Untangling the interactions between the Sustainable Development Goals in China

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ABSTRACT

Understanding the interactions (synergies and trade-offs) among the Sustainable Development Goals (SDGs) is crucial for enhancing policy coherence between different sectors. However, spatial differences in the SDG interactions and their temporal variations at the sub-national scale are still critical gaps that need to be urgently filled. Here, we assess the spatial and temporal variation of the SDG interactions in China based on the systematic classification framework of SDGs. The framework groups the seventeen SDGs into three categories, namely "Essential Needs," "Objectives," and "Governance." Spatially, we found that the SDGs in "Essential Needs" & "Objectives" and "Essential Needs" & "Governance" generally show trade-offs in the eastern provinces of China. Synergies among all three SDG categories are observed in some central and western China provinces, which implies that these regions conform to sustainable development patterns. In addition, temporally, the synergies of the three SDG categories have shown a weakening trend in the last decade, mainly due to the regional differences in the progress of SDG7 (Affordable and Clean Energy). Overall, our results identify the necessity for provinces to enhance the synergies between SDG12 (Responsible Production and Consumption) and other SDGs to tackle the trade-offs between the "Essential Needs" and "Objectives." Meanwhile, promoting the progress of SDG7 will also contribute to balanced development across provinces.

Keywords: Sustainable Development Goals; Essential Needs; Governance; Objectives; China

1. Introduction

In September 2015, the United Nations released the Sustainable Development Goals (SDGs), a results-oriented framework for sustainable development that contains 17 goals, 169 targets [1]. The purpose of the SDGs is to encourage countries to utilize the framework to guide national planning, policymaking, and investment decisions and regularly monitor and report on progress from 2016 to 2030 for sustainable transformation [2]. However, despite the broad content of SDGs, the comprehensiveness and complexity may limit the potential for their achievement [3]. Recent studies show that there are complex interactions between the SDGs, which can generally be classified as synergies and trade-offs [4,5]. The former implies that advances in one goal could benefit progress in another, while the latter indicates that progress in one goal will hinder progress in another [5]. Nevertheless, these studies have mostly been global-scale analyses and have focused on simplified indicators [6-8]. Assessing the SDG interactions on a sub-national scale remains an important knowledge gap, which needs to be urgently filled to provide scientific evidence for formulating sustainable development policies at a sub-national scale.

As China is the world's largest developing country and the second-largest economy, its economic development and socio-environmental issues have always received widespread attention [9-11]. Recent assessments showed that China's sustainable development level is steadily increasing. For example, the SDG Index score in China, assessed by Bertelsmann Stiftung and Sustainable Development Solutions Network, has increased from 59.1 in 2016 to 72.1 in 2021 [12,13]. This increased score means that China has achieved 72.1% of the targeted value for SDGs [13]. However, some studies also pointed out that addressing the uneven SDG Index at the provincial scale in China is still a significant challenge [11,14]. It has been suggested identifying the synergies and trade-offs between the different SDGs would facilitate policy coherence and balanced development across provinces [3]. But existing studies have

only assessed the SDG interactions at the national scale, which have overlooked the spatial differences in SDG interactions [15,16]. Considering that provinces may feature different strengths and dilemmas, assessing such differences could contribute to finding measures to advance the SDGs at a sub-national scale evenly. Additionally, previous studies are based on the SDG Index database, which usually has limited data availability and lacks a fit with the official SDG indicators framework [15,16]. Since the indicators at global or national scale may not be applicable at the sub-national scale [2], the use of indicators suitable for the provincial scale will be of further help in identifying the influencing factors that constrain the synergistic development across the SDGs.

Furthermore, no studies have analyzed the evolution of SDG interactions over time in China. Such information is crucial because the linkages between different sectors are often dynamic [17]. These linkages are vulnerable to multiple factors such as resource availability and policy coherence, which may cause the interactions to change over time [18-20]. Continuous monitoring of such changes will provide vital information for the adjustment of macro policies. Meanwhile, revealing the key SDGs that significantly affect the interactions can help explore adequate measures to transform trade-offs into synergies. These insights will provide valuable information for advancing the full implementation of SDGs at national and sub-national scales.

To fill the above-highlighted gaps, we quantified the spatial and temporal variability of the SDG interactions (synergies and trade-offs) in China. We aimed to address the following questions. First, what differences exist in the synergies and trade-offs of SDGs across provinces? Second, what are the time-varying characteristics of the SDG interactions in China? Third, what are the drivers for the change of SDG interactions? To answer these questions, we first constructed an indicator system applicable to the provincial scale in China according to the official SDG indicator framework requirements. We collected historical data of each indicator

through different statistical departments, resulting in 88 indicators for 71 targets of the 16 goals (see Table S1).

To make the indicators comparable, we normalized the raw data to a score range of 0-100 by referring to the method applied in the SDG Index and Dashboards [12,21] (see details in Methods). Here, indicator score 0 means the baseline value, and 100 is the achievement of the target posed by the SDG. Subsequently, the indicator scores are finally aggregated into the SDG scores by the arithmetic mean method, and the SDG scores for each province were used for synergy and trade-off analysis based on the systematic classification framework of SDGs proposed by Fu et al. [3] (Fig. 1a, see details in Methods). The framework group 17 SDGs into three categories, namely "Essential Needs," "Objectives," and "Governance." We calculated the "RV coefficients" (see details in Methods) between the three SDG categories to identify the synergies and trade-offs among the three SDG categories through the multiple factor analysis. The analysis was done from temporal and spatial perspectives. Based on the results of our analyses, we also discussed how to promote the synergistic development of the SDGs, the existing deficiencies, and future perspectives.

2. Materials and methods

2.1. The systematic classification framework of SDGs

The systematic classification framework of SDGs is an important perspective to analyze the complexity of linkages among SDGs [3] (Fig. 1a). Past studies have mainly classified SDGs into social, economic, and environmental categories [22,23]. However, specific targets and indicators within each SDG may simultaneously have multiple social, economic, and environmental attributes [24]. For example, SDG8 (Decent Job and Economic Growth) is generally classified as "economic," but achieving SDG8 requires maintaining sustainable economic growth and reducing per capita material consumption, and the latter is related to the "environment". SDG6 (Clean Water and Sanitation), widely regarded as an "environmental"

goal, but achieving SDG6 not only requires improving water quality but also ensuring the proper allocation of water resources and related services. Hence, relying on social, economic, and environmental perspectives to analyze the SDGs will not adequately reflect the holistic and indivisibility of SDGs. It may even keep supporting the past siloed management style, which will not be conducive to the overall implementation of the SDGs.

To remedy the deficiencies of the traditional classification of SDGs, Fu et al. [3] divided seventeen SDGs into three categories, including "Essential Needs," "Objectives," and "Governance," based on the theory of coupled human and natural systems. The "Essential Needs" are the needs that sustain human survival. It comprises SDG2 (Zero Hunger), SDG6 (Clean Water and Sanitation), SDG7 (Affordable and Clean Energy), SDG14 (Life below Water), and SDG15 (Life on Land). The "Objectives" refer to the demands for a spiritual dimension based on the satisfaction of necessary subsistence and consists of SDG1 (No Poverty), SDG3 (Health and Well-Being), SDG4 (Quality Education), SDG5 (Gender Equality), SDG8 (Decent Job and Economic Growth), SDG10 (Reduced Inequalities) and SDG16 (Peace, Justice and Strong Institutions). In addition, "Governance" represents the key coordination measures to ensure synergy between "Essential Needs" and "Objectives." It is composed of SDG9 (Industry, Innovation and Infrastructure), SDG11 (Sustainable Cities and Communities), SDG12 (Responsible Production and Consumption), SDG13 (Climate Action) and SDG17 (Partnerships for the Goals).

In short, this framework emphasizes that appropriate governance will ensure the minimization of essential inputs and the maximization of desired goals. In other words, achieving SDGs in the "Governance" category can coordinate the competition between SDGs in the "Essential Needs" and "Objectives" categories. This coordination facilitates the overall implementation of all SDGs [3]. However, the framework still has not been applied to quantitative assessment. Applying it to quantitative assessment timely can fill the research gap

and compare the potential differences between qualitative analysis and quantitative assessment. Therefore, we quantify SDG interactions in China based on the systematic classification framework, combined with the corresponding statistical methods.

2.2. Data preparation and processing

To accurately quantify SDGs progress in each province, we reconstructed the assessment indicators applicable to China at the provincial scale based on the official SDGs indicator framework [25] and the relevant published literature [11,26]. Please see Supplementary Information 1 for the specific principles of indicator selection. However, it should be noted that as SDG14 (Life below Water) is concerned with marine ecosystems, more than half of China's provinces lack indicators related to it. Hence, the relationships between SDG14 and the other SDGs have not been considered in this assessment. Overall, 88 indicators are included in this assessment, which corresponds to 71 SDG targets and 16 SDGs. We collected the historical data for all indicators from different statistical departments since 1990 or when statistics were available (see Table S1 for details).

Given that the raw indicator data were not comparable with each other, we normalized the data to a score range of 0-100 by referring to the methodology in the report of SDG Index and Dashboards [21]. The normalization process requires setting target and baseline values for each indicator to eliminate the bias introduced by extreme values on the composite results (see Supplementary Information 1 for details). Subsequently, we further considered the attributes of the indicator changes, including positive, negative, and intermediate [27]. A positive attribute means that the larger the data, the better for sustainable development. A negative attribute means that the smaller the data, the better for sustainable development. An intermediate attribute means an intermediate value, and the smaller the difference from the value, the better for sustainable development. The indicators with different attributes were normalized separately using the following equation.

$$\text{Positive: } x' = \frac{x - x_{min}}{x_{max} - x_{min}} \times 100 \quad (1)$$

$$\text{Negative: } x' = \frac{x_{max} - x}{x_{max} - x_{min}} \times 100 \quad (2)$$

$$\text{Intermediate: } x' = \begin{cases} 100 - \dfrac{x_{mod} - x}{\max(x_{mod} - \min(x),\ \max(x) - x_{mod})} \times 100, & x < x_{mod} \\ 100 - \dfrac{x - x_{mod}}{\max(x_{mod} - \min(x),\ \max(x) - x_{mod})} \times 100, & x > x_{mod} \\ 100, & x = x_{mod} \end{cases} \quad (3)$$

where x is the original data value for each SDG indicator, x_{max} and x_{min} represent the target and baseline values of the original data for both positive and negative indicators, x_{int} is the target value of the original data for moderate indicators, and x' is the normalized score for a given SDG indicator. After normalization, the scores for all indicators range from 0 (baseline value) to 100 (target value) points. This normalization ensures that the adjusted variables are ascending and easy to understand, i.e., the higher the score is closer to sustainability. For example, a score of 50 for an indicator indicates that it is 50% achieved [21].

