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Navigating Chinese cities to achieve sustainable development goals by 2030

Huijuan Xiao,[1] Zhenci Xu,[2,3,*] Jingzheng Ren,[1,*] Ya Zhou,[4,7] Ruojue Lin,[1] Sheng Bao,[5] Long Zhang,[1] Shengfang Lu,[1] Carman K.M. Lee,[1] and Jianguo Liu[6]
*Correspondence: xuzhenci@hku.hk (Z.X.); jzhren@polyu.edu.hk (J.R.)

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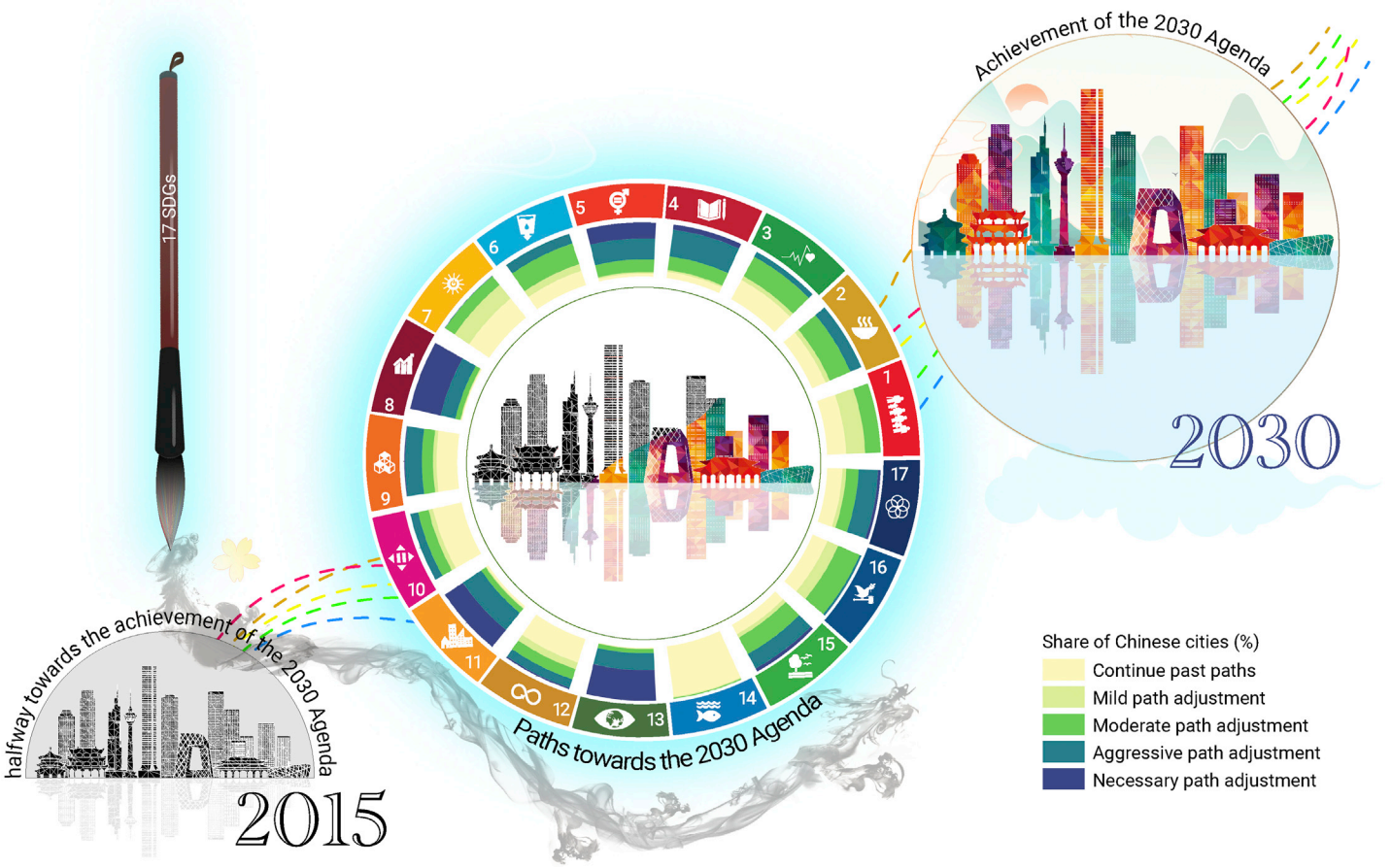
GRAPHICAL ABSTRACT



PUBLIC SUMMARY

- The first simulation of the performance of Chinese cities in 17 SDGs by 2030
- A scenario-based projection model is proposed to make simulation of SDGs
- Chinese cities can achieve an average of five SDGs by continuing past paths
- We present cost-effective integrated paths to promote the achievement of all SDGs

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[1]Department of Industrial and Systems Engineering, The Hong Kong Polytechnic University, Hong Kong SAR, China

[2]Department of Geography, The University of Hong Kong, Hong Kong SAR, China

[3]Peng Cheng Laboratory, Shenzhen 518000, China

[4]Key Laboratory for City Cluster Environmental Safety and Green Development of the Ministry of Education, School of Ecology, Environment and Resources, Guangdong University of Technology, Guangzhou 510006, China

[5]Otto Poon C. F. Smart Cities Research Institute, Department of Land Surveying and Geo-Informatics, The Hong Kong Polytechnic University, Hong Kong SAR, China

[6]Center for Systems Integration and Sustainability, Department of Fisheries and Wildlife, Michigan State University, East Lansing, MI 48824, USA

[7]Southern Marine Science and Engineering Guangdong Laboratory (Guangzhou), Guangzhou, 511458, China

*Correspondence: xuzhenci@hku.hk (Z.X.); jzhren@polyu.edu.hk (J.R.)

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Achieving the 17 United Nations sustainable development goals (SDGs) in China largely depends on the transition of cities toward sustainable development. However, significant knowledge gaps exist in evaluating the SDG index at the city scale and in understanding how to simulate pathways to achieve the 17 SDGs for Chinese cities by 2030. This study aimed to quantify the SDG index of 285 Chinese cities and developed a forecasting model to simulate the performance of each SDG in each city until 2030 using varied scenarios. The results indicated that although the SDG index in Chinese cities increased by 33.97% during 2005–2016, Chinese cities, which continued their past paths, achieved an average of only five SDGs by 2030. To promote the joint achievement of all SDGs, we designed different paths for all SDGs of each of the 285 cities and simulated their SDG index until 2030. Under the scenarios, 216 Chinese cities (75.79%) could achieve 9–13 more SDGs in 2030 and the overall SDG index can improve from 74.57 in 2030 to 97.49 (target score 100) by adopting more intensive path adjustment. We lastly determined a cost-effective path for each SDG of each city to promote joint achievement of all SDGs by 2030. The proposed simulation model and cost-effective path serve as a foundation for other countries to simulate SDG progress and develop pathways for achieving SDGs in the future.

