social and environmental costs led by the rise of inter-personal inequality, environmental degradation and strong provincial disparities (Li et al., 2014; Biggeri and Bortolotti, 2020). The growing political awareness of such imbalances paved the way for a high political sensitivity to the Sustainable Development Goals promoted by the Agenda 2030 and an immediate willingness to react. Second, and strictly related, when the Agenda was launched China's government had already designed and implemented a series of strategies aimed at promoting a more balanced path of development (Zheng, 2020; Kanbur et al., 2021). In particular, China's policymakers were already at work for defining and embracing a wider conception of development, well emblematized by the notion of "Harmonious Society" introduced by Hu Jintao in 2004 and the slogan "Chinese Dream" adopted by Xi Jinping some years later.

As a consequence, China's 13th Five-Year Plan adopted in March 2016 was committed to actively implement the Agenda 2030 and was promptly aligned to its Goals, with the explicit "*guiding thinking*" of achieving "higher quality, more efficient, more equitable, and more sustainable development" (Chapter 2). As demonstrated by Xue et al. (2018), indeed, the various chapters of China's 13th Five-Year Plan can be easily connected to each SDG, as both the 2030 Agenda and the Plan focus on analogous targets. More specifically, in the latter a package of action plans for scientific and technological innovation, poverty alleviation, environmental protection and other related issues was inspired by the five principles of innovation, coordination, green economy, openness and inclusiveness.

A few months later, in order to officially support the implementation effort, China adopted the National Plan on Implementation of the 2030 Agenda for Sustainable Development, which analysed the challenges and opportunities China had to face in implementing the Agenda, translated each of the 169 SDG targets into action plans for the country and aligned several sectoral plans with the SDGs (Xie et al., 2021). This National Plan was based on the recognition that 9 key areas should be prioritized in the implementation of the 2030 Agenda, including: eradicating poverty and hunger; fostering innovation to nurture sustainable, healthy and stable economic growth; advancing industrialization to coordinate development between urban and rural areas; improving social security and social services; safeguarding equity and social justice; protecting the environment; addressing climate change actively; promoting efficient utilization of resources and sustainable energy; and improving national governance and the rule of law.

With the adoption of the 14th Five-Year Plan in March 2021, China's commitment to pursue a development strategy fully aligned with the Agenda 2030 and aimed at promoting both environmental protection and shared prosperity was clearly remarked. In this context, it was the first time a Five-Year Plan did not mention GDP growth and prioritized non-monetary goals such as the production and consumption of clean energy, the reduction of fossil energy consumption and carbon intensity, and the engagement in climate-related global governance.

In order to coordinate the implementation efforts towards the achievement of such goals, the Chinese government also instituted an inter-agency coordinating mechanism among 43 departments, led by the Ministry of Foreign Affairs, which however excludes the direct participation of local and regional Governments because of the highly centralized structure of the political regime. Nevertheless, China can be evaluated relatively advanced in enabling the institutional environments for local governments in terms of supporting sustainable development (UCLG, 2020). The implementation of the SDGs, indeed, gives rise to the need for significant governance efforts in terms of multilevel coordination and, beyond the national framework, this constitutes the most important challenge that countries, and especially large countries like China, have to face for guaranteeing an effective and balanced SDG localization.

In this regard, the SDG Innovation Pilot Zone Initiative represents the most significant effort that the central government, through the Ministry of Science and Technology and the cooperation of the United Nations Development Programme (UNDP), has taken to collaborate with local governments (UNDP China, 2019). This initiative was the concrete outcome of the "Development Plan of China's Innovation Demonstration Zones for the Implementation of the 2030 Agenda for Sustainable Development", issued in December 2016 by China's State Council, and aims at providing replicable examples that may lead other Chinese regions on the road of sustainable development. In particular, the Pilot Zones (the first batch included Guilin city, Shenzhen city and Taiyuan city) are considered responsible for designing innovative policies and implementation strategies, improving public participation and favouring both vertical (among different government levels) and horizontal coordination (among different departments for each government level) (ASEAN and UNDP, 2019; UCLG, 2020).

As pointed out in UCLG (2020), other joint relevant initiatives for SDG localization in China are represented by: 50 projects implemented by Chinese cities to promote environmental sustainability and, in particular, to implement effective greenhouse gas (GHG) reduction strategies; 611 smart city pilot projects that took place between 2013 and 2016; the identification of a pilot area (Deqing County) for mapping and measuring 16 SDGs through the adoption of 102 different indicators meeting the standards of the UN Global Indicator Framework. These joint initiatives have been accompanied by single initiatives taken by single Chinese cities, such as the exemplary adoption of innovative urban green technologies by Xiangyang (wastewater recycling into energy), Wuhan (aerobic technology applied to recreational parks and ecological gardens), Shenzhen (electrification of public transport).

Although the numerous efforts for SDG localization have been also recognized by United Nations agencies (UNDP China, 2019; ASEAN and UNDP, 2019), their effectiveness may be limited by a series of challenges that have not yet been completely solved, such as the limited awareness of the Agenda 2030 showed by local governments, the high heterogeneity of Chinese counties that is reflected in extremely differentiated development conditions and challenges, the need for effectively scaling up the local pilot projects and initiatives mentioned above, and, most importantly, the lack of accessible technology and appropriate financial resources for local SDG implementation ASEAN and UNDP, 2019). To what extent China's policymakers will be able to solve such challenges will determine the success or failure towards a fully balanced, harmonious and sustainable development.

3. Data and methodology

3.1. Dimensions selection and data sources

The selection of data and sources that summarize sustainable development is a crucial element for our analysis. Indeed, the identification of national targets is one of the critical points in the SDGs framework, which at the same time must consider its universal purpose and countries' specificities (Scott and Lucci, 2015). Although there is no international agreement about the choices on how to select and aggregate the variables that describe sustainable development, several progresses have been marked in the literature (Sachs et al., 2020; Biggeri et al., 2019).

The Agenda 2030 identifies, within the 17 Goals, 231 targets, each of whom is attributed to one single Goal. This framework allows a sophisticated survey about countries' sustainable development but is not meant to synthetize it in a single value. The Sustainable Development Reports (SDRs) (Sachs et al., 2017) are widely regarded as the main attempt to measure sustainable development in a single index, the SDG Index. This measure was obtained for 2019 considering 85 indicators (Sachs et al., 2020). The SDR data were used to allows international comparability across statistics on subnational data from different countries. The SDR indicators vary over the years and are meant to measure sustainable development at the country level. This means that a corresponding datum cannot necessarily be found at the subnational level. For example, the Press Freedom Index (Goal 16, Peace, Justice and Strong Institutions) can be hardly framed or measured at the local level (despite it has several subnational, national and international impacts).

Strictly related to the SDRs, other reports explore the achievement of SDGs within specific countries or regions. These reports maintain the aim and the approach of the SDRs, adapting the dataset to the national specificities. Among those, there are the United States Sustainable Development Report (US SDR) 2018 and 2021 (Sachs et al., 2018; Lynch and Sachs, 2021), from which we derived data at the state level.

These state level data were in turn retrieved from several sources and make references, on average, to data collected in 2016 and 2019 respectively. The US SDR contains 103 indicators from 15 Goals. The indicators included have varied slightly over the years, while the Goals excluded are in both cases #14 (Life Below Water) and #17 (Partnerships for the Goals). Goal #14 is intrinsically connected to coastal areas, so there is a value attributed to the United States in its complex, but not information for all the 50 constituent states, 27 of whom are landlocked. Goal #17 relates to policies that are usually adopted and implemented at the national level, preventing comparison of subnational achievements.