After obtaining the scores of each indicator, these scores are aggregated into the scores of the corresponding SDGs targets using the arithmetic mean method. Then they are further aggregated into the scores of SDGs [21]. In the aggregation process, each indicator has the same weight, indicating that each indicator has the same importance and is not influenced by subjectivity [21]. We use these SDG scores for synergy and trade-off analysis. Additionally, the existing indicator data is not consistent over time due to the limitation of data availability. To reflect the actual characteristics of the indicator as much as possible, we limit our assessment to the period for which data are available (Table S1). After aggregation, it is found that the earliest data available for the indicators within SDG15 (Life on Land) is since 2004. Consequently, the period of the SDG scores used for assessment in each province is 2004-2018.

2.3. Analysis of SDG interactions

This study uses multiple factor analysis (MFA) to quantify the synergies and trade-offs between different SDG categories while identifying key SDGs that influence the interactions through significance tests. MFA is an emerging statistical method since the 1980s [28]. It is

widely used to analyze correlations between multiple data sets by calculating RV coefficients [29]. In statistics, the RV coefficient is often considered as multiple generalizations of the Pearson correlation coefficient (r_p), i.e., the square of r_p. Thus its values range from 0 (mutually independent) to 1 (totally homogeneous) [30]. Josse et al. [29] provide a detailed description of the process of calculating the RV coefficient and how it is tested.

We used the "MFA" function in the FactoMineR package of R 4.0.3 software for MFA analysis and significance testing [31]. Although the RV coefficients do not reflect the directionality of the interaction between different data sets, the "MFA" function gives a "partial axes" plot, which reflects the projection of the principal components of different data sets onto the global principal component analysis. The angles between the principal components of different data sets reflect the direction of the interaction, where acute angles represent positive correlations, obtuse angles are negative correlations and tend to be orthogonal to indicate low correlations [31]. Therefore, we judged the trade-offs and synergies between different SDG categories based on the angle between different first principal components in the "partial axes" plot. To avoid over-interpretation of correlations, different thresholds were set for the RV coefficients in this study. With reference to related studies [6,7], we defined the coefficient values located in four different intervals [-1, -0.5], (-0.5, 0], (0, 0.5), and [0.5, 1] as a trade-off, weak trade-off, weak synergy, and synergy, respectively. In addition, the "MFA" function also gives the r_p between individual SDGs in the calculation of RV coefficients to help us analyze the impacts of key SDGs on the overall interactions [31].

Based on the above assessment process, we quantified the spatial differences in the SDG interactions and their temporal variation in China, respectively. For the spatial differences, we used time-series data (2004-2018) of SDG scores for each province to calculate the RV coefficients between the three SDG categories for 31 provinces separately. The "partial axes" plots of three SDG categories and correlations among individual SDGs for each province are

given in Supplementary Information 2 and 3. The figures are listed in alphabetical order according to the names of 31 provinces. For the temporal variations, we calculated the RV coefficients between the different SDG categories over the period 2004-2018 using cross-sectional data of SDG scores for 31 provinces per year. The "partial axes" plots of three SDG categories and correlations among individual SDGs for each year are given in Supplementary Information 4 and 5. The above two Supplemental Figures are in chronological order from 2004 to 2018.

3. Results

3.1. The spatial difference in SDG interactions

Our results show that the interactions between different SDG categories vary spatially across provinces. Overall, we found that the interactions between "Essential Needs" & "Governance" and "Essential Needs" & "Objectives" show trade-offs in most provinces (Fig. 1b,c), but synergies are mainly observed between "Governance" & "Objectives" (Fig. 1d). These results suggest that while in most provinces, the SDGs in the "Governance" category could contribute to the improvement of "Objectives," they have not reconciled the trade-offs between "Essential Needs" and "Objectives."

Specifically, for the interaction between "Essential Needs" & "Governance", Fig. 1b reveals that there are 18 provinces show trade-offs ($-1 \leq RV \leq -0.5$) and weak trade-offs ($-0.5 < RV \leq 0$), which are mainly distributed among the provinces in eastern China; meanwhile, we could see that 13 provinces with synergies ($0.5 \leq RV \leq 1$) and weak synergies ($0 < RV < 0.5$) are mainly found in western China. The spatial distribution of interactions between "Essential Needs" & "Objectives" is similar to the distribution between "Essential Needs" & "Governance" but with a difference in the degree of interaction (Fig. 1b,c). The difference is that the RV coefficients between "Essential Needs" & "Objectives" show stronger interaction, with 15 provinces showing trade-offs and 13 provinces with synergies (Fig. 1c). In addition, from Fig.

1d, the results find that interactions between "Governance" & "Objectives" show synergies in 28 provinces; and the weak synergies are found in Qinghai and Yunnan provinces, with the RV coefficients are 0.489 ($p < 0.01$) and 0.451($p < 0.01$), respectively. However, there is a trade-off between "Governance" & "Objectives" in Tibet, as the RV coefficient is -0.573 ($p < 0.01$). Overall, our results suggest that as some provinces in western China could show synergies among the three SDG categories, this may imply that these provinces have more potential to implement SDGs as a whole.

3.2. Temporal variation of SDG interactions

We analyzed cross-sectional data on indicator scores by province from 2004-2018 to understand the temporal variation of SDG interactions. Interestingly, we found an "inverted U-shaped" trend in the synergies between different SDG categories (Fig. 2). The "inverted U-shaped" curves between "Essential Needs" & "Objectives" and "Governance" & "Objectives" are significant ($p < 0.01$) but not significant between "Essential Needs" & "Governance" ($p > 0.05$). The synergies between "Essential Needs" & "Objectives" and "Governance" & "Objectives" have gradually weakened over the past decade. However, Fig. 2 also shows that the RV coefficients between "Governance" & "Objectives" are higher than those between the other two SDG categories at different times. For example, the RV coefficient between "Governance" & "Objectives" is 0.396 ($p < 0.01$) in 2018, but only 0.109 ($p > 0.05$) between "Essential Needs" & "Governance," and 0.098 ($p > 0.05$) between "Essential Needs" and "Objectives," respectively (Fig. 2). This result indicates that there is still a positive interaction between "Governance" and "Objectives." However, there is almost no correlation in the other two SDG categories.

3.3. Drivers for Spatio-temporal variation of SDGs interaction

We revealed the key SDGs that dominate SDG interactions' spatial and temporal variation by significance tests in the multiple factor analysis. Spatially, we found some similarities in the

key SDGs affecting the overall interaction among different SDG categories across provinces. However, there were also slight differences between several provinces (Table 1). In general, SDG6 (Clean Water and Sanitation) and SDG15 (Life on Land) play a significant role in the "Essential Needs" across provinces. For the "Governance" category, SDG11 (Sustainable Cities and Communities) was substantial in 25 provinces. At the same time, SDG12 (Responsible Production and Consumption), SDG13 (Climate Action), and SDG17 (Partnerships for the Goals) were significant in nine different provinces. Moreover, in the "Objectives" category, SDG1 (No Poverty), SDG5 (Gender Equality), and SDG10 (Reduced Inequalities) have significant effects in 29, 28, and 26 provinces, respectively (Table 1). However, it should be noted that the trade-offs between "Essential Needs" and other SDG categories are mainly influenced by SDG15 (Life on Land) and SDG7 (Affordable and Clean Energy). Meanwhile, SDG6 (Clean Water and Sanitation) generally has synergies with SDGs within other categories. The trade-offs between "Governance" and other SDG categories are mainly influenced by SDG12 (Responsible Production and Consumption). In addition, SDG16 (Peace, Justice and Strong Institutions) dominated the trade-offs between "Objectives" and other SDG categories.

Regarding the temporal variation, the key SDGs affecting the RV coefficients between the three SDG categories at different stages showed some variability (Table 2). In the years with high RV coefficients (e.g., in 2008, 2009, and 2014), SDG2 (Zero Hunger) and SDG6 (Clean Water and Sanitation) have a significant role in the "Essential Needs." They positively correlate with the SDGs in the other categories, thus making it possible to have a high RV coefficient between "Essential Needs" and the other two SDG categories. However, as the correlation between these SDGs (i.e., SDG2 and SDG6) and other SDGs weakened, SDG7 (Affordable and Clean Energy) gradually took a dominant role in "Essential Needs." The weak trade-offs and weak synergies between SDG7 (Affordable and Clean Energy) and other SDGs were

mainly manifested, and thus weakening the synergies between "Essential Needs" and other SDG categories.

4. Discussion

The effectiveness of actions and policies to advance the SDGs depends fundamentally on grasping the SDG interactions [19,32]. Global-scale analyses have pointed out that there will be variations in the interactions of the SDGs across regions and demographics [5,7]. So far, the trade-offs between certain SDGs have hardly been transformed [6]. Hence, performing assessments at the sub-national scale is necessary to explore the pathways for shifting the trade-offs into synergies.

Our results found a striking spatial variation in the synergies and trade-offs among the SDGs in China, with the trade-offs appearing significantly between "Essential Needs" & "Objectives," and "Essential Needs" & "Governance." These trade-offs are widely distributed in the eastern provinces of China. In contrast, the synergies appear in the central and western provinces of China. Although the eastern provinces have higher levels of sustainable development than those in the west [11], our results emphasize that progress made in these provinces for some SDGs may have come at the cost of other SDGs. Meanwhile, we found that SDG15 (Life on Land) significantly influences the trade-offs between "Essential Needs" & "Objectives." This finding exemplifies that past economic growth in these provinces has been detrimental to forest resources and biodiversity [33]. A series of ecological restoration projects being implemented in China is trying to increase forest cover. However, they still have little effect in protecting and restoring biodiversity [9,34]. China's Red List Index shows a declining trend, having fallen from 0.82 in 1993 to 0.73 in 2021 [35]. Hence, exploring win-win paths for ecological protection and economic development is always critical to address the trade-offs between "Essential Needs" & "Objectives."

Besides, the trade-off between "Governance" & "Essential Needs" is also noteworthy. Fu

et al. [3] point out that the SDGs in the "Governance" category should play a coordinating role, i.e., reducing the consumption of "Essential Needs" while facilitating the maximum output of "Objectives." Yet, we found that although there are synergies between "Governance" & "Objectives" in most provinces, the trade-offs and weak trade-offs between "Governance" & "Essential Needs" are generally observed in the provinces of eastern China. This finding implies that the SDGs in the "Governance" category are not making progress as desired. The results of the significance analysis show that the trade-offs between SDG12 (Responsible Production and Consumption) and the SDGs in other categories play a significant influence. Past assessments have shown that SDG12 (Responsible Production and Consumption) is characterized by a decline in most provinces in China [11,26], implying that current consumption and production patterns are unsustainable. While improving consumption and production patterns mitigates the disruption of critical Earth system processes by human activities [36], it requires substantial changes to existing behavior patterns. A few also argue that it may even negatively impact current economic development [37]. Hence, how to change the consumption and production patterns of human beings rationally and avoid its adverse effects may be essential for the realization of all SDGs.