INTRODUCTION

The 2030 Agenda that incorporated 17 sustainable development goals (SDGs) was implemented by all United Nations (UN) member states as a universal plan toward achieving sustainability.[1,2] Since the launch of the SDGs, numerous studies have investigated sustainability under the framework of the 2030 Agenda at the global, regional, and national levels.[1–4] While most goals specifically indicate the responsibility of national governments for the localization and implementation of SDGs, local governments such as cities are responsible for providing most of the needed progress.[5,6] The Sustainable Development Solutions Network estimated that 65% of SDG targets will not be fully reached without proper engagement of and coordination with cities.[7]

However, only several reports evaluated city-level SDG index (an aggregated score that is used to evaluate where each region stands with regard to achieving 17 SDGs) of some countries or regions.[7,8] For instance, European cities SDG Index and Dashboards Report evaluated the SDG index of 45 capital cities and large metropolitan areas in Europe in 2019 with 56 indicators.[7] As for China, Xu et al. (2020) constructed a provincial indicator system of SDGs and evaluated the SDG index of 31 provinces from 2000 to 2015 based on this system,[1] but did not present a city-level indicator system for China. The city-level indicator system of China is still missing and is more challenging to construct, because of a large number of cities, less data disclosure, and more frequent changes of administrative boundaries.

Additionally, most studies, including that by Xu et al. (2020), only evaluated the past progress of SDGs and did not answer whether the Chinese cities can achieve the 17 SDGs by 2030 or how paths can be simulated to achieve these goals by 2030.[1,2] Studies on the simulations of 17 SDGs and the SDG index up to 2030 under various scenarios are absent not only for China, but also for other member states of the UN. The answers to the above-mentioned two questions are, thus, critical for policymakers to effectively allocate resources to vulnerable cities, formulate long-term integrated strategies, and underpin the achievement of the 2030 Agenda.[9]

To address these knowledge gaps, we first made a methodological contribution by proposing a scenario-based projection model to simulate the SDG index and 17 SDGs until 2030 with scenarios representing various improvement paths. The proposed projection model is not limited to a specific country and can be applied to other member states of the UN to predict SDGs under various scenarios. Then, we presented the first evaluation of the SDG index (scores 0–100) of Chinese cities over time and stimulated the SDG index and 17 SDGs up to 2030 based on our proposed scenario-based projection model. Our results revealed the extent to which different policy implementations of the 17 SDGs could direct the future sustainability outcomes of the cities. Finally, we determined a cost-effective path for each SDG of each city to enhance sustainability by 2030. Based on the available data, 285 Chinese cities were selected for analysis. A comprehensive, consistent, and comparable indicator system that is used to evaluate the SDG index of 285 Chinese cities is shown in Table S1.

RESULTS

Spatiotemporal performance of SDGs

The SDG index of the Chinese cities increased by 33.97% during 2005–2016, from 37.93 to 50.82 (target score 100) (Figure 1A), showing Chinese cities are halfway toward the achievement of the 2030 Agenda and significant further progress is required to finish the second half. Zhuhai (Guangdong province) showed the highest index (75.73) among the Chinese cities in 2016, followed by Beijing (73.12), Shenzhen (72.50, Guangdong province), Hangzhou (72.32, Zhejiang province), and Xiamen (70.39, Fujian province) (Figure 1B). The top 10 cities with the highest SDG index were non-resource-based cities, while among the 10 cities with the worst index, eight were resource-based cities, that is, Lvliang (39.05, Shanxi province), Linfen (39.34, Shanxi province), Xinzhou (39.78, Shanxi province), Shuozhou (39.78, Shanxi province), Yulin (40.39, Shaanxi province), Handan (40.76, Hebei province), Zhangjiakou (40.87, Hebei province), and Liupanshui (41.96, Guizhou province) (Figure 1C). Resource-based cities also showed an increase in their SDG index from 35.19 in 2005 to 47.75 in 2016 (Figure 1A), but their index was generally 5.15 (10.78%) lower than that of non-resource-based cities (52.90) (Figure 1A).

Simulation of the SDG index up to 2030

To observe the changes in the trajectory of the SDGs under different scenarios, we simulated the SDG index from 2017 to 2030 based on five scenarios (continue past paths, mild path adjustment, moderate path adjustment, aggressive path adjustment, and necessary path adjustment). If Chinese cities continue the past paths, the highest SDG index in 2030 could be 95.54 and 133 Chinese cities could score in the range of 70–80 (Figure 2A; Scenario 1). The sustainability patterns across the Chinese cities could change significantly under different scenarios. The number of Chinese cities scoring in the range of 80–85, 85–95, and 95–100 under mild, moderate, and aggressive path adjustments are 98, 238, and 252, respectively (Figures 2B–2D; Scenarios 2–4).