The dataset from the US SDR 2021 has 12 missing data (they were 16 in the US SDR 2018), corresponding to 1.8‰ of the total sample. In these cases, following the methodology of the US SDR, we exclude the missing values in aggregating the synthetic score of the related state. As a similar report does not exist for China, we select and collect 60 official provincial statistics, related to the same 15 Goals (i.e. excluding Goals #14 and #17 for the same reasons as above). Their selection was guided by the literature on Chinese provinces' achievements of SDGs (Xue et al., 2018; Wang et al., 2016; Xu et al., 2020). The data are retrieved from various official yearbooks of Chinese statistics, with the only exception of the share of weapons in total export value, which is taken from the Observatory of Economic Complexity.[3] All but 13 of these indicators refer to 2019 (5 in 2016), while the remaining are selected from previous yearbooks; no provincial data is missing. The data of US states and China's provinces are therefore retrieved from different sources and, despite large overlaps, do not fully coincide although referring to the same 15 Goals. Therefore, an international adjustment (through the SDRs data) is necessary to allow international comparability between the US SDR and the China's yearbooks datasets (see Section 3.2). The Goals #14 and #17, which as mentioned are mostly related to national level characteristics, are assumed as spatially invariant, and the yearly national score is attributed to all the provinces/states.[4]

3.2. Normalization and aggregation methods

The ISD index allows to compare the progresses towards the 2030

[3] See https://oec.world/en.

[4] We decide not to completely exclude these two Goals, because there the United States performs much better than China and an exclusion would have biased the ISD comparison. These two Goals are on the other hand excluded from the cluster analysis, which is based on the variability between Goals.

Agenda achieved at the local level. This implies rescaling variables that catch the local SD (which may differ in different countries) and aggregating them into Goal indicators and a synthetic index. The building of the ISD index is therefore a three-step procedure requiring: (i) normalization and adjustment of variables (Eq. (1)); (ii) aggregation of normalized variables into Goal Scores (Eq. (2)); (iii) aggregation of Goal Scores into the ISD Index (Eq. (3)).

Multidimensional indexes rely on variables which are usually expressed in different units of measure. A normalization or standardization is therefore a necessary step to combine these variables. In the literature on multidimensional indexes, the variables are usually transformed in order to range in [0; 1] where 0 corresponds to the worst performances and 1 to the best performances; intermediate performances are linearly distributed in that interval. This is the case, among others, of the Human Development Index (HDI) by the United Nations Development Programme (Klugman et al., 2011)[5] and the SDG Index in the SDRs (Sachs et al., 2020). Yet, this normalization alone would, in our case, allow comparability only within a subgroup (states or provinces) but the 0 and 1 boundaries would not be comparable across the two groups nor with the SDRs literature.

Therefore, normalization is followed by an international adjustment: the normalized variables catch the subnational variation in SD achievements, the international adjustment guarantees comparability with the international standards. Therefore, the normalization considers the distance from the (weighted) mean and the adjustment anchor these variables to the national performance collected in the SDRs, as in Eq. (1):

$$z_{s,d} = \begin{cases} \dfrac{x_{s,d}}{\underline{x_d}} \times SDR_G & \text{if } x_{s,d} \text{ is higher for better performance} \\ 1 - \left[\dfrac{x_{s,d}}{\underline{x_d}} \times (1 - SDR_G)\right] & \text{if } x_{s,d} \text{ is higher for worse performance} \end{cases} \quad (1)$$

where $x_{s,\ d}$ are the values recorded in state (or province) s concerning a dimension of development d, which in turn concerns one of the 15 Goals G. These variables are linearly rescaled based on the national performance in goal g recorded at the country level as measured by the SDR (SDR_G) and the weighted average of that variable recorded across states and provinces ($\underline{x_d}$), where weights depend on states/provinces population.[6]

As a result of (1), we have the variables $z_{s,\ d}$, which represent the internationally comparable performance of state (province) s in the dimension d. These variables are then aggregated two times. The first aggregation results in 15 Goal Scores in each state/province ($s_{s,\ G}$). This procedure conforms to the so-called reflective synthesis (Maggino, 2017), and is therefore treated with a simple mean aggregation, as described in Eq. (2). Consistently with the literature on SDG (e.g. Biggeri et al., 2019; Sachs et al., 2020), and with the HDI (Klugman et al., 2011), all the variables at the basis of a Goal Score/dimension are equally weighted, although there is no agreement on equal weights in synthetic indexes (Maasoumi and Nickelsburg, 1988; Decancq and Lugo, 2013). Bounding the results in [0; 1] is a necessary step to enhance comparability with the previous literature on SDGs and for most of the aggregation techniques[7]:

$$s_{s,G} = \begin{cases} 0 \ if \ \overline{z_{s,d \in G}} \le 0 \\ \overline{z_{s,d \in G}} \quad if \ 0 < \overline{z_{s,d \in G}} \le 1 \\ 1 \ if \ \overline{z_{s,d \in G}} > 1 \end{cases} \quad (2)$$

where $\overline{z_{s,d \in G}}$ is the average score z recorded in state (province) s in all the dimensions d concerning the goal G. Once we have a measure of the performance of each unit in each goal, we can proceed to the ISD computation, combining the 15 Goal Scores just obtained to the country performance in Goals #14 and #17, reaching a total of 17 $s_{s,\ G}$ to be aggregated. In this case the aggregation involves a formative synthesis, as the unit aggregated involves different aspects, whose relation is not established a priori. For this reason, we adopt the MSI aggregation procedure, which rejects the hypothesis of perfect substitutability across the indicators, but rather penalizes the heterogeneity of achievements, consistently with the literature of non-compensatory indicators (Klugman et al., 2011; Mazziotta and Pareto, 2018; Mauro et al., 2018).[8] This procedure operates according to Eq. (3):

$$ISD_s = 1 - \left[\frac{1}{17}\sum\nolimits_{G=1}^{17} \left(1 - s_{s,G}\right)^{\frac{1}{\underline{s_s}}}\right]^{\underline{s_s}} \quad (3)$$

where $\underline{s_s}$ is the average Goal score recorded by state (province) s. As a result, we have the index ISD_s which ranges in [0; 1] and increases, ceteris paribus, when any Goal Score increases or their distribution gets more homogeneous.

3.3. Convergence and cluster analysis

After building the $s_{s,\ G}$ and the ISD_s measures, we can use the index to measure whether and how much the states (provinces) have converged towards similar levels of development and clustering areas with similar levels of development. These aspects are investigated respectively through convergence and cluster analysis. Convergence analysis investigates whether there is a significant progress in filling the gap between more and less developed areas. Convergence is treated in the literature through two main approaches: β-convergence and σ-convergence. β-convergence explores the sign of the estimated correlation coefficient (β) between the original score and its subsequent growth (Barro and Sala-i-Martin, 1992). A coefficient significant and negative would support the hypothesis of convergence, i.e. the poorer areas improve faster than the richer ones. Additionally, σ-convergence focuses on the trend over time of the deviation in the scores of a group: there is convergence if and only if such deviation decreases over time (Quah, 1993). Whilst β-convergence analysis treats convergence as the case of provinces that 'climb the ladder', moving from the worst to the best positions, the risks of new, diverging, frontrunners is accounted by the

[5] In the HDI case the standardization is not linear but logarithmic with respect to the GNI per capita variable.

[6] In order to measure the 'distance from the mean' in $z_{s,d}$, we construct the weighted average across states and across provinces. As the weighting system, both in aggregating territories and in aggregating dimensions is a crucial aspect of aggregation techniques, we remove the idea of population weights in the robustness tests in the Appendix.