Interestingly, our results also showed that synergies between all three SDG categories are mainly present in western China. These findings imply that these provinces have more plausible development paradigms. However, the assessment by Xu et al. [11] has indicated that progress in implementing the SDGs in these provinces is relatively slow. Maintaining the current progress rate would not ensure that these provinces could fully achieve the SDGs. Although western China usually has better resource advantages, such as abundant coal, oil, natural gas, and solar energy resources, other aspects of the natural environment, such as dry climate and complex topography, are usually limit the local economic development [38]. Since the reform and opening-up, China's economic growth has benefited more from economic trade in the

eastern plains and coastal provinces. However, the trade also required resources and energy support from the western region, thus increasing the pressure on resource extraction and environmental protection in the latter [10]. To promote the development of western provinces, the Chinese government has implemented a range of supportive policies, including infrastructure development, talent introduction, and ecological protection and restoration [39]. A combination of these efforts has led these provinces to exhibit synergistic interactions among SDGs. However, the potential challenge facing these regions may be accelerating the regional development process without breaking the synergy among the various SDGs.

Additionally, the assessment of SDG interactions from a cross-sectional perspective is gradually attracting attention. It could effectively reflect the consistency of development in different regions [6,18]. For China, we found that the synergy between different SDG categories has gradually decreased in the last decade. This decrease is partly caused by the differences in the progress or priority of different SDGs across provinces. Our results showed that while there is still a weak synergy between "Governance" and "Objectives" in 2018, there is almost no correlation between "Essential Needs" and other SDG categories. Through significance analysis, we found that the SDG that limits the synergy between "Essential Needs" and other categories is SDG7 (Affordable and Clean Energy). This may be due to the uneven progress of SDG7 across provinces, i.e., some provinces are faster while others are relatively slow, leading to that SDG7 having weak synergies and weak trade-offs with the SDGs in other categories.

Past assessment has shown that the score of SDG7 performs better in the Northwest and Southwest provinces and relatively poorly in other provinces [11]. Indeed, thermal power generation is still the dominant form of electricity generation in China, accounting for nearly 75% of total electricity generation each year. Nonetheless, clean energy generation is relatively low, and it is distributed unevenly across provinces due to the constraints of the natural environment [40]. For example, solar power is widely distributed in northwest China, where

has stronger solar radiation. Hydroelectric power is primarily concentrated in the Southwest provinces of China, where have the advantage of complex topography and an abundance of river flows [40,41]. In addition, although nuclear power generation is more efficient and promising, there are only eight provinces in China with nuclear power generation facilities due to the scarcity of uranium resources and the complexity of operating technologies [40,42]. Given the uneven progress of SDG7 in China, we, therefore, speculate that promoting a balanced development of SDG7 may be an effective way to promote synergies between "Essential Needs" and other SDG categories. Meanwhile, considering that Chinese government's commitment to achieving peak carbon emissions by 2030 and carbon neutrality by 2060, accelerating the development of clean energy is crucial. However, achieving carbon neutrality also requires more research to ensure that the expansion of clean energy does not compromise the consumption of other natural resources, such as water, food, and forests. Thus, advancing SDG7 (Affordable and Clean Energy) through the framework of the Food-Energy-Water (FEW) nexus would be an effective measure [43].

5. Conclusions

In this study, we quantify the synergies and trade-offs between three SDG categories ("Essential Needs", "Governance", and "Objectives") in China from both temporal and spatial perspectives and reveal the key SDGs that play the dominant role in the different interactions. Spatially, the interactions between different SDG categories somewhat differ across provinces, but enhancing synergies between SDG12 (Responsible Production and Consumption) and other SDGs will contribute to the implementation of SDGs in all provinces. Temporally, due to the differences in the development of SDG7 (Affordable and Clean Energy) in each province, the synergy between different SDG categories shows a weakening trend in the last decade. Therefore, it is of great significance to promote clean energy in each province to achieve the synergy among SDGs. However, we cannot ignore the uncertainty of the current results since

applying different classifications may have a significant impact on the results, while indicator selection is also one of the other influencing factors. Even so, the current results do reflect essential issues in China's progress toward sustainable development. Hence, our quantitative evidence could provide general guidance for SDGs achievement and the evolution of future sustainable development policies in China.

Although we initially quantify the spatial and temporal characteristics of SDG interactions in China. There are still some important gaps that need to be filled in the future. First, it is noteworthy that there are also synergies and trade-offs among SDGs within each category which are not discussed in this study. For example, for the "Essential Needs," the linkages between SDG2 (Zero Hungry), SDG6 (Clean Water and Sanitation), SDG7 (Affordable and Clean Energy) correspond to the FEW nexus. If the linkages of FEW nexus with other SDGs are further considered, some informative insights can also be detected. But this is beyond the scope of the current study, as we are concerned with applying the systematic classification framework of SDGs to quantitative assessments to inform national macro-management policies. Second, this study is an assessment at the goal level, yet to promote policy coherence across different sectors, there is a need to conduct relevant studies at the indicator level, including the non-linear relationships, threshold effects, and causality between different indicators. Overall, the assessment framework used in this study does provide some novel insights for understanding the SDG interactions on a sub-national scale, and it is also applicable to other countries and regions. Timely monitoring and assessing the interactions between SDGs at different scales is crucial for adjusting sustainable development policies. It will continue to be a research subject that requires attention even after 2030.

Conflict of interest

The authors declare that they have no conflict of interest.

Acknowledgments

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Author contributions

Bojie Fu designed the study. Junze Zhang collected the data. Junze Zhang, Shuai Wang, Prajal Pradhan, Wenwu Zhao performed most of the data analysis. Bojie Fu coordinated and supervised the study. Junze Zhang, Prajal Pradhan, and Bojie Fu drafted the manuscript. All authors reviewed the manuscript and approved it for submission.

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Figures captions

Fig.1. RV coefficients among different Sustainable Development Goal (SDG) categories in each province. (a) shows the SDGs systematic classification framework, which divided the seventeen SDGs into three categories, namely "Essential Needs", "Objectives", and "Governance" (Revised from Fu et al. [3]). Due to limitations in data availability, SDG14-related indicators were not available in all provinces, so this assessment did not consider SDG14 (Life below Water) in "Essential Needs." (b), (c) and (d) show the RV coefficients between "Essential Needs" & "Governance," "Essential Needs" & "Objectives," and "Governance" & "Objectives" in each province, respectively. Please note that (b), (c), and (d) were made based on the standard map downloaded from http://bzdt.ch.mnr.gov.cn/, and we did not make any changes to the base map. The standard map No. is GS(2019)1708.

Fig.2. The changing trend of RV coefficient among three Sustainable Development Goal categories from 2004 to 2018. (a), (b) and (c) show the changing trend of RV coefficients between "Essential Needs" & "Governance," "Essential Needs" & "Objectives," and "Governance" & "Objectives" from 2004 to 2018, respectively. The grey ribbon represents the 95% confidence interval of the regression curve (the blue line).