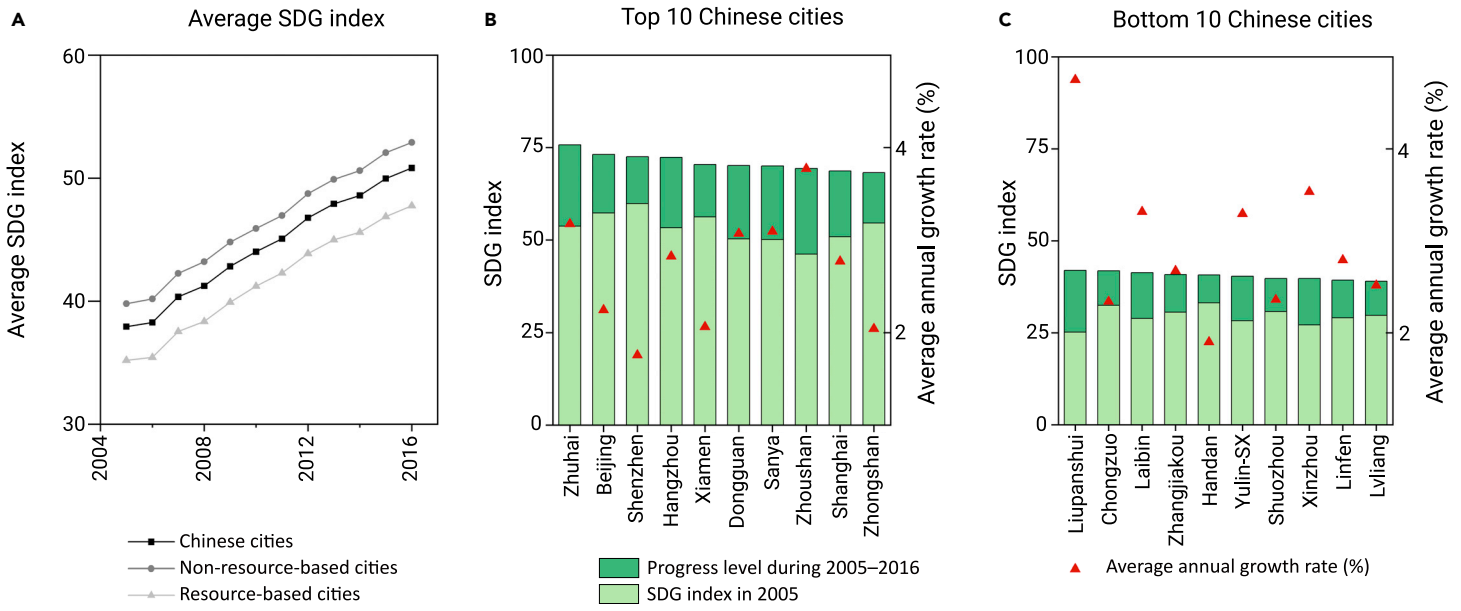

Figure 1. SDG index of the Chinese cities in 2005–2016 (A) Average SDG index of 285 Chinese cities during 2005–2016. (B and C) The top/bottom 10 Chinese cities in the SDG index in 2016. The stacked bar chart in (B) and (C) indicates the SDG index (left *y* axis), while the triangle indicates the average annual growth rate from 2005 to 2016 (right *y* axis). The bottom section of the stacked bar in (B) and (C) indicates the SDG index in 2005, while the top section shows the progress level during 2005–2016.

Simulation of the 17 SDGs up to 2030

As shown in Figure 3, although all 17 goals exhibited a promising increase during 2005–2016, the performance of some was still low and the gap to achieve these goals was large. SDG 8 (Decent work and economic growth), SDG 9 (Industry, innovation, and infrastructure), and SDG 15 (Life on land), with a score of 36.17, 30.63, and 36.39, respectively, had the lowest scores for the Chinese cities in 2016 (Figure 3). Continuing the past paths could improve the performance of these three SDGs to 48.17, 69.62, and 65.85 in 2030, respectively (Figures 3H, 3I, and 3O; Scenario 1), with 23 (8.07%), 124 (43.51%), and 72 (25.26%) Chinese cities scoring 100 before 2030, respectively (Figure 4; Scenario 1). If the Chinese cities adopted a further intensive path adjustment, such as a moderate path adjustment, the average scores of SDG 8 (Decent work and economic growth), SDG 9 (Industry, innovation, and infrastructure), and SDG 15 (Life on land) could increase to 51.04, 75.30, and 73.78, respectively, in 2030 (Figures 3H, 3I, and 3O; Scenario 3). Under the aggressive path adjustment, the average scores of the three SDGs could further improve to 88.86, 99.80, and 98.29, respectively (Figures 3H, 3I, and 3O; Scenario 4).

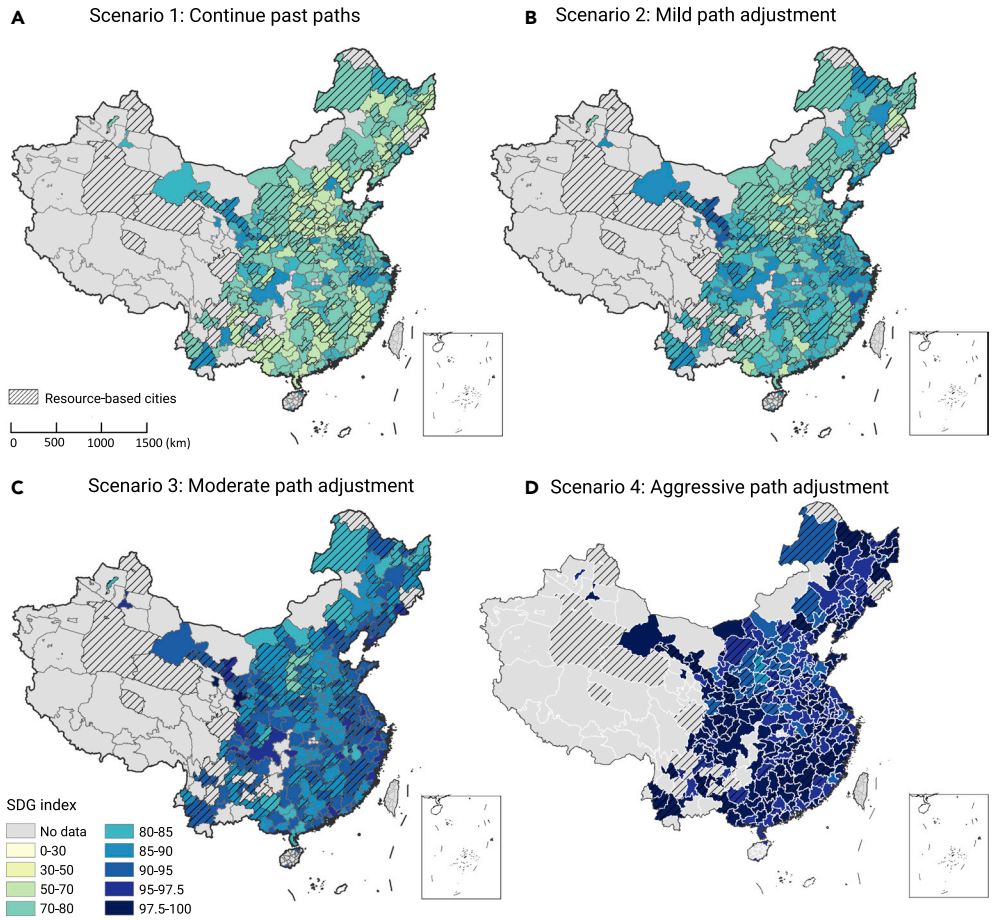

Figure 2. Simulation of the SDG index of the Chinese cities in 2030 (A–D) SDG index under scenario 1 (A), scenario 2 (B), scenario 3 (C), and scenario 4 (D). As the SDG index under scenario 5 (necessary path adjustment) in 2030 is equal to 100 for all cities, the SDG index under this scenario was not demonstrated here.