[7] In order to check the robustness of our results, in the Appendix an alternative indicator is built based on different choices about weights across territories, weights across dimensions, relationship between local and national scores, aggregation method.

[8] The MSI aggregation method maintains the properties of strict monotonicity, continuity and heterogeneity penalization (Mauro et al., 2018), and assumes the degree of substitutability across dimensions is not fixed but increases with development. For more details on the MSI, see Biggeri et al., 2021, where the MSI is compared with other non-compensatory aggregation methods, including the geometric mean (which is widely adopted but has the disadvantage of collapse to zero if a single element goes to zero (see the Appendix containing an alternative SD indicator based on the geometric mean).

σ-convergence, which links the concept of convergence to that of inequality.

On the other hand, cluster analysis allows to distinguish which units are more similar on the basis of a matrix of characteristics (Rencher, 2005). A hierarchical clustering identifies at first which are the two most different groups, followed by subsequent clustering based on different characteristics, disposing all the units close to their more similar elements. In our case, the units are the pooled states and provinces, and the characteristics are the 15 comparable Goal Scores (Goals #14 and #17 are excluded because they are by construction invariant across provinces and across states). The cluster analysis has already been applied to explore sustainable development, as in EU countries (Pérez-Ortiz et al., 2014; Popescu et al., 2017; Zaburanna et al., 2019) and in China's coastal provinces (Wang et al., 2016). Different techniques can be deployed in the cluster analysis in order to determine how to group the clusters and how many clusters to obtain. Similarly, to the previous literature (Wang et al., 2016; Popescu et al., 2017), this paper selects the Ward method (Arabie et al., 1996), which minimizes the intra-cluster variability.[9] A crucial issue with this method is the selection of the number of clusters that we want to obtain. As a special case, by deciding a priori to set the number of clusters equal to two, we investigate if China's provinces and US states constitute separate groups or not. However, the hierarchical clustering allows to further note the similarities within these two clusters, by setting a number of clusters $k > 2$. k can be identified in correspondence of the kinks of the coefficient $\eta^2{}_k$ where $\eta^2{}_k = 1 - \frac{WSS(k)}{WSS(1)}$ and in turn WSS is the Within Sum of Square, decreasing with the number of clusters k and reaching its highest at WSS(1) corresponding to the Total Sum of Squares (TSS).

4. Results

4.1. Sustainable development in the United States and China

The first result of this paper is a comparison between the United States and China in terms of sustainable development and SDGs achievements, as illustrated in Table 1. The US and China exhibit in 2019 an ISD index of 0.746 and 0.724 respectively. This corresponds to the ranking 32nd for the US and 46th for China, out of a sample of 166 countries. After the introduction of the 2030 Agenda, the two countries have proceeded rapidly towards the 17 Goals, both in absolute and relative terms: if we consider the 2016 ISD, the US score was 0.694 (42nd) while China's score was 0.654 (68th). These results represent some of the most striking improvements recorded in the 2016–2019 period, especially in the case of China, which has halved its gap with the US in these three years. Moreover, China exhibits a high level of homogeneity across the goals, being one of the most balanced countries in the world, which constitutes part of its success. On the other hand, the United States exhibits a high level of heterogeneity in the achievements, although such imbalances decreased over time as the most backward goals grew faster (this is the case, for example, of many Planet-related goals). Only more recently, in the 2022 SDR, we can observe a worsening in the ranking of the United States and China, most likely due to the effects of the Covid-19 pandemic and the growing international tensions.

The two countries also share a similar structure in terms of Goal specialization. In 2019, both of them were particularly strong in terms of SDG #1 (No Poverty) and #4 (Quality Education), almost fulfilling such Goals. On the other hand, SDG #10 (Reduced Inequalities), #14 (Life Below Water) and #15 (Life on Land) were particularly weak. China was also poor in terms of #17 (Partnership for the Goals), while the US in #12 and #13 (two other Planet-related Goals).

Considering the dynamics of sustainable development, the two countries improved in most of the Goals, despite having some that deteriorated in the period 2016–19. Among the fastest growing achievements, several are Planet-related, despite environmental aspects remain relatively backward. On the other hand, the Goal #6 (Clean Water and Sanitation) is the one that worsened the most in both countries. China is also worsening in terms of Peace, Justice and Strong Institutions and Partnership for the Goals, while the US in Reduced Inequalities and Sustainable Cities and Communities.

4.2. Sustainable development in US states and China's provinces

The second result of the paper is the investigation of how the Goal scores (Table 2) and ISD (Table 3) and its changes over time are distributed within the two countries. Generally, the US states overperform the Chinese provinces in 2016; the results are mitigated in 2019.

In the United States, the state with the highest ISD is Washington, with a score of 0.817. This score would rank fourth at the worldwide level, just below Sweden, Denmark and Finland. Vermont and California are respectively the second and the third top ranked. These states already occupied the top three positions in 2016 ranking. They generally exceed the US average score in almost all goals, recording a weakness only in Goal #10 but performing much better than overall US in all the Planet Goals.

The state with the lowest ISD is Louisiana, with the score 0.586, a level that would fall in the second half of world ranking, along with Arkansas and West Virginia. In these states, the Goals #7 #12 and #13 are all particularly weak, indicating that some Planet-related deficiencies of the US are exacerbated in the most backward areas.

Generally, all the states have improved their performance in the 2016–19 period, although at different rates. The state with the strongest development is Mississippi (+0.120), followed by Wyoming and Kentucky; all these states were below the country's average in 2016. On the other hand, Delaware recorded the weakest growth: +0.003; also New York and Alaska were characterized by slight improvements. Indeed, both core states (as California and New York) as well as the most remote ones (Alaska) grew lower than average. It is worth noticing that the states that voted for Trump in 2016 were characterized by a lower ISD level but grew more than the others.

In China, the province with the highest ISD is Guangdong (east), with the score 0.754, 31st in the world ranking and above several rich countries including the US. The second and third most developed provinces are respectively Jiangsu (east) and Hubei (centre). While all the coastal areas exhibit good performances, triggered by good results in several Prosperity-related dimensions, such as Goal #9, weaker scores are observed in the West and in the North. Indeed, the province with the lowest ISD score is Tibet (0.569). Among the provinces that would fall in the bottom half of the world ranking, there are 6 other provinces, all in the West with the exception of Heilongjiang located in the Northeast. A critical point of these provinces, besides Goal #6 (which is weak in all China), is #9 (Industry, Innovation and Infrastructure), which varies significantly across the country.

Tibet is also the province that grew fastest, followed by Ningxia and Guizhou, which are two other Western provinces still among the least developed ones. On the other hand, the weakest growth between 2016 and 2019 was recorded in Heilongjiang, while Beijing and Shanghai were characterized by slight improvements as well. Indeed, the worst increase in ISD occurred both in advanced coastal provinces and in backward Northern provinces. The Northeast emerges as a critical region in terms of weak development.

In general, China's achievements seem in line with the harmonious society strategy: promoting sustainable development beyond the monetary aspect to achieve a "xiaokang" (prosperous) society and spread such development across the country. In any case, China remains characterized by a coastal-inner divide, and the relative over-development in most provinces based on monetary terms when

[9] The robustness of the results is tested with the k-means approach. For other approaches on cluster analysis see García-Escudero et al. (2008).

Table 1
Goal achievements in the United States and China (2016 and 2019).