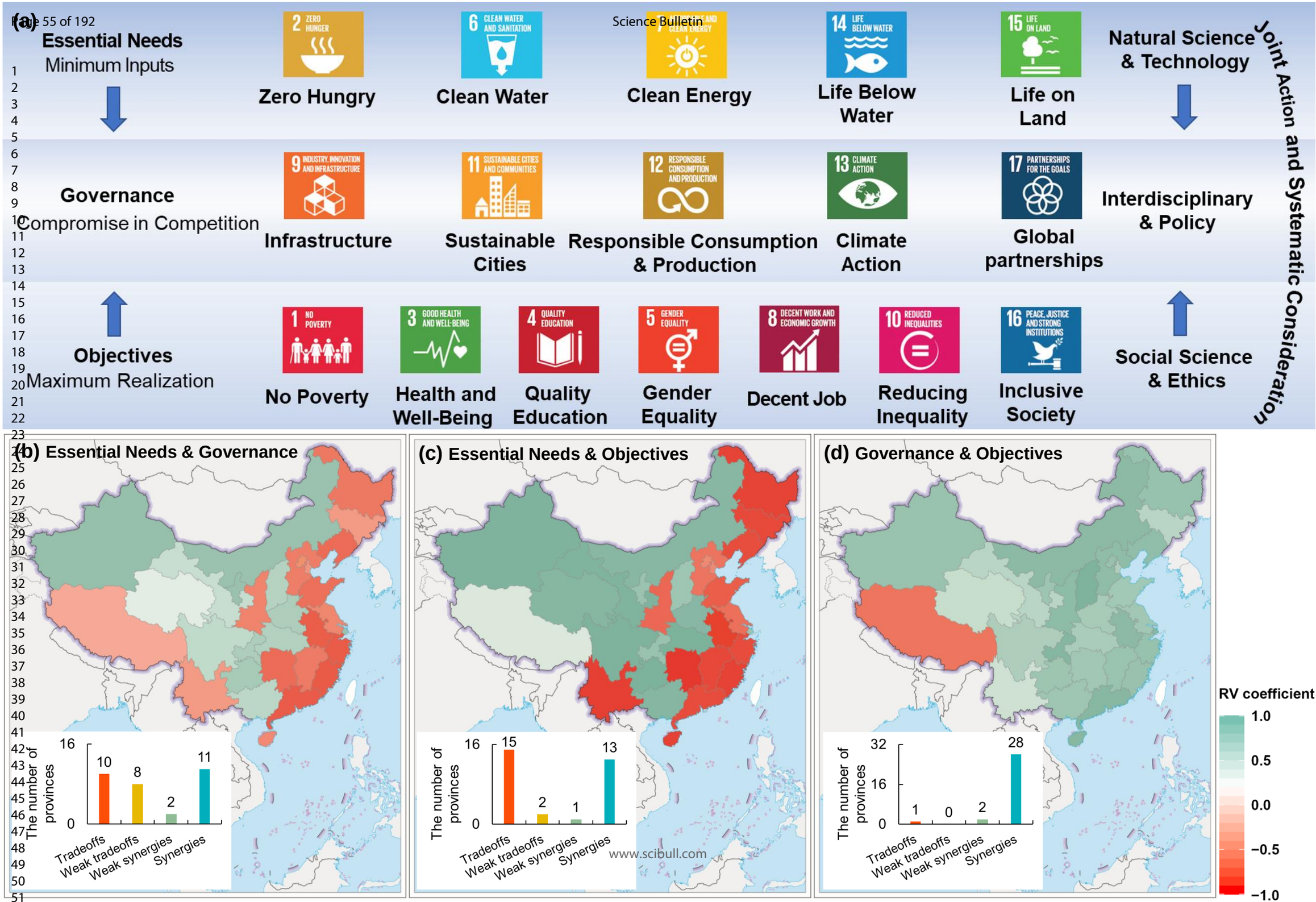
Tables

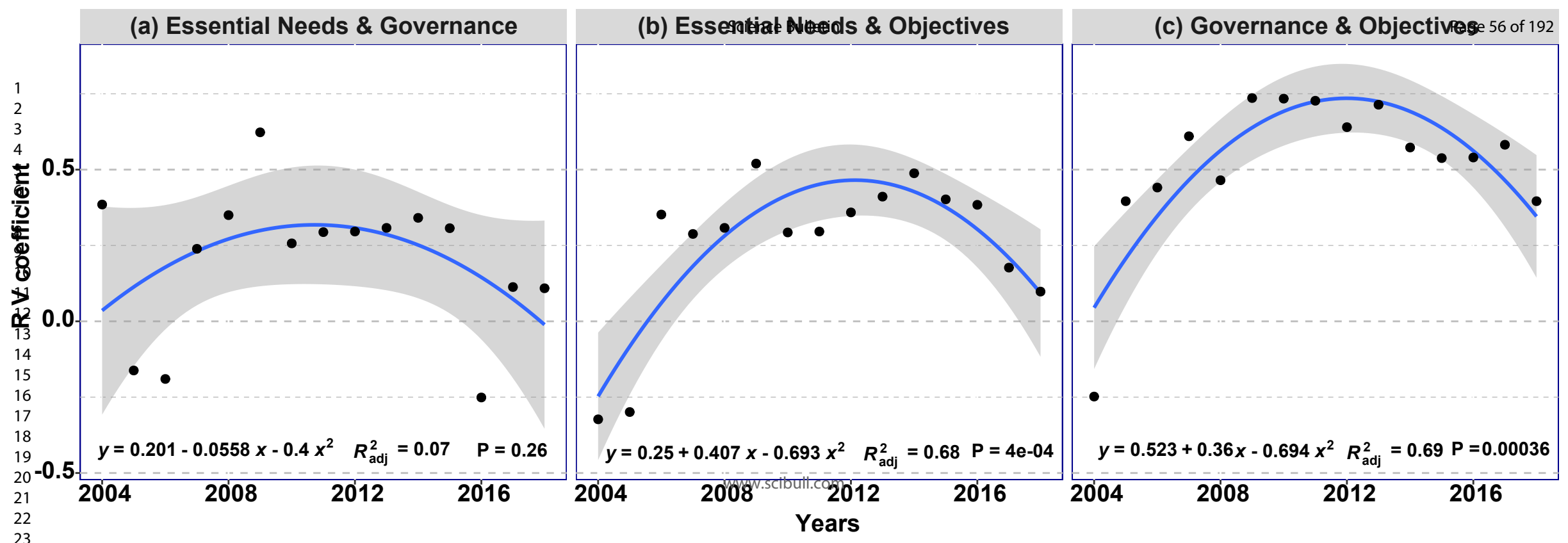
Table 1. Key Sustainable Development Goals (SDGs) affecting the RV coefficient among the SDG categories in each province.

Regions	Provinces	SDG categories		
		Essential Needs	Governance	Objectives
North China	Beijing	SDG6, SDG15	SDG13, SDG17	SDG1, SDG8, SDG10
	Tianjin	SDG6, SDG7	SDG12, SDG13, SDG17	SDG1, SDG5, SDG8, SDG10, SDG16
	Shanxi	SDG6	SDG11, SDG13	SDG1, SDG5, SDG8, SDG10, SDG16
	Hebei	SDG6	SDG11, SDG17	SDG1, SDG16
	Inner Mongolia	SDG6, SDG15	SDG11, SDG13	SDG1, SDG5, SDG8, SDG16
Eastern China	Shandong	SDG6, SDG15	SDG11, SDG12	SDG1, SDG5
	Shanghai	SDG6, SDG15	SDG13, SDG17	SDG1, SDG5, SDG8, SDG10
	Zhejiang	SDG6, SDG15	SDG11, SDG17	SDG1, SDG5, SDG8, SDG16
	Anhui	SDG6, SDG15	SDG9, SDG11	SDG1, SDG4, SDG5, SDG8, SDG10
	Jiangsu	SDG6, SDG15	SDG11, SDG12, SDG17	SDG1, SDG5, SDG8, SDG10, SDG16
	Fujian	SDG6, SDG15	SDG11, SDG17	SDG1, SDG5, SDG8, SDG10
	Jiangxi	SDG6, SDG15	SDG11	SDG1 SDG4, SDG5, SDG8, SDG10
Central China	Hubei	SDG6, SDG7, SDG15	SDG9, SDG11	SDG1, SDG5, SDG6, SDG8
	Hunan	SDG6, SDG15	SDG11	SDG1, SDG4, SDG5, SDG10
	Henan	SDG6	SDG11	SDG1, SDG4, SDG5, SDG10
South China	Guangdong	SDG6, SDG15	SDG11, SDG13, SDG17	SDG1, SDG3, SDG5, SDG8, SDG10
	Guangxi	SDG6, SDG15	SDG11	SDG1, SDG4, SDG5, SDG10
	Hainan	SDG6, SDG15	SDG11, SDG17	SDG1, SDG5, SDG8, SDG10
Southwest China	Sichuan	SDG6, SDG7, SDG15	SDG11, SDG12	SDG1, SDG4, SDG5, SDG10, SDG16
	Yunnan	SDG7, SDG15	SDG11, SDG12, SDG13	SDG1, SDG4, SDG5, SDG10
	Chongqing	SDG15	SDG11, SDG13	SDG1, SDG4, SDG5, SDG10
	Guizhou	SDG6, SDG7, SDG15	SDG11	SDG1, SDG4, SDG5, SDG10
	Tibet	SDG7	SDG12	SDG5, SDG10
Northeast China	Heilongjiang	SDG6, SDG15	SDG11	SDG1, SDG6, SDG10, SDG16
	Jilin	SDG6, SDG15	SDG11	SDG1, SDG5, SDG10
	Liaoning	SDG6, SDG15	SDG11, SDG17	SDG1, SDG5, SDG10
Northwest China	Shaanxi	SDG6, SDG15	SDG11	SDG1, SDG5, SDG8, SDG10
	Xinjiang	SDG6, SDG15	SDG12, SDG13	SDG3, SDG5, SDG10, SDG16
	Qinghai	SDG6, SDG7, SDG15	SDG12	SDG1, SDG3, SDG5, SDG8, SDG10, SDG16
	Ningxia	SDG6, SDG7, SDG15	SDG11, SDG12	SDG1, SDG3, SDG5, SDG8, SDG10
	Gansu	SDG6, SDG7, SDG15	SDG11	SDG1, SDG3, SDG5, SDG8, SDG10

Table 2. Key Sustainable Development Goals (SDGs) affecting the RV coefficient among the SDG categories in different periods.

Years	SDG categories		
	Essential Needs	Governance	Objectives
2004	SDG7	SDG9, SDG12, SDG17	SDG1, SDG4, SDG5, SDG8
2005	SDG15	SDG9, SDG11, SDG12, SDG13	SDG1, SDG3, SDG5
2006	SDG2, SDG7	SDG9, SDG11, SDG12, SDG13	SDG1, SDG4, SDG5, SDG8, SDG10
2007	SDG2, SDG7	SDG11, SDG13, SDG17	SDG1, SDG4, SDG5, SDG8, SDG10
2008	SDG2, SDG6, SDG7	SDG12, SDG17	SDG1, SDG3, SDG4, SDG5, SDG8
2009	SDG2, SDG6, SDG7	SDG11, SDG12, SDG13, SDG17	SDG1, SDG4, SDG5, SDG10
2010	SDG2, SDG15	SDG11, SDG13, SDG17	SDG1, SDG5, SDG8, SDG10, SDG16
2011	SDG2, SDG7	SDG11, SDG13, SDG17	SDG1, SDG5, SDG8, SDG10, SDG16
2012	SDG2	SDG13, SDG17	SDG1, SDG4, SDG5, SDG10, SDG16
2013	SDG2, SDG7	SDG11, SDG13, SDG17	SDG1, SDG4, SDG5, SDG10, SDG16
2014	SDG2, SDG6, SDG7	SDG9, SDG12, SDG17	SDG1, SDG4, SDG5, SDG10, SDG16
2015	SDG2, SDG6	SDG12, SDG17	SDG1, SDG4, SDG8, SDG10, SDG16
2016	SDG2, SDG7	SDG9, SDG12, SDG17	SDG1, SDG4, SDG8, SDG16
2017	SDG7	SDG9, SDG12, SDG17	SDG1, SDG8, SDG10, SDG16
2018	SDG7	SDG12, SDG13, SDG17	SDG1, SDG10, SDG16


(a)
Essential Needs
Minimum Inputs
Governance
Compromise in Competition
Objectives
Maximum Realization
Zero Hungry
Clean Water
Clean Energy
Life Below Water
Life on Land
Natural Science & Technology
Infrastructure
Sustainable Cities
Responsible Consumption & Production
Climate Action
Global partnerships
Interdisciplinary & Policy
No Poverty
Health and Well-Being
Quality Education
Gender Equality
Decent Job
Reducing Inequality
Inclusive Society
Social Science & Ethics
Joint Action and Systematic Consideration
(b) Essential Needs & Governance
(c) Essential Needs & Objectives
(d) Governance & Objectives
The number of provinces
Tradeoffs
Weak tradeoffs
Weak synergies
Synergies
10
8
2
11
15
2
1
13
1
0
2
28
RV coefficient
1.0
0.5
0.0
−0.5
−1.0
www.scibull.com


(a) Essential Needs & Governance
(b) Essential Needs & Objectives
(c) Governance & Objectives
RV coefficient
0.5
0.0
-0.5
2004
2008
2012
2016
Years
y = 0.201 - 0.0558 x - 0.4 x² R²adj = 0.07 P = 0.26
y = 0.25 + 0.407 x - 0.693 x² R²adj = 0.68 P = 4e-04
y = 0.523 + 0.36 x - 0.694 x² R²adj = 0.69 P = 0.00036
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Supplementary Information 1 – Table S1 and S2

Untangling the interactions between the Sustainable Development Goals in China

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SUPPLEMENTARY METHODS

Selection of indicators

Here, we introduce the process of selecting the indicators for our study. To ensure the representativeness of indicators, we used official SDG indicators approved by the United Nations Statistics Division in 2017 [1], those applied in the 2019 Sustainable Development Report [2], and related published literature [3]. However, when identical indicators proved unobtainable, we utilized indicators that corresponded as closely as possible to those according to official SDGs and SDG targets. Generally, we complied with the five criteria for selecting indicators in the 2019 Sustainable Development Report [2], with some adjustments necessitated by scale and data availability issues. Firstly, selected indicators must be considered to have policy relevance, i.e., provide evidence suitable for the monitoring and implementation of SDGs. Secondly, indicators must be universally, or at least broadly accessible, i.e., indicator data are available across provinces to allow for inter-provincial comparisons. Thirdly, indicators need to have reasonable reference ranges or thresholds that can be used to determine whether they are in a reasonable state. Fourthly, indicators must exhibit timeliness, be available continuously or at regulated intervals to facilitate monitoring of trends. Fifthly, indicators must be statistically reliable to ensure that the indicator data meets the quality standards of official statistics. Considering that the indicator data related to SDG14 (Life Below Water) can be obtained in only 11 provinces, SDG14 was not considered in this assessment. The list of SDG indicators includes a total of 88 indicators, which correspond to 71 SDG targets and 16 goals (Table S1).