Cost-effective integrated paths of the 17 SDGs

As shown in Figure 2A, if the cities continued with their past paths, it will be difficult for them to achieve the 2030 Agenda, and substantial challenges would exist to address all SDGs by 2030. On an average, Chinese cities could achieve five goals (31.03%) before 2030 by continuing the past paths (Dataset S1, Scenario 1). Based on the improvement paths of other cities, if cities adopted more intensive path adjustment, including a mild path adjustment (Scenario 2), moderate path adjustment (Scenario 3), or aggressive path adjustment (Scenario 4) (Dataset S1), 11

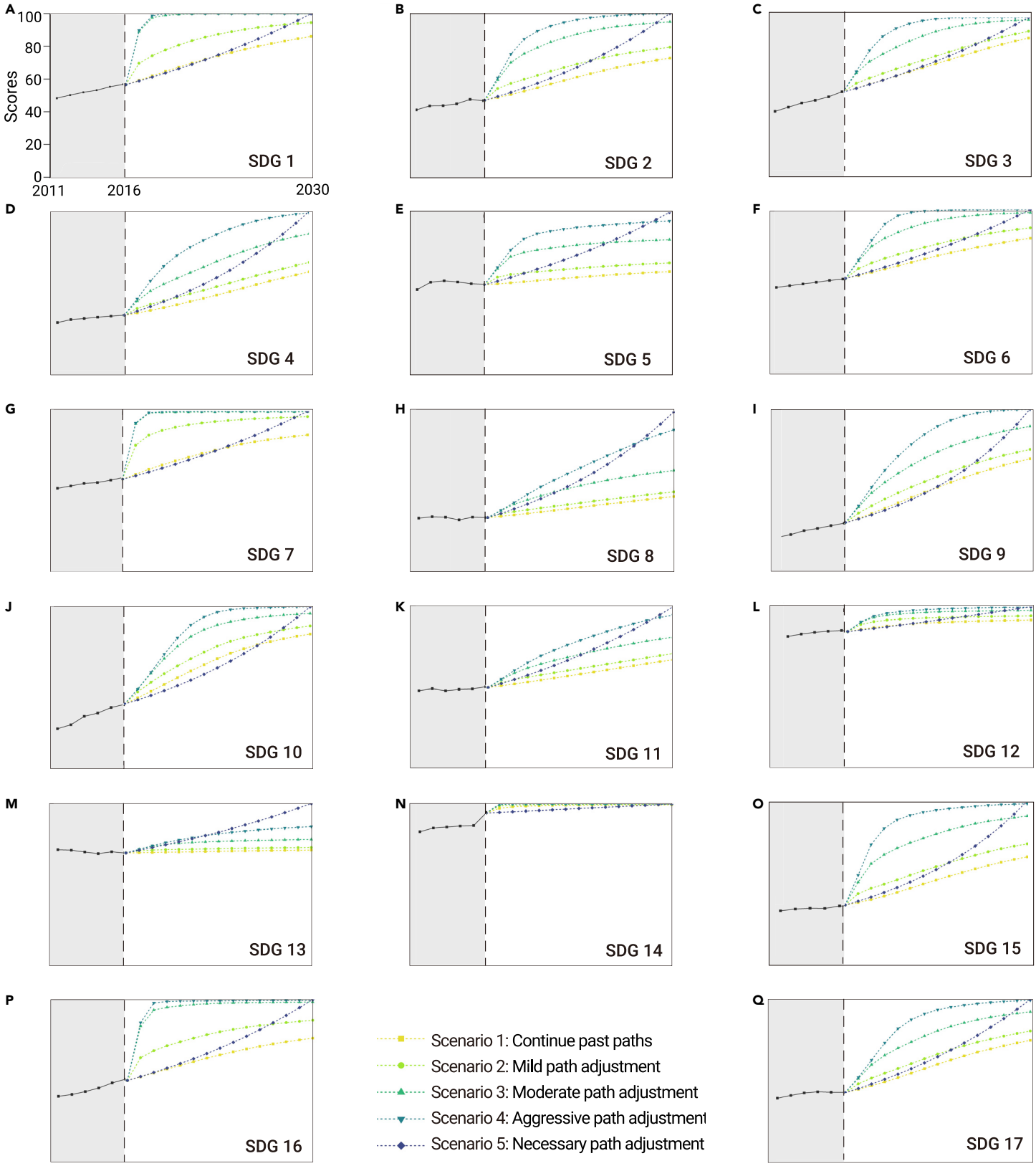

Figure 3. Performance of the 17 SDGs during 2011–2016 and the scenario-based projections of the Chinese cities up to 2030 (A–Q) The 17 graphs correspond to 17 SDGs. The performance of 285 Chinese cities during 2011–2016 are on the left side of each graph, while the simulations of the Chinese cities for 2030 are on the right side. The horizontal and vertical axes of 17 graphs are all the same.

more goals on an average (67.88%) could be achieved (Dataset S1). Two hundred sixteen Chinese cities (75.79%) can achieve 9–13 more goals by shifting to Scenarios 2, 3, and 4 (Dataset S1). On an average, the SDG index of the Chinese cities could improve from 74.57 in 2030 following the existing paths (Figure 2A; Scenario 1) to 80.38, 90.59, and 97.49 after mild, moderate, and aggressive path adjustments, respectively (Figure 2D; Scenarios 2, 3, and 4). To ensure that all goals of a city collectively score 100 points by 2030 and to avoid excessive efforts, we further designed a cost-effective path based on the specific context of each goal (Figure 5; Dataset S1). Considering Zhuhai (Guangdong province), with the best SDG index in