	Goal																	$\bar{A}$	*ISD*
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17		
US 2016	99.3	70.0	90.3	93.1	74.1	96.1	87.4	85.5	84.4	55.6	98.2	38.2	54.2	45.8	44.6	63.5	50.5	72.4	69.4
	(61)	(15)	(29)	(20)	(32)	(11)	(34)	(15)	(8)	(89)	(9)	(153)	(150)	(60)	(129)	(75)	(138)	(42)	(42)
PRC 2016	99.5	66.8	79.5	74.1	74.8	88.2	67.7	71.9	57.7	52.4	61.6	74.8	58.7	31.1	58.5	69.1	54.5	67.1	65.4
	(50)	(21)	(62)	(97)	(31)	(60)	(98)	(54)	(29)	(94)	(113)	(66)	(145)	(106)	(90)	(48)	(119)	(71)	(68)
US 2019	98.9	66.3	88.9	99.7	74.0	83.7	93.4	85.2	93.8	47.7	89.1	54.7	58.1	63.7	59.5	74.8	67.8	76.4	74.6
	(44)	(27)	(30)	(2)	(36)	(28)	(29)	(15)	(6)	(93)	(17)	(135)	(142)	(48)	(104)	(48)	(56)	(31)	(32)
PRC 2019	98.0	76.4	79.8	95.0	75.7	68.6	69.4	87.5	72.1	61.3	75.9	88.6	89.8	50.5	59.5	63.8	44.4	73.9	72.4
	(54)	(2)	(58)	(53)	(33)	(86)	(109)	(4)	(30)	(64)	(87)	(44)	(76)	(99)	(105)	(97)	(140)	(48)	(46)

Note: The scores of the United States and China (PRC) are shown for each Goal, while the last two columns report the arithmetic mean ($\bar{A}$) and the ISD Index. Rankings are in parentheses.

Table 2
Goal Scores in the United States and China (2016 and 2019).

Goal	US 2016				China 2016				2016 Higher Score	US 2019				China, 2019				2019 Higher Score
	Mean	Min	Max	S.D.	Mean	Min	Max	S.D.		Mean	Min	Max	S.D.	Mean	Min	Max	S.D.	
1	0.98	0.98	0.99	0.00	0.97	0.88	1.00	0.04	US**	0.98	0.98	0.99	0.00	0.97	0.89	1.00	0.03	US*
2	0.69	0.57	0.79	0.05	0.66	0.28	0.88	0.13	US	0.65	0.51	0.76	0.05	0.76	0.45	0.93	0.10	CH***
3	0.90	0.85	0.94	0.02	0.78	0.42	0.95	0.10	US***	0.89	0.80	0.96	0.04	0.78	0.56	0.88	0.06	US***
4	0.92	0.79	1.00	0.05	0.71	0.00	0.88	0.17	US***	0.97	0.85	1.00	0.04	0.94	0.84	0.97	0.03	US***
5	0.73	0.60	0.84	0.06	0.75	0.69	0.80	0.02	CH	0.74	0.54	0.90	0.08	0.75	0.70	0.80	0.02	CH
6	0.97	0.85	0.98	0.02	0.83	0.35	1.00	0.14	US***	0.85	0.09	0.96	0.13	0.64	0.27	1.00	0.18	US***
7	0.83	0.55	1.00	0.15	0.65	0.06	0.83	0.17	US***	0.87	0.57	1.00	0.14	0.66	0.19	0.85	0.16	US***
8	0.85	0.61	0.98	0.07	0.72	0.47	0.96	0.09	US***	0.84	0.69	0.99	0.06	0.86	0.72	1.00	0.06	CH
9	0.79	0.57	1.00	0.12	0.51	0.15	1.00	0.26	US***	0.87	0.68	1.00	0.10	0.59	0.20	1.00	0.25	US***
10	0.57	0.40	0.76	0.07	0.52	0.45	0.58	0.04	US***	0.50	0.24	0.68	0.09	0.61	0.52	0.73	0.04	CH***
11	0.89	0.73	1.00	0.10	0.60	0.22	0.86	0.15	US***	0.87	0.77	1.00	0.06	0.76	0.52	0.91	0.08	US***
12	0.31	0.00	0.75	0.24	0.71	0.21	0.85	0.15	CH***	0.48	0.00	0.77	0.22	0.87	0.61	0.93	0.07	CH***
13	0.40	0.00	0.81	0.23	0.56	0.00	1.00	0.20	CH***	0.59	0.15	0.83	0.16	0.88	0.72	1.00	0.08	CH***
14	0.47	0.06	1.00	0.15	0.57	0.19	1.00	0.21	CH**	0.61	0.17	0.84	0.15	0.58	0.18	1.00	0.21	US
16	0.63	0.45	0.81	0.08	0.66	0.30	0.83	0.12	CH	0.73	0.49	0.88	0.08	0.62	0.00	0.79	0.17	US***

Note: Means are not weighted by population; the 'Higher score' columns report whether the US or China (CH) are significantly higher scores at 10% 5% and 1% (respectively marked with *, **, ***.

compared to environmental consideration indicating that there is still room for harmonious society policies.

When the ISD scores of US states and China's provinces are combined, we observe how the two groups overlap. The US were ahead of China both in 2016 and 2019, and consistently the states occupy the highest places in the mixed ranking reported in Table 3. However, China's top provinces were always well ahead of most of the US states. The stronger growth recorded in China, moreover, mirrors the jump of the provinces that occupied the lowest ranks, while the top positions are maintained by US states. This resulted in Chinese provinces being concentrated in the middle of the mixed ranking. Focusing on the top performers, some of them in both countries remained relatively stagnant, such as New York and California, and Beijing and Shanghai.

4.3. Spatial convergence

The third result is about within-country spatial convergence of ISD, i.e. whether backward states and provinces in terms of sustainable development are growing faster than the advanced ones. In 2016 the standard deviation across states and across provinces was in both cases 0.059. It then reduced in both countries, reaching 0.051 in the United States and 0.041 in China. These results, reported in Fig. 1, suggest that both countries experienced a spatial convergence (σ-convergence), although this process has been much stronger in China.

Another way to identify convergence is looking at the relation between states' (provinces') ISD level in 2016 and its subsequent growth. A significantly negative correlation points to convergence (β-convergence) (Barro and Sala-i-Martin, 1992), which is the case for both the US and China. Again, the convergence among China's provinces has been faster than the convergence across the United States. Fig. 2 illustrates the distribution of states and provinces in terms of ISD level in 2016 and ISD change between 2016 and 2019. The slope of this relation and its steepness represent the existence of a converging trend and its speed.

4.4. Cluster analysis

A fourth result is the clustering of states and provinces across the two countries to point out differences and commonalities. Clusters are determined based on the state and provinces (pooled in a unique sample) based on the Goal Scores. The analysis is replicated in 2016 and 2019 to observe the evolution of the (dis)similarities. Given the kink in the η^2 curve, 2 appears as the most suitable number of groups. This value also corresponds to the dualistic nature of our sample (US states and China's provinces, whose Goal Score incorporates a different SDR_G value). Observing η^2, another appropriate number of clusters is 7, which is also an appropriate number of clusters according to the Duda-Hart stopping rule which indicates an optimal number of clusters in correspondence of a high Je(2)/Je(1) index and a low pseudo-T2 (Duda et al., 2001). Tables 4A and B report the Ward clustering with 7 and 2 groups respectively for 2016 and 2019, which correspond to the partition of the countries into 7 clusters illustrated in Fig. 3A and B. A broader differentiation is represented in the dendrograms of Fig. 4, which allow to rank and measure the similarities between the pooled sample of provinces and states. Table 5 reports the Duda-Hart stopping rule.

In 2016 (Table 4A) the distinction between provinces and states was blurred: by imposing 7 clusters, 3 of them contains elements from both the countries; by imposing 2 clusters, the first comprises all the states plus some of the richest provinces that are therefore separated from the rest of China. For 2019 (Table 4B), the cluster analysis provides a much sharper distinction between provinces and states. By limiting the

Table 3
Combined ISD ranking of states and provinces, 2016 and 2019.