However, we acknowledge that the indicators chosen in this paper do not represent a perfect assessment criterion. It can only be considered as a reference framework that satisfies the above principles of indicator selection, and some indicators may be replaced by others. Taking the indicators for SDG13 as an example, SDG13 has five Targets, including Targets

13.1, 13.2, 13.3, 13.a, and 13.b. However, in the official SDG indicator framework, different Targets have different numbers of indicators [1]. For example, Target 13.1 has three indicators, namely indicators 13.1.1, 13.1.2, and 13.1.3, but Target 13.2 has only one indicator, e. i., indicator 13.2.1. In this study, after considering the requirements of the official indicator framework and other indicators relevant to SDG13 in the published literature, we found that only indicators 13.1.1 (The proportion of the population affected by natural disasters to the total population (%)) and 13.2.1 (SO_2 emissions per capita (kg/person)) were available for the 31 provinces. Therefore, we chose these two indicators for our assessment.

In addition, it should be noted that the content of indicator13.1.1 is fully consistent with the official indicator framework, but for indicator13.2.1 we have selected indicators that are applicable at the provincial level in China. This is because the official SDG indicator framework does not give specific recommendations for indicator13.2.1, and other studies have used different indicators such as Energy-related CO_2 emissions per capita (tCO_2/capita) [2]. However, there is a lack of official statistics on CO_2 emissions by provinces in China. Considering that the reduction of SO_2 emissions is one of the important processes in the fight against air pollution and climate change [4,5], and that SO_2-related indicators are available in China's official statistics (Table S1). We, therefore, chose to use SO_2 emissions per capita (kg/person) to represent indicator13.2.1. Generally, although we have constructed the indicator framework that is applicable at the provincial scale in China, it will be necessary to upgrade the existing indicators in the future with the improvement of data availability, thereby enhancing the reliability of the assessment results.

Indicator baseline and target values

By normalizing the raw indicator data to a score range of 0-100, the change in the indicators can be comparable [6]. However, normalization is sensitive to extreme values. To minimize the possible effect of extreme values on both tails of the data distribution, we reset

the target and baseline values for each indicator by referring to the methodology in the report of SDG Index and Dashboards [2,6], rather than using the maximum and minimum values of the indicator for normalization. The target value is the level at which the indicator is considered to have accomplished its task. The baseline value is a reasonable initial value for assessment.

Regarding target values, firstly, we adopted those used in the 2019 Sustainable Development Report or published literature [2,3] (28 out of 88 indicators). Secondly, we used the absolute or relative quantitative thresholds of SDGs and targets [7] (25 out of 88 indicators). Thirdly, we employed the principle of "leave no one behind" [7] (11 out of 88 indicators) to determine the target value for the SDGs where no explicit target is stated, as is the case for SDG9 (Industry, Innovation and Infrastructure) and SDG6 (Clean Water and Sanitation). Fourthly, we set the target value equal to the mean of the top five values exhibited at provincial levels in China for all other indicators (24 out of 88 indicators). It is important to emphasize that as we are concerned with the comparison of indicators across Chinese provinces. Therefore, the target values set through the fourth approach are not necessarily applicable to other countries and regions. Furthermore, using the arithmetic average of the five best performers to set target values does not mean that these provinces have achieved the corresponding indicators. This approach is only an exploratory assessment within the constraints of data availability. Overall, these target values are subject to change as assessment methods, and data availability improves, and all target values for each indicator and their reference sources are given in Table S2.

For baseline values, we also initially adopted those used in the 2019 Sustainable Development Report or cited literature as appropriate [2,3]. To ensure representability of the baseline values chosen for other SDG indicators, we collated the data for each indicator in all 31 provinces from 1990 (or from when the data became available) to 2018 and determined the lowest 2.5% value for each one following the method in the report of SDG Index and Dashboards [2] (Table S2).

SUPPLEMENTARY TABLES

Table S1. Indicators selected in this study and their data sources.

Goals	Targets	Indicators		Time range	Data source
Goal 1. End poverty in all its forms everywhere					
1	1.2 By 2030, reduce at least by half the proportion of men, women and children of all ages living in poverty in all its dimensions according to national definitions	1.2.1	Rural poverty incidence (%)	2010-2018	Poverty Monitoring Report of Rural China (2019) [8]
1	1.3 Implement nationally appropriate social protection systems and measures for all, including floors, and by 2030 achieve substantial coverage of the poor and the vulnerable	1.3.1	Unemployment insurance coverage rate (%)	2000-2018	China Labour Statistical Yearbook (2001-2019) [9]
1	1.4 By 2030, ensure that all men and women, in particular the poor and the vulnerable, have equal rights to economic resources, as well as access to basic services, ownership and control over land and other forms of property, ...	1.4.1	The penetration rate of sanitary toilet in rural area (%)	2008-2018	China Rural Statistical Yearbook (2009-2019) [10]
1	1.5 By 2030, build the resilience of the poor and those in vulnerable situations and reduce their exposure and vulnerability to climate-related extreme events and other economic, social and environmental shocks and disasters	1.5.1	The proportion of the population affected by natural disasters to the total population (%)	2005-2018	China Statistical Yearbook on Environment (2006-2019) [11]
1	1.5	1.5.2	The direct economic losses caused by natural disasters as a percentage of GDP (%)	2005-2018	China Statistical Yearbook on Environment (2006-2019) [11]
Goal 2. End hunger, achieve food security and improved nutrition and promote sustainable agriculture					
2	2.1 By 2030, end hunger and ensure access by all people, in particular the poor and people in vulnerable situations, including infants, to safe, nutritious and sufficient food all year round	2.1.1	Number of patients with foodborne diseases (per million population)	2012-2018	China Health Statistics Yearbook (2013-2019) [12]
2	2.1	2.1.2	Cereal yield per unit area (tons/ha)	1991-2018	China Statistics Yearbook (1992-2019) [13]

2	2.2 By 2030, end all forms of malnutrition, including achieving, by 2025, the internationally agreed targets on stunting and wasting in children under 5 years of age, and address the nutritional needs of adolescent girls, …	2.2.2	Proportion of moderate to severe malnutrition in children under 5 years old (%)	2002-2018	China Social Statistical Yearbook (2003-2019) [14]
2	2.a Increase investment, including through enhanced international cooperation, in rural infrastructure, agricultural research and extension services, technology development and …	2.a.1	Agriculture orientation index for government expenditures	2007-2018	China Statistical Yearbook (2008-2019) [13]
Goal 3. Ensure healthy lives and promote well-being for all at all ages					
3	3.1 By 2030, reduce the global maternal mortality ratio to less than 70 per 100,000 live births	3.1.1	Maternal mortality (per 100,000 live births)	2004-2018	China Health Statistical Yearbook (2005-2019) [12]
3	3.1	3.1.2	Proportion of births attended by skilled health personnel (%)	2002-2018	China Health Statistical Yearbook (2003-2019) [12]
3	3.2 By 2030, end preventable deaths of newborns and children under 5 years of age, with all countries aiming to reduce neonatal mortality to at least as low as 12 per 1,000 live births and …	3.2.1	Percentage of infants with birth weight <2500 grams (%)	2002-2018	China Health Statistical Yearbook (2003-2019) [12]
3	3.2	3.2.2	Perinatal mortality rate	2002-2018	China Health Statistical Yearbook (2003-2019) [12]
3	3.3 By 2030, end the epidemics of AIDS, tuberculosis, malaria and neglected tropical diseases and combat hepatitis, water-borne diseases and other communicable diseases	3.3.1	AIDS incidence per 100,000 population	2002-2018	China Health Statistical Yearbook (2003-2019) [12]
3	3.3	3.3.2	Tuberculosis incidence per 100,000 population	2002-2018	China Health Statistical Yearbook (2003-2019) [12]
3	3.3	3.3.3	Malaria incidence per 100,000 population	2002-2018	China Health Statistical Yearbook (2003-2019) [12]
3	3.3	3.3.4	Hepatitis B incidence per 100,000 population	2002-2018	China Health Statistical Yearbook (2003-2019) [12]
3	3.3	3.3.5	Schistosomiasis incidence per 100,000 population	2005-2018	China Health Statistical Yearbook (2006-2019) [12]
3	3.6 By 2020, halve the number of global deaths and injuries from road traffic accidents	3.6.1	Death rate due to road traffic injuries (per 100,000 population)	1999-2018	China Statistical Yearbook (2000-2019) [13]

3	3.8 Achieve universal health coverage, including financial risk protection, access to quality essential health-care services and access to safe, effective, quality and affordable essential medicines and vaccines for all	3.8.1	The proportion of urban residents covered by basic medical insurance in the total population (%)	2007-2018	China Labour Statistical Yearbook (2008-2019) [9]
3	3.9 By 2030, substantially reduce the number of deaths and illnesses from hazardous chemicals and air, water and soil pollution and contamination	3.9.1	Keshan disease incidence per 100,000 population	2002-2018	China Health Statistical Yearbook (2003-2019) [12]
3	3.b Support the research and development of vaccines and medicines for the communicable and non-communicable diseases that primarily affect developing countries, provide access to affordable essential medicines and vaccines, …	3.b.2	The proportion of local medical and health expenditure in the fiscal budget (%)	2007-2018	China Statistical Yearbook (2008-2019) [13]
3	3.c Substantially increase health financing and the recruitment, development, training and retention of the health workforce in developing countries, …	3.c.1	Number of health worker per 10,000 population	2008-2018	China Health Statistical Yearbook (2009-2019) [12]
Goal 4. Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all					
4	4.3 By 2030, ensure equal access for all women and men to affordable and quality technical, vocational and tertiary education, including university	4.3.1	Proportion of population aged 6 and over without education (%)	2004-2018	China Statistical Yearbook (2005-2019) [13]
4	4.4 By 2030, substantially increase the number of youth and adults who have relevant skills, including technical and vocational skills, for employment, decent jobs and entrepreneurship	4.4.1	Percentage of population receiving higher education (%)	2004-2018	China Statistical Yearbook (2005-2019) [13]
4	4.5 By 2030, eliminate gender disparities in education and ensure equal access to all levels of education and vocational training for the vulnerable, including persons with disabilities, indigenous peoples and children in vulnerable situations	4.5.1	Difference in the ratio of male and female educated over 6 years old (%)	2004-2018	China Statistical Yearbook (2005-2019) [13]
4	4.6 By 2030, ensure that all youth and a substantial proportion of adults, both men and women, achieve literacy and numeracy	4.6.1	Percentage of illiterate and semi-illiterate population over 15 (%)	1996-2018	China Statistical Yearbook (1997-2019) [13]