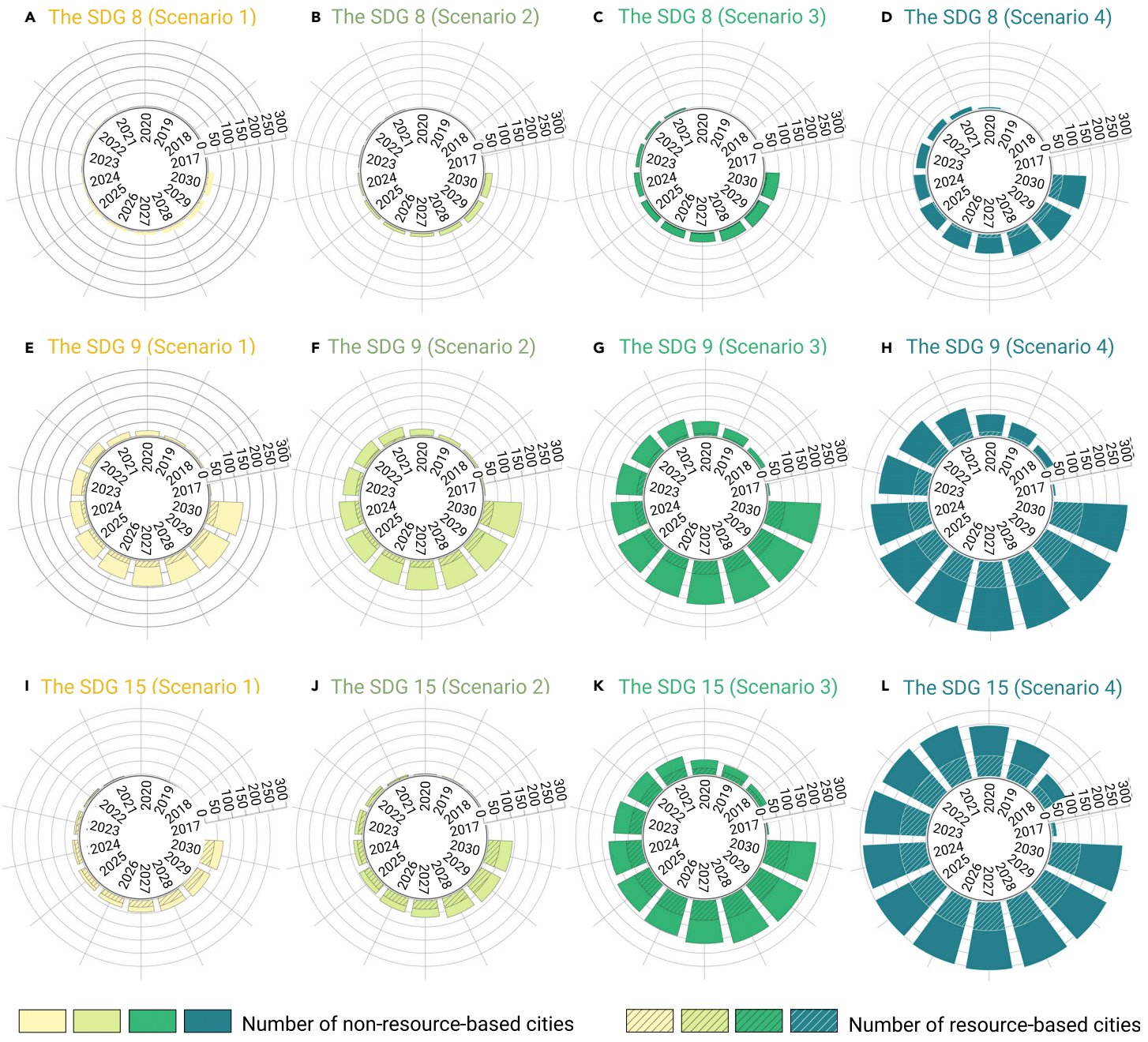

Figure 4. Number of Chinese cities scoring 100 under various scenarios during 2017–2030 (A–L) Number of Chinese cities with scores of 100 regarding SDG 8 (A–D), SDG 9 (E–H), and SDG 15 (I–L) under four scenarios. As the performance of each SDG under scenario 5 in 2030 is equal to a score of 100 for all cities, the situation under this scenario was not demonstrated here. The bottom part of the radial stacked bar represents the number of resource-based cities, while the upper part indicates the number of non-resource-based cities.

2016, as an example (Figure 1B), the cost-effective integrated scenarios of Zhuhai were the combination of Scenarios 1, 3, 1, 1, 5, 1, 1, 1, 1, 1, 1, 4, 4, 1, 4, 1, and 1 corresponding with the 17 goals (Figure 5). Twelve goals (SDGs 1, 3, 4, 6, 7, 8, 9, 10, 11, 14, 16, and 17) of Zhuhai could be achieved by continuing the past path (Figure 5; Scenario 1).

The integrated paths of 285 Chinese cities shown in Figure 5 are summarized in Figure 6. On an average, 34.18% of the Chinese cities could achieve one SDG by 2030 if the past improvement paths were maintained (Figure 6A; Scenario 1). Among the 17 SDGs, SDG 14 (96.23%), SDG 10 (58.95%), SDG 12 (50.88%), SDG 7 (48.42%), and SDG 9 (43.51%) (Figure 6A; Scenario 1) had the greatest contribution under Scenario 1. This finding suggests that a relatively large number of Chinese cities can achieve these five goals directly without changing their past paths. In contrast, the proportion of Chinese cities that could achieve the desired goals by continuing the past paths was relatively low for SDG 4 (15.09%), SDG 11 (11.93%), SDG 5 (9.82%), SDG 13 (8.42%), and SDG 8 (9.07%) (Figure 6A; Scenario 1).