2016		2019	
California	0.765	Washington	0.817
Vermont	0.752	Vermont	0.808
Washington	0.750	California	0.805
Massachusetts	0.748	Massachusetts	0.800
New York	0.741	Maine	0.799
Oregon	0.736	Maryland	0.796
Minnesota	0.731	Minnesota	0.794
Rhode Island	0.729	Oregon	0.791
Maryland	0.729	New Hampshire	0.785
Maine	0.720	Hawaii	0.779
New Hampshire	0.720	Colorado	0.778
Hawaii	0.718	New York	0.778
Shanghai	0.715	Wisconsin	0.775
Connecticut	0.714	Connecticut	0.773
Beijing	0.706	Rhode Island	0.771
Wisconsin	0.705	Virginia	0.758
Delaware	0.705	New Jersey	0.756
Jiangsu	0.704	Michigan	0.755
Guangdong	0.702	Guangdong	0.754
Zhejiang	0.701	Jiangsu	0.748
Colorado	0.698	Illinois	0.747
Virginia	0.688	Iowa	0.741
Michigan	0.679	Hubei	0.741
Tianjin	0.678	Hunan	0.740
North Carolina	0.677	Zhejiang	0.739
Florida	0.676	Florida	0.737
Illinois	0.676	New Mexico	0.737
Idaho	0.674	Idaho	0.735
Georgia	0.673	Anhui	0.735
New Jersey	0.671	Georgia	0.733
Iowa	0.670	Fujian	0.731
Chongqing	0.666	North Carolina	0.731
Fujian	0.658	Shanghai	0.731
Shandong	0.657	Tianjin	0.730
South Carolina	0.657	Kansas	0.727
Arizona	0.657	Utah	0.724
Pennsylvania	0.655	Chongqing	0.724
Hunan	0.655	Arizona	0.724
Anhui	0.648	South Carolina	0.721
New Mexico	0.645	Beijing	0.720
Utah	0.644	Nebraska	0.717
Tennessee	0.643	Nevada	0.710
Sichuan	0.643	Shandong	0.709
Kansas	0.639	Sichuan	0.708
Nebraska	0.639	Delaware	0.707
Ohio	0.638	Jiangxi	0.707
Nevada	0.637	South Dakota	0.706
Montana	0.637	Tennessee	0.703
Jilin	0.635	Pennsylvania	0.702
Missouri	0.633	Montana	0.701
Hubei	0.628	Kentucky	0.701
South Dakota	0.626	Hainan	0.698
Shaanxi	0.625	Missouri	0.697
Jiangxi	0.616	Hebei	0.697
Texas	0.615	Shaanxi	0.695
North Dakota	0.615	Henan	0.695
Henan	0.614	Guizhou	0.694
Alaska	0.612	Inner Mongolia	0.694
Gansu	0.612	Ohio	0.690
Liaoning	0.610	Gansu	0.688
Indiana	0.609	Texas	0.685
Heilongjiang	0.606	Wyoming	0.684
Hainan	0.603	Qinghai	0.683
Hebei	0.603	Liaoning	0.682
Guangxi	0.599	Alabama	0.681
Kentucky	0.597	Indiana	0.679
Alabama	0.587	North Dakota	0.673
Xinjiang	0.582	Jilin	0.672
Shanxi	0.579	Mississippi	0.663
Wyoming	0.579	Shanxi	0.659
Guizhou	0.578	Xinjiang	0.659
Inner Mongolia	0.575	Oklahoma	0.659
West Virginia	0.568	Guangxi	0.657
Qinghai	0.568	West Virginia	0.656
Oklahoma	0.560	Alaska	0.650
Arkansas	0.554	Yunnan	0.643
Yunnan	0.549	Ningxia	0.639
Mississippi	0.543	Arkansas	0.637
Louisiana	0.536	Heilongjiang	0.618
Ningxia	0.517	Louisiana	0.586
Tibet	0.435	Tibet	0.569

number of clusters to 2, we obtain a cluster with 49 states and a cluster of 32 elements (all China's provinces plus the state of Delaware): considering their sustainable development characteristics, states and provinces constitute two separate groups. In other words, in 2016 there was a fracture within China's sustainable development that made some provinces more similar to the US than to their neighbouring provinces. Such fracture has healed in the following years: in 2019, we can see that – with the exception of Delaware – US states and China's provinces are perfectly distinguished into two groups. A similar result is obtained with the k-means (k = 7) clustering. Further differentiations within these two groups highlight their internal differences, isolating more and less developed provinces and states. As shown in Fig. 3B, the US territory appears as divided in a way that tends to highlight differences between states of the Appalachian region and Central states (with low and medium-low ISD) and the remaining states (that display generally medium-high and high ISD). At the same time, in China the clustering distinguishes roughly Eastern (with higher ISD), Central, and Western provinces (with lower ISD).

5. Discussion and conclusions

This research investigates the United States' and China's pathways towards the 2030 Agenda by introducing a novel index, the ISD Index, which measures the SDGs progress at the subnational level while preserving international comparability. Overall, the results indicate that both countries have recorded significant improvements, reaching good levels of sustainable development and thus representing virtuous examples worldwide. This is the first research to our knowledge that try to compare the subnational progresses in terms of the Agenda 2030. Indeed, the ISD index allows to explore sustainable development not only across countries, but also in territories whose specific development dynamics may substantially detach from the country level patterns. However, as already mentioned in Section 3.1, although we constructed comparable data for the subnational level Goal Scores, due to lack of data, we could not use the information for goals 14th (on life below water) and 17th (partnership for the goals) which can be found only at national level.

Sustainable development in US states and China's provinces is analysed, placing therefore this paper in the economic literature that compares these two countries but adopting a novel perspective combining subnational and multidimensional analyses. In this regard, the paper contributed to answer *four* questions. The *first* was whether these countries have been moving towards a sustainable development agenda and progressing in the achievement of the SDGs at the national level. This has resulted from different combinations of SDGs performance in the two countries, with China being characterized by a more balanced mix of achievements. Conversely, both countries have recorded relatively weak (although progressing) environmental achievements. This weakness may reflect the relatively scarce sensibility towards environment which has marked the political approach in the two countries over time. The presidencies of Trump and Xi Jinping, indeed, have been less sensitive to environmental issues than their predecessors Obama and Hu Jintao, and both countries have exhibited scarce enthusiasm for the environmental measures promoted by the COPs; nevertheless, these facts were probably not the only causes for such weak performance, as it is more likely to derive from long-run

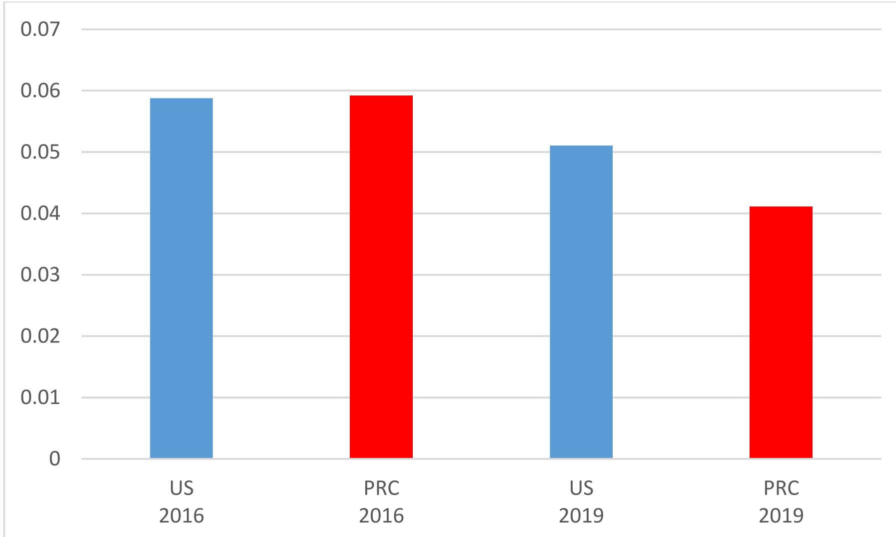

Fig. 1. σ-convergence within the United States (US) and within China (PRC).
Source: Authors' elaboration on ISD data.