4	4.a Build and upgrade education facilities that are child, disability and gender sensitive and provide safe, non-violent, inclusive and effective learning environments for all	4.a.1	The ratio of the number of pupils in school to the number of computers	2003-2018	Educational Statistics Yearbook of China (2004-2019) [15]
4	4.b By 2020, substantially expand globally the number of scholarships available to developing countries, in particular least developed countries, small island developing States and African countries, …	4.b.1	Education expenditure as a percentage of fiscal expenditure	2007-2018	China Statistical Yearbook (2008-2019) [13]
4	4.c By 2030, substantially increase the supply of qualified teachers, including through international cooperation for teacher training in developing countries, especially least developed countries and small island developing States	4.c.1	The ratio of the teacher-student ratio of urban elementary schools to that of rural elementary schools	1999-2018	Educational Statistics Yearbook of China (2000-2019) [15]
Goal 5. Achieve gender equality and empower all women and girls					
5	5.5 Ensure women's full and effective participation and equal opportunities for leadership at all levels of decision-making in political, economic and public life	5.5.1	Proportion of female employees in civil affairs deparment	1997-2018	China Civil Affairs Statistical Yearbook (1998-2019) [16]
5	5.5	5.5.2	Proportion of female employees in urban units	2000-2018	China Labour Statistical Yearbook (2001-2019) [9]
5	5.6 Ensure universal access to sexual and reproductive health and reproductive rights as agreed in accordance with the Programme of Action of the International Conference on Population and Development…	5.b.1	Mobile phone penetration rate (the number of mobile phones per 100 people)	2005-2018	China Statistical Yearbook (2006-2019) [13]
Goal 6. Ensure availability and sustainable management of water and sanitation for all					
6	6.1 By 2030, achieve universal and equitable access to safe and affordable drinking water for all	6.1.1	The proportion of the population benefiting from the treated water in the total population of the sick area — Endemic fluorosis (water type) (%)	2002-2018	China Health Statistical Yearbook (2003-2019) [12]
6	6.2 By 2030, achieve access to adequate and equitable sanitation and hygiene for all and end open defecation, paying special attention to the needs of women and girls and those in vulnerable situations	6.2.1	The penetration rate of sanitary toilet in rural area (%)	2008-2018	China Rural Statistical Yearbook (2009-2019) [10]
6	6.3 By 2030, improve water quality by	6.3.1	Sewage treatment rate in cities (%)	2002-2018	China Urban Construction Statistical Yearbook

	reducing pollution, eliminating dumping and minimizing release of hazardous chemicals and materials, halving the proportion of untreated wastewater…				(2003-2019) [17]
6	6.4 By 2030, substantially increase water-use efficiency across all sectors and ensure sustainable withdrawals and supply of freshwater to address water scarcity…	6.4.1	Water-use efficiency (m^3/RMB)	2003-2018	China Statistical Yearbook (2004-2019) [13]
6	6.4	6.4.2	Ratio of total water consumption to total water resources (%)	2003-2018	China Statistical Yearbook (2004-2019) [13]
6	6.a By 2030, expand international cooperation and capacity-building support to developing countries in water- and sanitation-related activities and programmes, …	6.a.1	Investment in environmental pollution control as a percentage of GDP (%)	2003-2018	China Statistical Yearbook on Environment (2004-2019) [11]
Goal 7. Ensure access to affordable, reliable, sustainable and modern energy for all					
7	7.1 By 2030, ensure universal access to affordable, reliable and modern energy services	7.1.2	Gas penetration rate in cities (%)	1999-2018	China Statistical Yearbook (2000-2019) [13]
7	7.2 By 2030, increase substantially the share of renewable energy in the global energy mix	7.2.1	Proportion of clean energy power generation to total power generation (%)	1995-2018	China Energy Statistical Yearbook (1996-2019) [18]
7	7.3 By 2030, double the global rate of improvement in energy efficiency	7.3.1	Energy intensity (ton standard coal per 10,000 RMB)	2000-2018	China Energy Statistical Yearbook (2001-2019) [18]
Goal 8. Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all					
8	8.1 Sustain per capita economic growth in accordance with national circumstances and, in particular, at least 7 per cent gross domestic product growth per annum in the least developed countries	8.1.1	Annual growth rate of real GDP per capita (%)	1994-2018	China Statistical Yearbook (1995-2019) [13]
8	8.4 Improve progressively, through 2030, global resource efficiency in consumption and production and endeavour to decouple economic growth from environmental degradation, …	8.4.2	Wood consumption per unit of added value of construction industry (m^3/10,000 yuan)	2004-2018	China Statistical Yearbook on Construction (2005-2019) [19]
8	8.5 By 2030, achieve full and productive employment and decent work for all women and men, including for young people and persons with disabilities, and	8.5.2	The urban registered unemployment rate (%)	1999-2018	China Statistical Yearbook (2000-2019) [13]

	equal pay for work of equal value				
8	8.6 By 2020, substantially reduce the proportion of youth not in employment, education or training	8.6.1	Proportion of employed persons who have never attended school (%)	1996-2018	China Labour Statistical Yearbook (1997-2019) [9]
8	8.8 Protect labour rights and promote safe and secure working environments for all workers, including migrant workers, in particular women migrants, and those in precarious employment	8.8.1	The determination of work-related injuries per 10,000 employed persons	2006-2018	China Labour Statistical Yearbook (2007-2019) [9]
8	8.8	8.8.2	Work-related injury insurance coverage rate (%)	2003-2018	China Labour Statistical Yearbook (2004-2019) [9]
8	8.9 By 2030, devise and implement policies to promote sustainable tourism that creates jobs and promotes local culture and products	8.9.1	The added value of the tertiary industry as a proportion of GDP (%)	1996-2018	China Statistical Yearbook (1997-2019) [13]
Goal 9. Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation					
9	9.1 Develop quality, reliable, sustainable and resilient infrastructure, including regional and trans-border infrastructure, to support economic development and human well-being, …	9.1.2	Railway passenger density (the ratio of passenger turnover to mileage of operating lines)	1990-2018	China Statistical Yearbook (1991-2019) [13]
9	9.2 Promote inclusive and sustainable industrialization and, by 2030, significantly raise industry's share of employment and gross domestic product, in line with national circumstances, …	9.2.1	The ratio of industrial added value to gross national product (%)	2000-2018	China Statistical Yearbook (2001-2019) [13]
9	9.3 Increase the access of small-scale industrial and other enterprises, in particular in developing countries, to financial services, including affordable credit, and their integration into value chains and markets	9.3.1	The sales output value of small industrial enterprises as a percentage of the industrial sales output value (%)	2001-2018	China Industry Statistical Yearbook (2002-2019) [9]
9	9.4 By 2030, upgrade infrastructure and retrofit industries to make them sustainable, with increased resource-use efficiency and greater adoption of clean and environmentally sound technologies and …	9.4.1	Waste gas emissions per unit of industrial added value (m^3/RMB)	1993-2018	China Statistical Yearbook on Environment (1994-2019) [11]
9	9.5 Enhance scientific research, upgrade the technological capabilities of industrial sectors in all countries, in particular	9.5.1	Research and development expenditure as a proportion of GDP (%)	2006-2018	China Statistical Yearbook on Science and Technology (2007-2019) [20]

	developing countries, including, by 2030, encouraging innovation and …				
9	9.5	9.5.2	Researchers (in full-time equivalent) as a proportion of total population (%)	2009-2018	China Statistical Yearbook on Science and Technology (2010-2019) [20]
9	9.a Facilitate sustainable and resilient infrastructure development in developing countries through enhanced financial, technological and technical support to African countries, least developed countries, …	9.a.1	Investment in environmental pollution control as a percentage of GDP (%)	2003-2018	China Statistical Yearbook on Environment (2004-2019) [11]
9	9.c Significantly increase access to information and communications technology and strive to provide universal and affordable access to the Internet in least developed countries by 2020	9.c.1	Number of 4G mobile phones used per 100 people	2014-2018	China Statistical Yearbook (2015-2019) [13]
Goal 10. Reduce inequality within and among countries					
10	10.1 By 2030, progressively achieve and sustain income growth of the bottom 40 per cent of the population at a rate higher than the national average	10.1.1	Ratio of income of urban and rural residents (income of rural residents = 1)	2006-2018	China Rural Statistical Yearbook (2007-2019) [10]
10	10.4 Adopt policies, especially fiscal, wage and social protection policies, and progressively achieve greater equality	10.4.1	Proportion of total wages of employed persons in urban units to regional GDP	2000-2018	China Labour Statistical Yearbook (2001-2019) [9]
10	10.5 Improve the regulation and monitoring of global financial markets and institutions and strengthen the implementation of such regulations	10.5.1	The proportion of non-performing loans of commercial banks to total loans (%)	2006-2018	Almanac of China's Finance and Banking (2007-2019) [21]
Goal 11. Make cities and human settlements inclusive, safe, resilient and sustainable					
11	11.1 By 2030, ensure access for all to adequate, safe and affordable housing and basic services and upgrade slums	11.1.1	Basic pension insurance coverage rate	2010-2018	China Labour Statistical Yearbook (2011-2019) [9]
11	11.2 By 2030, provide access to safe, affordable, accessible and sustainable transport systems for all, improving road safety, notably by expanding public transport, …	11.2.1	Number of buses per 10,000 people	1996-2018	China Statistical Yearbook (1997-2019) [13]
11	11.3 By 2030, enhance inclusive and sustainable urbanization and capacity for participatory, integrated and sustainable	11.3.1	The ratio of the growth rate of construction land to the growth rate of urban population	2013-2018	China Urban Construction Statistical Yearbook (2014-2019) [17]

	human settlement planning and management in all countries				
11	11.5 By 2030, significantly reduce the number of deaths and the number of people affected and substantially decrease the direct economic losses relative to global gross domestic product caused by disasters, …	11.5.1	The proportion of the population affected by natural disasters to the total population (%)	2005-2018	China Statistical Yearbook on Environment (2006-2019) [11]
11	11.5	11.5.2	The direct economic losses caused by natural disasters as a percentage of GDP (%)	2005-2018	China Statistical Yearbook on Environment (2006-2019) [11]
11	11.6 By 2030, reduce the adverse per capita environmental impact of cities, including by paying special attention to air quality and municipal and other waste management	11.6.1	Harmless treatment rate of household waste (%)	2003-2018	China Statistical Yearbook (2004-2019) [13]
11	11.6	11.6.2	Proportion of days with air quality reaching level 2 or higher within a year	2005-2018	China Environment Yearbook (2006-2019) [22]
11	11.7 By 2030, provide universal access to safe, inclusive and accessible, green and public spaces, in particular for women and children, older persons and persons with disabilities	11.7.1	Park green area per capita (m^2/person)	1999-2018	China Statistical Yearbook (2000-2019) [13]
Goal 12. Ensure sustainable consumption and production patterns					
12	12.2 By 2030, achieve the sustainable management and efficient use of natural resources	12.2.1	SO_2 emissions per capita (kg/person)	2002-2018	China Statistical Yearbook (2003-2019) [13]
12	12.2	12.2.2	Wood consumption per unit of added value of construction industry (m^3/10,000 yuan)	2004-2018	China Statistical Yearbook on Construction (2005-2019) [19]
12	12.4 By 2020, achieve the environmentally sound management of chemicals and all wastes throughout their life cycle, in accordance with agreed international frameworks, and …	12.4.2	Amount of hazardous waste generated per capita (kg/person)	1999-2018	China Statistical Yearbook on Environment (2000-2019) [11]
12	12.5 By 2030, substantially reduce waste generation through prevention, reduction, recycling and reuse	12.5.1	Comprehensive utilization rate of industrial solid waste (%)	2000-2018	China Statistical Yearbook (2001-2019) [13]
Goal 13. Take urgent action to combat climate change and its impacts					
13	13.1 Strengthen resilience and adaptive capacity to climate-related hazards and	13.1.1	The proportion of the population affected by natural disasters to the total population (%)	2005-2018	China Statistical Yearbook on Environment (2006-2019) [11]