DISCUSSION

The SDG index and simulation results were evaluated, and the results provided a scientific reference not only for China, but also for other UN member states to investigate the SDG index at the city level, facilitate the city transformation toward sustainability, and underpin the achievement of the 2030 Agenda. Achieving the 2030 Agenda is challenging for Chinese cities because it requires a holistic achievement of all goals rather than biased selection of some goals.[10] We observed that substantial challenges remain for the Chinese cities to jointly achieve all SDGs by 2030. Specifically, by continuing the past paths, an average of five goals could be achieved for Chinese cities before 2030. The challenge of joint achievement can be interpreted as unbalanced development across the 17 SDGs, some overly ambitious targets,[11] and pervasive trade-offs across economic growth, social inclusion, and environmental protection.[11–13] Achieving the 2030 Agenda is challenging not only for Chinese cities, but also for some other cities around the world.[7,8] For instance, as mentioned in the 2019 US Cities Sustainable Development Report, 66 of the 105 most populous US cities are less than

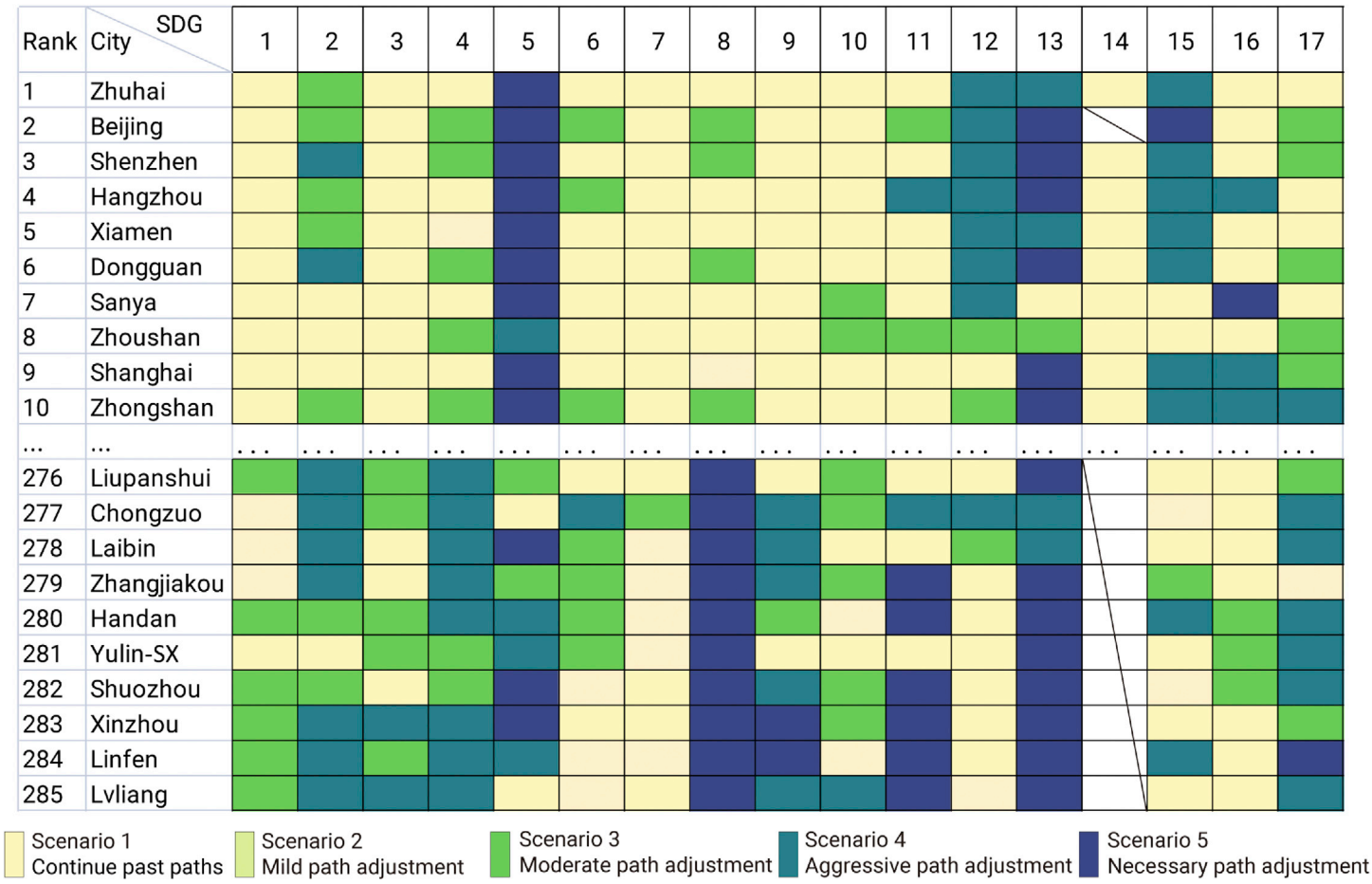

Figure 5. Cost-effective improvement paths for the top 10 and bottom 10 Chinese cities Cities are arranged according to their ranks of SDG index in 2016. Five scenarios could be selected for each SDG. We determined one scenario, which was the most cost-effective, for each SDG of each city.

one-half way to achieving these SDGs (the SDG index was <50).[8] As the best performing European city, Oslo still had 25.2% of the way toward the achievement of the 2030 Agenda (the SDG index was 74.8 in 2019).[7] Future research can focus on evaluating long time series subnational SDG index of other countries with consistent indicators and make comparisons with them regarding development levels and change rates.[14]

Policymakers could include greater feasibility in achieving SDGs (eg, having the time frame extended), and at the same time, adopt more powerful and effective strategies to advance the SDG progress. On the one hand, the strategies should consider metacoupling—human-nature interactions within cities as well as between cities and other places nearby and faraway.[15,16] For example, advancing SDG progress in Chinese cities should avoid or minimize negative spillover impacts, such as excessive resource exploitation and environmental pollution, on adjacent and distant rural areas that provide many essential resources.[17–19] In contrast, local policymakers could adopt further intensive path adjustment, which is specific to each SDG, to facilitate the improvement of the SDG index. To adjust paths toward achieving SDGs, different driving factors (eg, population size, economic growth, industry structure, and transparency of governance) specific to each SDG should be considered and integrated since these internal and external factors generally work together to promote the path adjustment.[17]

The "leave no one behind" principle proposed by the UN highlighted that the 2030 Agenda should reduce inequalities and vulnerabilities. Chinese policymakers should closely monitor laggards, that is, resource-based cities. To improve the SDG index of resource-based cities, upgrading industry and diversifying economic structure can be regarded as crucial strategies to broaden development channels and should be implemented in advance of resource depletion.[20] Second, improving institutional quality is an important factor that can help to decrease the negative effects of resource use in resource-based cities (eg, increasing governance transparency).[21,22] Governance transparency is the government's obligation to share information with citizens, such as the proactive disclosure of how officials conduct public business and spend taxpayers' money.[23] As for non-resource-based cities, many of them are supported by importing energy resources and raw materials from resource-based cities located nearby, so consumption-oriented policies may allow cities with a high SDG index to subsidize the development pressure of resource-based cities.