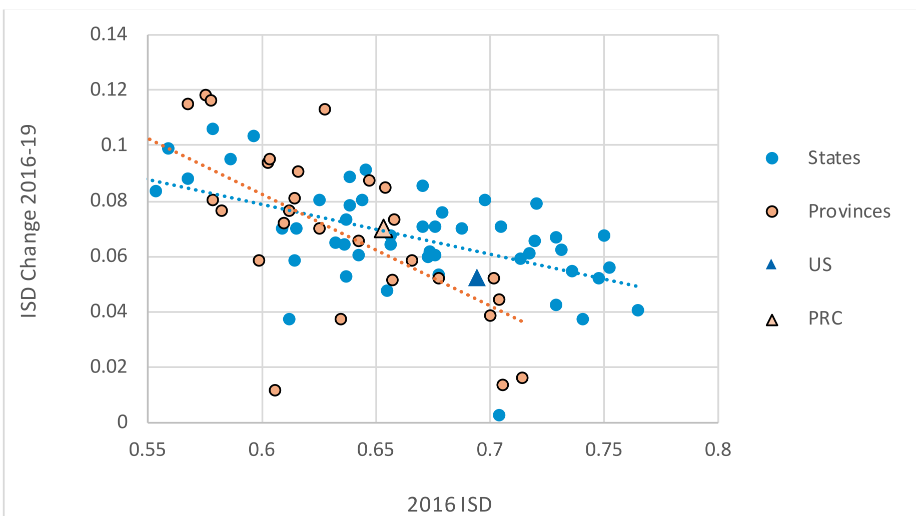

Fig. 2. β-convergence within the United States (US) and within China (PRC).
Source: Authors' elaboration on ISD data.

Table 4A
Results of cluster analysis, 2016.

2 clusters	7 clusters	Areas	Country	Mean ISD	Min ISD	Max ISD
	1	**Beijing**; Connecticut; Delaware; California; **Guangdong**; **Jiangsu**; Maryland; Massachusetts; New Hampshire; New York; Rhode Island; **Shanghai**; **Tianjin**; Vermont; **Zhejiang**	Both	0.721	0.678	0.765
	2	Minnesota; Michigan; Maine; Illinois; Hawaii; Georgia; Florida; Colorado; Arizona; Nevada; New Jersey; North Carolina; Oregon; Pennsylvania; **Shandong**; South Carolina; Tennessee; Texas; Virginia; Washington; Wisconsin	Both	0.682	0.615	0.750
	3	**Ningxia**; Mississippi; Louisiana; Arkansas; North Dakota; Oklahoma; West Virginia; Wyoming	Both	0.559	0.517	0.615
1	4	Utah; South Dakota; Ohio; New Mexico; Nebraska; Montana; Missouri; Kentucky; Kansas; Iowa; Indiana; Idaho; Alaska; Alabama	USA	0.632	0.587	0.674
	5	**Shaanxi; Liaoning; Jilin; Hunan; Hubei; Henan; Hebei; Fujian; Chongqing; Anhui**	PRC	0.634	0.603	0.666
	6	**Gansu; Guangxi; Guizhou; Hainan; Heilongjiang; Inner Mongolia; Jiangxi; Qinghai; Shanxi; Sichuan; Xinjiang; Yunnan**	PRC	0.593	0.549	0.643
2	7	**Tibet**	PRC	0.435	0.435	0.435

Note: The cluster analysis is based on the 15 Goals available by using Ward's clustering method and selecting a number of clusters k = 7 (and k = 2 in the first column).

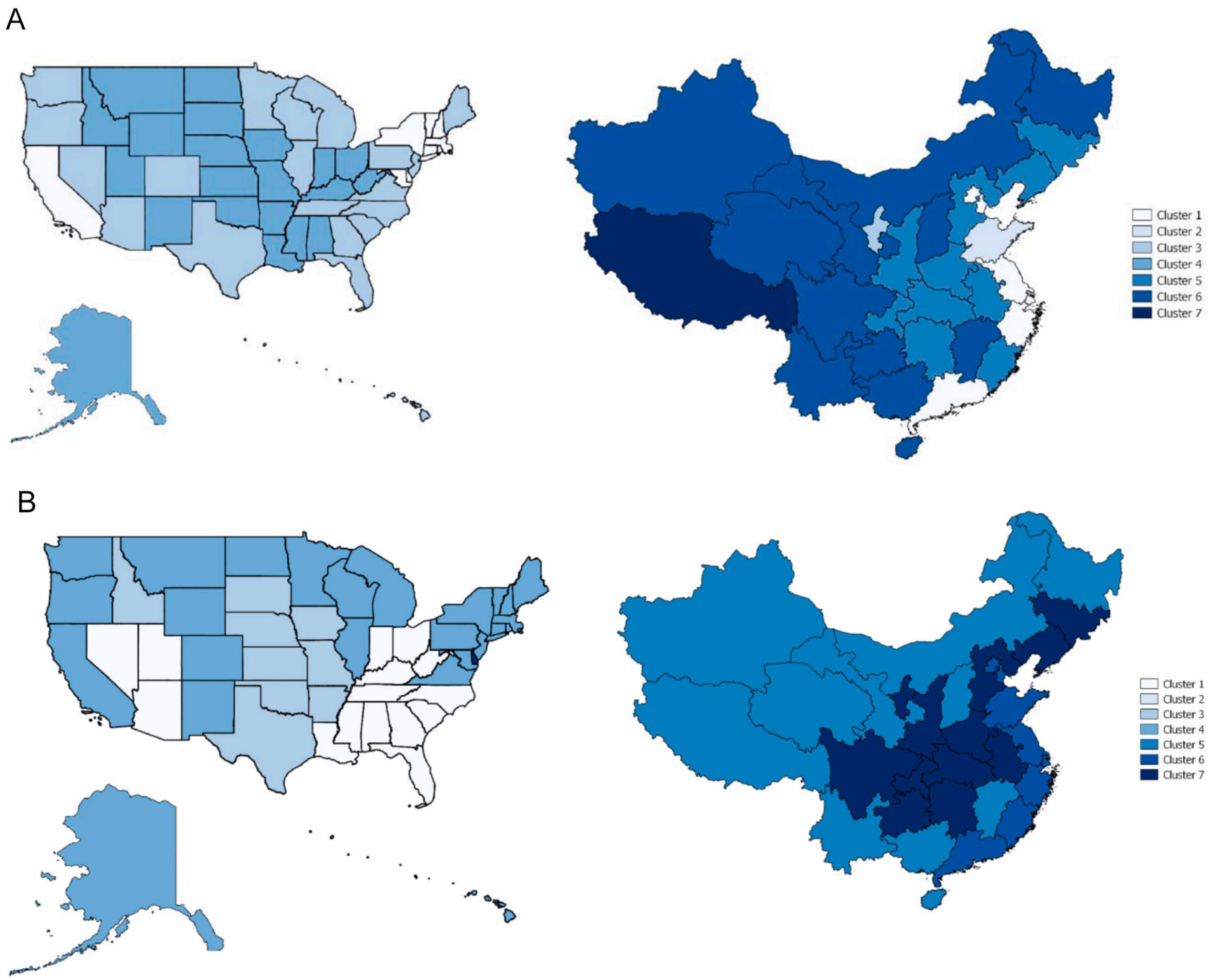

Fig. 3. A. Clusters in 2016.
B. Clusters in 2019.
Source: Authors' elaboration on ISD data.

trends that require years to be reversed.