	natural disasters in all countries				
13	13.2 Integrate climate change measures into national policies, strategies and planning	13.2.1	SO_2 emissions per capita (kg/person)	2002-2018	China Statistical Yearbook (2003-2019) [13]
Goal 15. Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss					
15	15.1 By 2020, ensure the conservation, restoration and sustainable use of terrestrial and inland freshwater ecosystems and their services, in particular forests, wetlands, mountains and drylands, …	15.1.1	Forest cover rate	2004-2018	China Statistical Yearbook (2005-2019) [13]
15	15.1	15.1.2	The area of wetland ecological nature reserve accounts for the proportion of forestry system nature reserve area	2009-2018	China Forestry and Grassland Yearbook (2010-2019) [23]
15	15.2 By 2020, promote the implementation of sustainable management of all types of forests, halt deforestation, restore degraded forests and substantially increase afforestation and reforestation globally	15.2.1	The area of forest ecological nature reserves accounts for the proportion of forestry system nature reserves	2009-2018	China Forestry and Grassland Yearbook (2010-2019) [23]
15	15.3 By 2030, combat desertification, restore degraded land and soil, including land affected by desertification, drought and floods, and strive to achieve a land degradation-neutral world	15.3.1	The proportion of desertified land in total land area (%)	2004-2018	China Statistical Yearbook on Environment (2005-2019) [11]
15	15.4 By 2030, ensure the conservation of mountain ecosystems, including their biodiversity, in order to enhance their capacity to provide benefits that are essential for sustainable development	15.4.1	The proportion of the area of wild animal and plant nature reserves in the area of nature reserves in the forestry system	2009-2018	China Forestry and Grassland Yearbook (2010-2019) [23]
15	15.5 Take urgent and significant action to reduce the degradation of natural habitats, halt the loss of biodiversity and, by 2020, protect and prevent the extinction of threatened species	15.5.1	Ecological protection and construction investment as a percentage of forestry investment	2011-2018	China Forestry and Grassland Yearbook (2012-2019) [23]
15	15.a Mobilize and significantly increase financial resources from all sources to conserve and sustainably use biodiversity and ecosystems	15.a.1	Forestry investment as a percentage of GDP	2011-2018	China Forestry and Grassland Yearbook (2012-2019) [23]

15	15.b Mobilize significant resources from all sources and at all levels to finance sustainable forest management and provide adequate incentives to developing countries to advance such management, …	15.b.1	State investment as a percentage of forestry investment	2011-2018	China Forestry and Grassland Yearbook (2012-2019) [23]
Goal 16. Promote peaceful and inclusive societies for sustainable development, provide access to justice for all and build effective, accountable and inclusive institutions at all levels					
16	16.7 Ensure responsive, inclusive, participatory and representative decision-making at all levels	16.7.1	Proportion of female employees in administrative agencies of civil affairs departments	1997-2018	China Civil Affairs Statistical Yearbook (1998-2019) [16]
16	16.10 Ensure public access to information and protect fundamental freedoms, in accordance with national legislation and international agreements	16.10.2	The proportion of rural cable radio and television users to the total number of households in rural area	2010-2018	China Statistical Yearbook of the Tertiary Industry (2011-2019) [24]
Goal 17. Strengthen the means of implementation and revitalize the Global Partnership for Sustainable Development					
17	17.1 Strengthen domestic resource mobilization, including through international support to developing countries, to improve domestic capacity for tax and other revenue collection	17.1.1	Local government general budget revenue as a percentage of GDP	2000-2018	Finance Yearbook of China (2001-2019) [25]
17	17.1	17.1.2	Local government tax as a percentage of fiscal revenue	2002-2018	China Statistical Yearbook (2003-2019) [13]
17	17.6 Enhance North-South, South-South and triangular regional and international cooperation on and access to science, technology and innovation and enhance knowledge-sharing on mutually agreed terms, …	17.6.2	Number of computers per 100 households	2015-2018	China Statistical Yearbook (2016-2019) [13]
17	17.8 Fully operationalize the technology bank and science, technology and innovation capacity-building mechanism for least developed countries by 2017 and enhance the use of enabling technology, in particular information and communications technology	17.8.1	Internet penetration rate (Internet users as a percentage of the total population)	2002-2018	China Statistical Yearbook (2003-2019) [13]

Table S2. Descriptive statistics of SDG indicators and their attribute characteristics.

Goals	Targets	Indicators	Target value	Baseline value	Attributes	Sample size	Minimum	Maximum	Average	Standard Deviation	Percentile: 2.5%	Percentile: 97.5%	Sources for Target Values
1	1.2	1.2.1	0	72.6	Negative	253	0.2	49.2	10.05	9.15	0.74	38.32	Sachs et al. (2019) [2]
	1.3	1.3.1	100	3.44175	Positive	608	2.39	57.6	10.82	7.62	3.39	31.53	Xu et al. (2020) [3]
	1.4	1.4.1	100	9.7	Positive	344	32.6	99.8	71.95	16.46	38.39	98.48	Sachs et al. (2019) [2]
	1.5	1.5.1	0	67.15	Negative	411	0	107.1	24.63	19.02	0.52	67.14	Xu et al. (2020) [3]
		1.5.2	0	5	Negative	407	0	17.6	1.02	1.54	0.01	5.01	Xu et al. (2020) [3]
2	2.1	2.1.1	0	77.4162	Negative	217	0.13	108.38	20.45	19.24	1.75	80.03	United Nations (2015) [7]
		2.1.2	8.6	0.2	Positive	890	2.42	8.02	5.12	1.06	3.02	6.89	Sachs et al. (2019) [2]
	2.2	2.2.2	0	42.3	Negative	544	0.06	9.59	1.84	1.46	0.13	5.43	Sachs et al. (2019) [2]
	2.a	2.a.1	9.79	—	Moderate	384	0.32	19.7	1.73	2.39	0.53	9.08	Author constructed
3	3.1	3.1.1	3.5	117	Negative	480	1.1	310.43	27.92	35.86	3.60	116.71	Author constructed
		3.1.2	100	10	Positive	544	26.74	100	92.75	12.86	52.87	100.00	United Nations (2015) [7]
	3.2	3.2.1	0.5	5	Negative	544	0.97	5.95	2.48	0.94	1.13	4.75	United Nations (2015) [7]
	3.2	3.2.2	1	20	Negative	544	2.02	25.8	8.45	4.47	2.81	20.08	United Nations (2015) [7]
	3.3	3.3.1	0	12	Negative	504	0.01	18.15	1.93	2.93	0.03	12.31	United Nations (2015) [7]
		3.3.2	0	173	Negative	511	19.52	304.94	76.90	35.80	26.66	173.38	United Nations (2015) [7]
		3.3.3	0	23	Negative	500	0	112.91	1.75	8.33	0.01	23.06	United Nations (2015) [7]
		3.3.4	0	229	Negative	512	7.79	413.29	80.12	52.52	12.44	228.76	United Nations (2015) [7]
		3.3.5	0	7	Negative	239	0	39.9	0.58	2.92	0.00	6.64	United Nations (2015) [7]
	3.6	3.6.1	1	14	Negative	639	1.71	21.79	6.69	3.04	2.86	13.75	United Nations (2015) [7]
	3.8	3.8.1	100	11.5	Positive	384	6.65	117.6	45.60	27.98	11.54	105.74	United Nations (2015) [7]
	3.9	3.9.1	0	78	Negative	276	0.01	81.44	7.66	16.75	0.07	77.25	United Nations (2015) [7]

	3.b	3.b.2	10	4	Positive	384	3.77	10.56	6.94	1.53	4.34	10.12	Author constructed
	3.c	3.c.1	108	30	Positive	352	22	155	55.47	18.07	29.83	108.35	Xu et al. (2020) [3]
4	4.3	4.3.1	0	34	Negative	448	1.51	45.54	7.76	6.45	2.13	34.30	United Nations (2015) [7]
	4.4	4.4.1	50	3	Positive	448	0.89	48.65	10.70	6.97	3.13	30.63	United Nations (2015) [7]
	4.5	4.5.1	0	9	Negative	448	-0.48	10.88	4.54	2.13	0.67	8.94	United Nations (2015) [7]
	4.6	4.6.1	0	40	Negative	639	1.23	66.18	10.34	8.92	1.85	39.60	United Nations (2015) [7]
	4.a	4.a.1	4	75	Negative	512	3.52	160.67	23.24	19.97	4.87	74.94	Author constructed
	4.b	4.b.1	21	—	Moderate	384	9.89	22.22	16.44	2.59	11.18	20.96	Author constructed
	4.c	4.c.1	1	—	Moderate	640	0.44	2.6	1.23	0.37	0.69	2.15	United Nations (2015) [7]
5	5.5	5.5.1	50	19	Positive	704	11.04	56.3	30.49	6.03	19.44	43.30	United Nations (2015) [7]
		5.5.2	50	32	Positive	608	31.14	45.2	36.71	2.77	32.24	42.80	United Nations (2015) [7]
	5.b	5.b.1	100	20	Positive	448	13	189.5	74.99	32.78	20.01	139.04	United Nations (2015) [7]
6	6.1	6.1.1	100	14	Positive	486	1.92	148.57	68.98	24.34	13.59	103.01	Sachs et al. (2019) [2]
	6.2	6.2.1	100	9.7	Positive	344	32.6	99.8	71.95	16.46	38.39	98.48	Sachs et al. (2019) [2]
	6.3	6.3.1	100	19	Positive	534	0.06	98.6	71.21	23.31	18.94	96.86	United Nations (2015) [7]
	6.4	6.4.1	0.0024	0.125	Negative	512	0	0.27	0.02	0.03	0.00	0.12	Xu et al. (2020) [3]
		6.4.2	12.5	647	Negative	512	0.53	915.47	76.51	139.31	0.80	647.57	Xu et al. (2020) [3]
	6.a	6.a.1	3.1	0.45	Positive	512	0.05	4.66	1.33	0.69	0.44	3.20	Xu et al. (2020) [3]
7	7.1	7.1.2	100	35	Positive	639	23.5	113.84	83.91	15.74	46.60	100.00	United Nations (2015) [7]
	7.2	7.2.1	84	0.05	Positive	377	0	95.67	25.70	25.70	0.05	89.05	Sachs et al. (2019) [2]
	7.3	7.3.1	0.31	4	Negative	590	0.25	23	1.31	1.48	0.40	4.00	Xu et al. (2020) [3]
8	8.1	8.1.1	7	—	Moderate	800	-27.9	46.03	13.28	7.85	0.68	31.40	Sachs et al. (2019) [2]
	8.4	8.4.2	0.29	3.45	Negative	480	0.14	27.15	1.18	1.42	0.29	3.34	Author constructed
	8.5	8.5.2	0.5	25.9	Negative	629	0.62	6.5	3.52	0.72	1.43	4.50	Sachs et al.