In the future, we should focus on the following two issues. First, current city-level indicator systems still cannot comprehensively reflect the progress of SDGs, mainly because of data limitations. We call for international institutions and bureaus of statistics to increase investments in SDG data and monitoring systems based on Table S9, which presents the major data gap of Chinese cities. Second, the coronavirus disease that began in late 2019 and the trade war between the US and China that began in 2018 had significant impacts on many SDGs of China and may continue to have impacts until 2030.[24,25] The ongoing Russia-Ukraine war also has cascading effects on food, energy, biodiversity, climate, and many other dimensions of SDGs around the world.[26] Future work will need to explore how these factors affect the achievement of the 2030 Agenda and how to strengthen systemic resilience to cope with various shocks.

METHODS

Sample cities and city categorization

We selected 285 Chinese cities for analysis based on the available data, including four direct-administered municipalities (Beijing, Chongqing, Shanghai, and Tianjin) and 281 prefecture-level cities (Table S2). In terms of sustainable development, resource-based cities face more challenges than others since heavy reliance on resource exploiting and processing activities could give rise to many economic, social, and environmental problems.[27–31] For decades, resource-based cities are regarded as significant strategic bases of energy resources and raw materials in China, which promoted the establishment of an independent and complete industrial system of China and drive national economic and social progress.[23,32] Monitoring SDG progress of resource-based cities is of great importance for China to improve a country's overall sustainability (Table S10), and is also of global interest since unsustainable development of these cities has also been recognized worldwide.[32–35] Therefore, this study classified 285 Chinese cities into two categories, that is 170 non-resource-based cities and

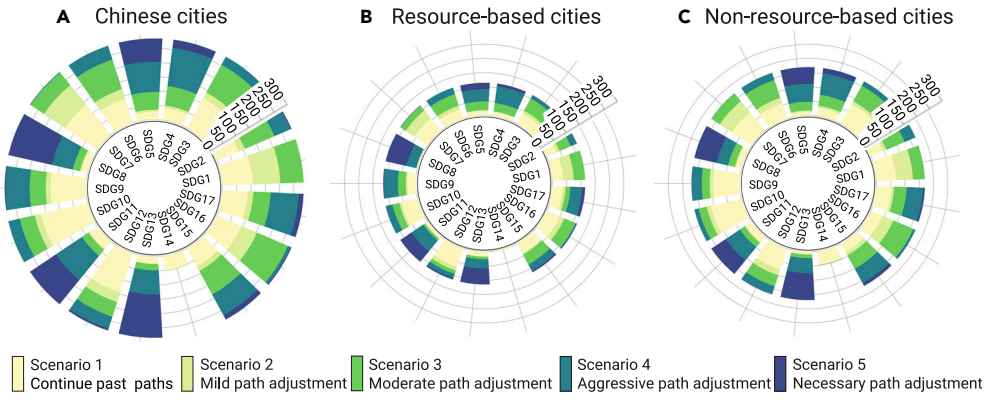

Figure 6. Number of cities under the cost-effective scenario for each SDG (A–C) The total number of Chinese cities (A), resource-based cities (B), and non-resource-based cities (C) under the cost-effective scenario for each SDG. The figures shown in (A) are the summation of those in (B) and (C).

115 resource-based cities based on Sustainable Development Plan for Resource-based Cities in China (2013–2020) issued by the State Council (Table S2).

Evaluation of the SDG index

There are 17 SDGs with several targets under each goal, adding up to 169 targets and 231 unique indicators in the global indicator framework. Our indicators were selected mainly based on the official list of global SDG indicators proposed by the UN, and supported by the study about SDGs evaluation of Chinese provinces and countries,[1,2] and reports from international institutions.[36,37] The study includes as many indicators with as robust data as possible from these sources. In cases where these indicators had data limitation problems, we chose alternative indicators based on the circumstance of Chinese cities and our understanding of targets shown in UN's official list of global SDG indicators. In general, 61 indicators can be used to evaluate SDG index and their data sources are shown in Table S1. Four interrelated steps for evaluating the SDG index of Chinese cities are shown in supplemental information, which are consistent with our previous study.[1]

Scenario-based projections of 17 SDGs

We developed a scenario-based projection model to forecast the scores of each goal as well as the SDG index for each city under various scenarios, that is, an adjacency-based iteration forecasting model. The theoretical basis of this model is that a city can follow its past path or facilitate the progress of the SDG index by learning from others' paths, and it is easier for it to learn the improvement path from another city with similar situations in economic, social, and environmental development.[38,39] Based on the various similarity degree of development across cities, a city can adopt various paths by learning from each other to facilitate the progress, and then the SDG outcomes will be different.[39] Here, we define the adjacency-based iteration forecasting model as a scenario analysis tool to forecast the trend of a decision-making unit (DMU) in the next period based on its adjacent DMUs (similar DMUs in sustainability, geography, economy, or other characteristics) and this process will iterate until a specific period. The advantage of this model is that it is not limited to a specific country but can be applied to other nations to simulate SDGs progress (or even other research fields) based on different scenarios. The steps for the proposed model are as follows.

Step 1: Estimate the past annual growth rate. The past average annual growth rate from period t_0 to t of SDG j of city l (g_{lj}^t) can be obtained, as follows:

$$g_{lj}^t = \left(\frac{Y_{lj}^t}{Y_{lj}^{t_0}}\right)^{\frac{1}{t-t_0}} - 1, \qquad \text{(Equation 1)}$$

where Y_{lj}^t and $Y_{lj}^{t_0}$ is the score of SDG j for city l in period t and t_0, respectively. Since the study period of this study is from 2005 to 2016, we set $t_0 = 2005$ and $t = 2016$.