Overall, the fact that the United States maintains a higher ranking than China should not overshadow that (i) China is growing faster than the United States in terms of ISD and (ii) several Chinese provinces present scores higher than some US states. The *second* question answered by the paper, indeed, was about the distribution of SDG achievements within the two countries and also allowed to combine the ISD scores of US states and China's provinces. From this perspective, poor US areas (as the Deep South) turned out to be less developed than the cutting-edge provinces of China (the West). This overtaking, which is also occurring in the monetary field (Japan Center for Economic Research Asian Research Team (JCER), 2021), was not yet discussed in terms of sustainable development and opens the ground to new considerations about the world hegemony in the next decades. In any case, it should be noticed that top-ranks are still dominated by US states, giving rise to strong polarization between top performing and left behind states. This polarization was also reflected in the results of convergence analysis, which helped to answer the *third* question, i.e. whether backward states and provinces have been evolving faster than the advanced ones. Although both countries have been experiencing spatial convergence, this process was much weaker in the United States than it was in China. The stronger convergence among Chinese provinces was fully confirmed also by answering the *fourth* question, namely whether the existing differences and analogies between states and provinces have resulted in common clusters across the two countries. In 2016, there was an evident fracture within China making some provinces more similar to the US states than to their neighbouring provinces. Such fracture has healed in the following years, bringing China's provinces to appear more homogeneous among themselves and more differentiated from the US counterparts.

To sum up, one robust conclusion emerges from the analysis: if the United States can claim a better positioning in the national and subnational rankings of sustainable development, China exhibits a more balanced sustainable development path in terms of both SDGs achievement combination and spatial distribution. Nonetheless, both countries are still characterized by deep territorial disparities and scarce achievements of Planet-related Goals. These latter issues suggest two main policy recommendations for both countries.

First, public policies for sustainable development should devote particular attention to reduce territorial disparities in terms of SDGs achievement. This entails the implementation of public programs localized at the subnational level that prioritize especially backward states and provinces, in order to stimulate them to evolve faster than the advanced ones. In fact, the activation and promotion of convergence processes require the expansion of specific local capabilities, associated with the development of technological and economic opportunities,

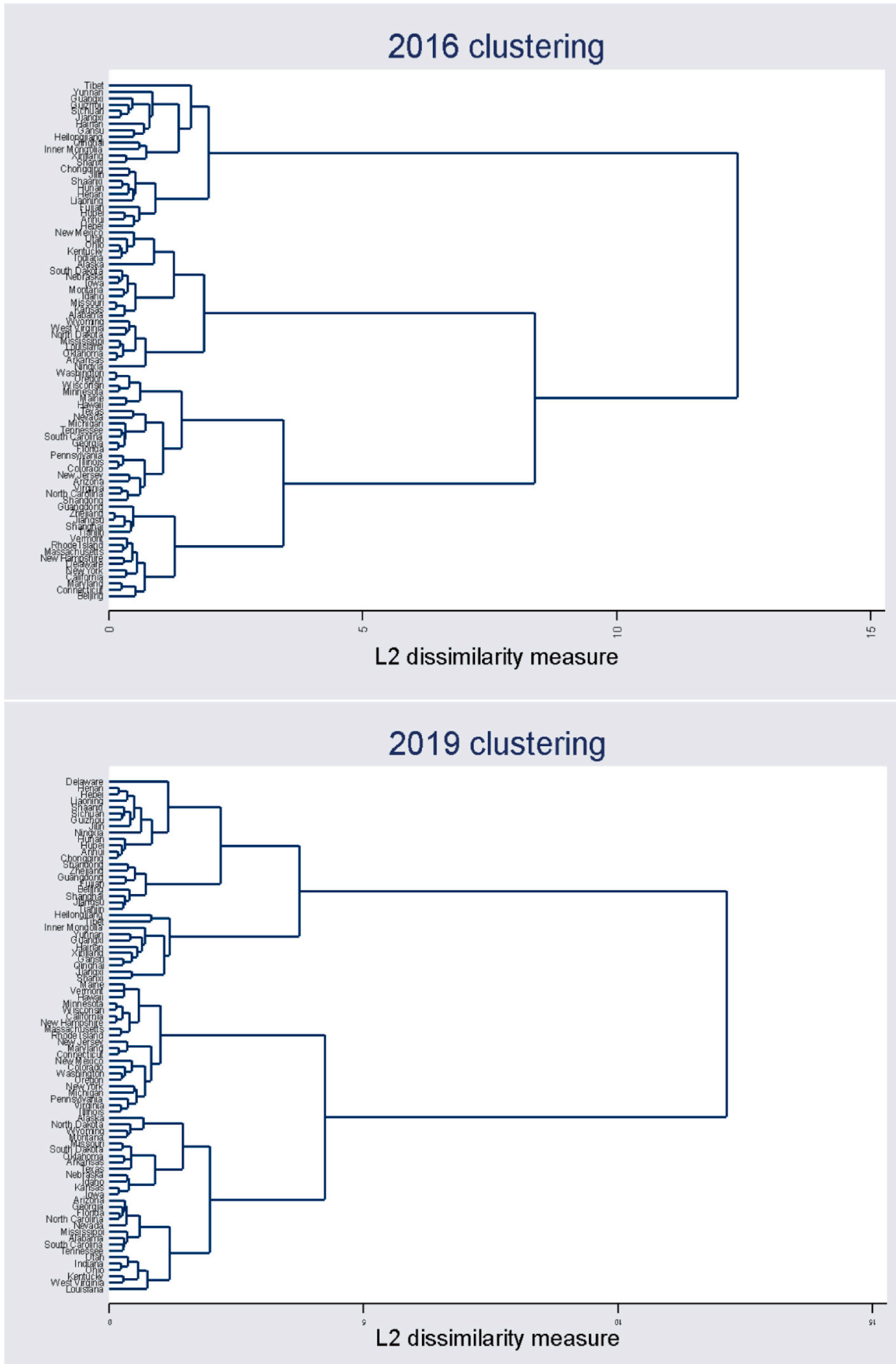

Fig. 4. Dendrogram for 2016 (A) and 2019 (B).
Source: Authors' elaboration on ISD data.

culture, and institutions for advancing sustainable development. While these capabilities cannot be easily transferred from one area to another, some initiatives can be crucial in fostering the sharing of virtuous experiences between the sub-national levels for the achievement of the 2030 Agenda. These initiatives may include, for instance, the promotion of platforms and databases for local policy-makers, to simplify the sharing of existing policy solutions, or to provide sources of information and knowledge derived from practical experience in support of the monitoring and implementation of policies for SDGs achievement. These arrangements can contribute to reduce disparities and to progress more uniformly towards the SDGs, as the Agenda 2030 itself calls for (Goal 10). While in China this purpose has already been integrated in the political agenda, in the United States the activation of effective convergence processes requires necessarily additional efforts for reducing the too many political differences that exist in the promotion of SDGs at the state level.