													(2019) [2]
	8.6	8.6.1	0	32	Negative	703	0.14	67.5	7.02	8.62	0.44	32.17	United Nations (2015) [7]
	8.8	8.8.1	2	54	Negative	415	0.9	66.66	13.79	12.54	2.15	54.12	Author constructed
		8.8.2	100	3	Positive	507	0.06	106.07	23.98	19.23	3.11	86.95	Author constructed
	8.9	8.9.1	67	27	Positive	735	24.6	80.98	41.15	8.71	29.64	66.57	Author constructed
9	9.1	9.1.2	2102	51	Positive	906	5	3462.86	844.52	576.21	51.32	2102.93	Author constructed
	9.2	9.2.1	57.2	7.86	Positive	608	6.81	55.75	37.71	9.67	7.91	51.16	Xu et al. (2020) [3]
	9.3	9.3.1	60.6	—	Moderate	544	13.77	74.66	33.74	10.28	15.98	52.55	Xu et al. (2020) [3]
	9.4	9.4.1	0.76	13	Moderate	828	0.4	25.39	4.54	3.10	1.05	12.52	Author constructed
	9.5	9.5.1	3.7	—	Moderate	416	0.17	6.17	1.44	1.06	0.25	5.43	Xu et al. (2020) [3]
		9.5.2	1.56	—	Moderate	320	0.05	1.84	0.36	0.33	0.07	1.47	Xu et al. (2020) [3]
	9.a	9.a.1	3.1	—	Moderate	512	0.05	4.66	1.33	0.69	0.44	3.20	Xu et al. (2020) [3]
	9.c	9.c.1	100	0.3493	Moderate	158	0.18	146.92	49.78	32.40	3.85	120.29	United Nations (2015) [7]
10	10.1	10.1.1	1	—	Moderate	416	1.85	4.6	2.86	0.54	2.06	4.16	United Nations (2015) [7]
	10.4	10.4.1	30.6	7.04	Moderate	608	6.84	39.84	13.53	4.97	7.41	27.85	Author constructed
	10.5	10.5.1	0	16.51	Moderate	416	0.23	24.6	2.90	3.80	0.48	16.27	United Nations (2015) [7]
11	11.1	11.1.1	100	21	Moderate	288	13.83	87.97	55.40	13.67	21.43	73.11	United Nations (2015) [7]
	11.2	11.2.1	26	—	Moderate	735	3	35.2	10.72	4.45	4.37	24.18	Author constructed
	11.3	11.3.1	1.12	—	Moderate	190	-183.95	16.46	-0.06	14.84	-9.99	7.81	Author constructed
	11.5	11.5.1	0	67.15	Negative	411	0	107.1	24.63	19.02	0.52	67.14	United Nations (2015) [7]
		11.5.2	0	5	Negative	407	0	17.6	1.02	1.54	0.01	5.01	United Nations (2015) [7]
	11.6	11.6.1	100	23	Positive	501	9.73	100	76.19	23.42	23.03	100.00	United Nations (2015) [7]
		11.6.2	100	40	Positive	448	13.42	100.3	78.75	16.23	41.37	100.00	United Nations (2015) [7]
	11.7	11.7.1	21.2	—	Moderate	637	0.42	29.38	9.74	3.68	3.44	17.91	Author constructed

12	12.2	12.2.1	0.5	68.3	Negative	544	0.28	64.47	16.85	12.48	1.03	56.54	Sachs et al. (2019) [2]
		12.2.2	0.29	3.45	Negative	480	0.14	27.15	1.18	1.42	0.29	3.34	Author constructed
	12.4	12.4.2	0.88	140	Negative	605	0.12	848.94	28.00	79.04	0.94	141.20	Author constructed
	12.5	12.5.1	100	20.9	Positive	602	1.52	136.06	63.14	22.41	20.67	99.15	Author constructed
13	13.1	13.1.1	0	67.15	Negative	411	0	107.1	24.63	19.02	0.52	67.14	Sachs et al. (2019) [2]
	13.2	13.2.1	0.5	68.3	Negative	544	0.28	64.47	16.85	12.48	1.03	56.54	Author constructed
15	15.1	15.1.1	63	2.9	Positive	480	2.9	66.8	30.15	17.67	4.20	63.00	Author constructed
		15.1.2	93.92	0.22	Positive	308	0.2	97.16	28.32	25.29	0.22	94.78	Author constructed
	15.2	15.2.1	88.99	1.7	Positive	310	1.34	90.5	47.70	25.15	1.78	86.91	Author constructed
	15.3	15.3.1	0	46.64	Negative	465	0	46.69	7.93	11.65	0.00	46.64	Xu et al. (2020) [3]
	15.4	15.4.1	100	1.47	Positive	300	0.84	100	21.67	20.71	2.31	100.00	Author constructed
	15.5	15.5.1	92	15	Positive	256	5.04	97	59.91	19.72	15.47	92.63	Author constructed
	15.a	15.a.1	4.9	—	Moderate	256	0.04	6.93	0.80	0.99	0.06	4.95	Xu et al. (2020) [3]
	15.b	15.b.1	59.291	—	Moderate	256	2.39	100	59.29	27.85	4.69	100.00	Xu et al. (2020) [3]
16	16.7	16.7.1	50	—	Moderate	704	11.04	56.3	30.49	6.03	19.44	43.30	United Nations (2015) [7]
	16.10	16.10.2	100	1.5	Positive	284	0.1	93.3	31.47	21.60	1.50	85.05	United Nations (2015) [7]
17	17.1	17.1.1	18.6	—	Moderate	608	4.4	22.73	9.35	3.23	4.89	18.36	Xu et al. (2020) [3]
		17.1.2	100	62	Positive	544	56.95	100.03	82.49	13.14	62.23	100.00	Author constructed
	17.6	17.6.2	100	20	Positive	128	18.72	131.18	54.17	19.43	20.62	113.88	United Nations (2015) [7]
	17.8	17.8.1	100	2.34	Positive	544	1.12	77.77	31.14	20.43	2.41	72.11	United Nations (2015) [7]

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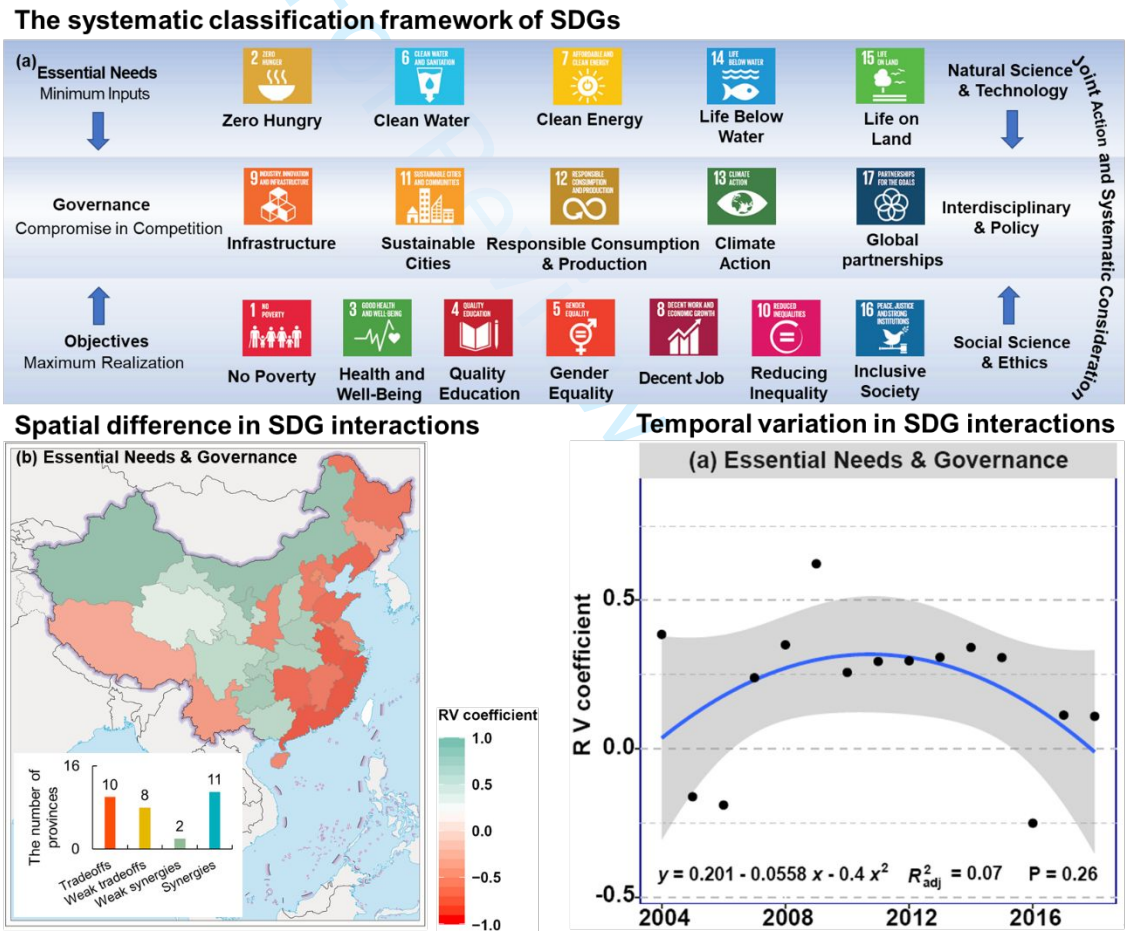
Graphic abstract

Based on the systematic classification framework of SDGs ("Essential Needs", "Governance", "Objectives"), this study quantifies the spatial and temporal variation of SDG interactions in China. Spatially the trade-offs among different SDG categories are mainly distributed in the eastern regions, while temporally the synergies among different SDG categories show a decreasing trend over the last decade.



解析中国可持续发展目标的相互作用特征

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理解可持续发展目标（SDGs）之间的相互作用（协同和权衡）对加强不同部门之间的政策一致性至关重要。基于 SDGs 系统分类框架（“基本要素”、“治理”和“目标”），本研究从省级尺度上量化了中国 SDGs 相互作用的时空变化特征。结果显示，在空间上“基本要素”和“目标”以及“基本要素”和“治理”之间在中国东部省份普遍表现出权衡关系，三类 SDGs 之间的协同关系主要出现在中西部省份。在时间上，各类 SDGs 之间的协同关系在过去十年表现出下降趋势。未来优先推进 SDG12 和 SDG7 的落实将有助于促进 SDGs 的协同落实和各省份的均衡发展。

关键词：可持续发展目标；基本要素；治理；目标；中国