Second, public policies should accelerate in advancing the Planet-related Goals, as the future realization of further improvements on the road of sustainable development will much depend on the fulfilment of such Goals. As GDP growth, as it is, tends to contrast environmental sustainability, significant trade-offs in decisions of policy maker may emerge, compromising possibilities to foster a true transition. Specifically, while in the past economic growth was typically considered per se one of the main ways to heal many evils, from unemployment to social

Table 4B
Results of cluster analysis, 2019.

2 clusters	7 clusters	Areas	Country	Mean ISD	Min ISD	Max ISD
	1	Alabama; Florida; Georgia; Arizona; Indiana; Kentucky; Louisiana; Mississippi; Nevada; North Carolina; Ohio; South Carolina; Tennessee; Utah; West Virginia	USA	0.696	0.586	0.737
	2	Texas; South Dakota; Oklahoma; Nebraska; Missouri; Kansas; Iowa; Idaho; Arkansas	USA	0.700	0.637	0.741
	3	Alaska; Montana; North Dakota; Wyoming	USA	0.677	0.650	0.701
1	4	Oregon; New Mexico; New Jersey; New York; New Hampshire; Minnesota; Michigan; Massachusetts; Maryland; Maine; Illinois; Hawaii; Connecticut; Colorado; California; Pennsylvania; Rhode Island; Vermont; Virginia; Washington; Wisconsin	USA	0.776	0.702	0.817
	5	**Tibet; Shanxi; Qinghai; Jiangxi; Inner Mongolia; Heilongjiang; Hainan; Guangxi; Gansu; Xinjiang; Yunnan**	PRC	0.661	0.569	0.707
	6	**Zhejiang; Tianjin; Shanghai; Shandong; Jiangsu; Guangdong; Fujian; Beijing**	PRC	0.733	0.709	0.754
2	7	**Anhui; Chongqing;** Delaware; **Guizhou; Hebei; Henan; Hubei; Hunan; Jilin; Liaoning; Ningxia; Shaanxi; Sichuan**	Both	0.702	0.639	0.741

Note: The cluster analysis is based on the 15 Goals available by using Ward's clustering method and selecting a number of clusters k = 7 (and k = 2 in the first column).

Table 5
Duda-Hart stopping rule, 2016 (left) and 2019 (right).

Number of clusters	Duda/Hart		Number of clusters	Duda/Hart	
	Je(2)/Je(1)	pseudo T-squared		Je(2)/Je(1)	pseudo T-squared
1	0.6682	39.22	1	0.6435	43.76
2	0.5937	39.01	2	0.7153	18.70
3	0.6789	16.08	3	0.6836	13.88
4	0.6945	9.24	4	0.6606	9.76
5	0.7772	5.73	5	0.7785	7.40
6	0.6219	5.47	6	0.6250	6.60
7	0.7603	5.99	7	0.7357	3.23
8	0.6919	5.79	8	0.6782	6.17
9	0.6557	4.20	9	0.6158	6.86
10	0.5940	7.52	10	0.6626	3.56
11	0.6898	4.05	11	0.8201	4.17
12	0.7267	4.89	12	0.5875	4.92
13	0.7510	2.65	13	0.7048	4.19
14	0.4741	2.22	14	0.0000	.
15	0.3567	1.80	15	0.7616	3.13

Source: Authors' elaboration on ISD data.

disparities, this model of development has become unviable today, as the rapid production of goods and services is increasingly compromising the ability of our planet to renew its natural resources, affecting the environmental sustainability of the system (e.g., Goldin, 2014). This suggests moving away from productions based on non-renewable resources and polluting processes towards the production of more eco-friendly goods and services (a so-called *green growth*). In this perspective, public policies should primarily focus, also at the local level, on the goal of making economic growth environmentally sustainable, taking care, at the same time, to ensure that growth processes contribute effectively to the equity of the system. This includes, for instance, the adoption of institutional arrangements creating incentives for greater efficiency in the use of natural resources, reducing waste and energy consumption, unlocking opportunities for innovation and value creation, and opening up new markets by stimulating demand for green goods, services and technologies (OECD, 2011). This urgently calls also for new research deeply investigating the synergies and trade-offs among the SDGs that are at play in the two countries and that can respectively foster or hinder the achievement of a fully integrated sustainable (economic, social and environmental) development in the next years.

Declaration of Competing Interest

None.

Data availability

Data will be made available on request.

Appendix A. Appendix

A.1. Robustness tests

The results described in Sections 4.2, 4.3 and 4.4 are related to the ISD index and its underlying methodology. As there is no consensus about aggregation techniques in the literature, in this section we test if the main results hold adopting alternative techniques to build a Robust Integrated Sustainable Development Index (RISD) whose main differences with ISD are:

1) Adoption of Principal Component Analysis (PCA) to calculate Goal Scores that avoid the risk of double counting.
2) Rejection of population weights in subdividing national scores SDR_G among states/provinces.
3) To account for international differences, SDR_G are summed to a variable with average 0 (rather than multiplied by a variable with weighted average 1).
4) Goal Scores are aggregated through geometric mean.

In other words, the first step is computing with PCA the rotated first component of variables belonging to the same country, same year and same goal $c_{s,\ G}$.

The Robust Goal Score $Rs_{s,\ G}$ in each unit s is then computed by dividing the values $c_{s,\ G}$ by the difference $c_{M,\ G} - c_{m,\ G}$ where $c_{M,\ G}$ and $c_{m,\ G}$ are respectively the minimum and maximum scores recorded in the year and Goal between units of the same country. In this way, we obtain a variable with arithmetic mean equal to 0 that ranges in a 1-long interval. The resulting scores are then summed to SDR_G so to account international differences, and extreme values, below 0 or above 1, are brought respectively to 0 and 1. In formula:

$$Rs_{s,G} = \begin{cases} 0 \ if \ \dfrac{c_{s,G}}{c_{M,G} - c_{m,G}} + SDR_G \leq 0 \\ \dfrac{c_{s,G}}{c_{M,G} - c_{m,G}} + SDR_G \ if \ 0 < \dfrac{c_{s,G}}{c_{M,G} - c_{m,G}} + SDR_G \leq 1 \\ 1 \ if \ \dfrac{c_{s,G}}{c_{M,G} - c_{m,G}} + SDR_G > 1 \end{cases}$$

Finally, the RISD is obtained as geometric mean between $Rs_{s,\ G}$. ISD and RISD appear significantly correlated (see Fig. A1), despite the geometric mean has the problem of collapsing in 0 whenever any $Rs_{s,\ G} = 0$. The analysis of $Rs_{s,\ G}$and RISD confirms our main previous findings:

1) There is an overlap between US states and China's provinces.
2) There is mild convergence in US states, stronger convergence in China's provinces.
3) Two clusters are not sufficient to perfectly distinguishing states and provinces based on their $Rs_{s,\ G}$, especially in 2019.

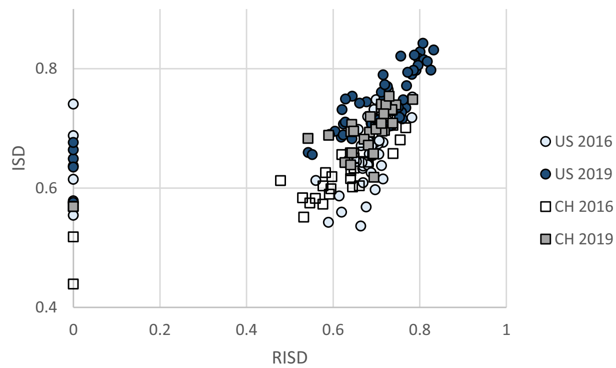

Fig. A1. Relation between ISD and RISD.
Source: Authors' elaboration on ISD and RISD data.

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