Step 2: Construct the matrix of distance in sustainability. The distance in sustainability indicates the similarity degree of sustainability between two cities. A shorter distance means greater similarity. We used a symmetric 285×285 matrix (D) with the diagonal elements equaling 0 to represent the distance in sustainability across 285 Chinese cities in period t, as follows:

$$D^t = \left[d_{il}^t\right]_{M\times M} = \begin{bmatrix} 0 & d_{12}^t & \cdots & d_{1M}^t \\ d_{21}^t & 0 & \cdots & d_{2M}^t \\ \vdots & \vdots & 0 & \vdots \\ d_{M1}^t & d_{M2}^t & \cdots & 0 \end{bmatrix}, \; i \text{ and } l = 1, 2, 3, \ldots M, \qquad \text{(Equation 2)}$$

where d_{il}^t indicates distance regarding sustainability between city i and city l in period t. M is the total number of cities (285). In this study, $d_{il}^t = \sum_{j=1}^{N} w_j \left| Y_{ij}^t - Y_{lj}^t \right|$, which is based on Manhattan distance. w_j indicates the weight of SDG j. In this study, all SDGs were weighted equally and $\sum_{j=1}^{N} w_j = 1$. N refers to the number of SDGs that can be used to measure the similarity between two cities. Since coastal cities have 17 SDGs and non-coastal cities have 16 SDGs (excluding SDG 14: Life below water), we only measured the distance of the sustainability of 16 SDGs if the city pair do not have the same number of SDGs, and thus set $N = \min(N_i, N_l)$. In other words, only the paired-up cities are both coastal cities, $N = 17$, or else, $N = 16$. In this study, d_{il}^t is in the range of [0, 100]. The smaller the d_{il}^t, the greater similarity in sustainability between city i and city l in period t.

Step 3: Determine the future growth rate in the next period based on an adjacent city.

$$g_{ij}^{t+1} \in \left[\min_{1\le l\le M}\left(g_{lj}^t \middle| d_{il}^t \le \alpha\right), \max_{1\le l\le M}\left(g_{lj}^t \middle| d_{il}^t \le \alpha\right)\right], \qquad \text{(Equation 3)}$$

where g_{ij}^{t+1} indicates the growth rate regarding SDG j of city i for the next period. g_{ij}^{t+1} is ranging from $\min_{1\le l\le M}(g_{lj}^t | d_{il}^t \le \alpha)$ to $\max_{1\le l\le M}(g_{lj}^t | d_{il}^t \le \alpha)$. There are 285 cities (including itself) that can be treated as adjacent cities for city i and we set a threshold (α) to screen out cities with a relatively large difference in sustainability. α is in the range of 0–100, which is the key parameter to designing different scenarios. For example, $\alpha = 0$ means only the city with the same sustainability in all SDGs can be treated as an adjacent city, and at least one city (itself) can be regarded as an adjacent city for city i. $\alpha = 100$ means that all cities can be treated as adjacent cities for city i, even if they are diametrically different in sustainability. Then, we chose the maximum of the average annual growth rate regarding SDG j within the adjacent city list for city i, that is $g_{ij}^{t+1} = \max_{1\le l\le M}(g_{lj}^t | d_{il}^t \le \alpha)$. This setting indicates, in the next period, that city i will learn from the growth path of the most fast-growing city with similar sustainable development in economy, society, and environment. If g_{ij}^{t+1} is negative, we keep the scores the SDG j of city i constant.[39]

Step 4: Simulate the scores of an SDG of a city in the next period.

$$Y_{ij}^{t+1}\left(g_{ij}^{t+1}, Y_{ij}^t\right) = Y_{ij}^t \times \left(1 + g_{ij}^{t+1}\right) \qquad \text{(Equation 4)}$$

Y_{ij}^{t+1} and Y_{ij}^t, respectively, indicate the scores of the SDG j of city i in period $t+1$ and t. For cities whose SDGs would reach 100 before 2030, the score of the SDG j would remain constant at 100 since then. The SDG index is the weighted average of the scores of all SDGs in the period $t+1$.

Step 5: Iterate from step 1 to step 4 up to 2030. After obtaining the simulation of the SDG j for city i in the period $t+1$ (Y_{ij}^{t+1}), the similarity degree of sustainability between city i and others has changed, so we need to find another fast-growing city with similar sustainable development in economy, society, and environment. Therefore, to obtain the scores of an SDG of a city in period $t+2$, we repeated steps 1–4 again by replacing t with $t+1$. Then, the scores of an SDG of a city in period $t+2$ can be obtained as follows:

$$Y_{ij}^{t+2}\left(g_{ij}^{t+2}, Y_{ij}^{t+1}\right) = Y_{ij}^{t+1} \times \left(1 + g_{ij}^{t+2}\right). \qquad \text{(Equation 5)}$$

There will be 14 iterations for simulation an SDG of a city since the simulation period is from 2017 to 2030. After this, we could obtain the simulated value of each SDG for each city from 2017 to 2030, and their overall SDG index.

It is more straightforward for a city to learn from the fast-growing paths of cities with similar sustainability in economy, society, and environment. Therefore, we designed scenarios 1, 2, 3, and 4 to simulate the scores of each SDG and the SDG index for Chinese cities from 2017 to 2030, representing learning from each other city's growth path.

(1) Scenario 1 (Continue past paths): The existing trends in the past years will continue until 2030 ($\alpha = 0$).
(2) Scenario 2 (Mild path adjustment): Learning from the path of the most fast-growing city with a mild difference in sustainability (on average less than a 10-point difference) ($\alpha = 10$).

(3) Scenario 3 (Moderate path adjustment): Learning from the path of the most fast-growing city with a moderate difference in sustainability (on average less than a 20-point difference) (α = 20).
(4) Scenario 4 (Aggressive path adjustment): Learning from the path of the most fast-growing city with a significant difference in sustainability (on average less than a 30-point difference) (α = 30).
(5) Scenario 5 (Necessary path adjustment): The necessary average annual growth rate to ensure an SDG score of 100 in 2030.[39]

For cities whose SDG cannot score 100 by 2030 under scenarios 1, 2, 3, and 4, we further designed scenario 5, which indicates that the achievement of the SDG of these cities should explore new growth paths instead of following its or other cities' existing paths.

Cost-effective integrated paths of 17 SDGs

We determined a cost-effective path for each SDG of each city, and then combined the path choices of all SDGs into a cost-effective integrated path for each city. There are five scenario choices for each SDG, that is, continue past paths, mild path adjustment, moderate path adjustment, aggressive path adjustment, and necessary path adjustment. Scenario 1 costs the least, followed by scenarios 2, 3, 4, and 5. We determined the most cost-effective scenario for an SDG of a city as follows: if an SDG can score 100 by 2030 under scenario 1, this SDG will be designed to continue its own trend. In contrast, this SDG will adopt a more intensive scenario, starting from a mild path adjustment, followed by moderate path adjustment and then aggressive path adjustment. If this SDG still cannot score 100 by 2030 even with aggressive path adjustment, we chose the necessary path adjustment that is scenario 5. By doing the above steps, all SDGs of a city can score 100 by 2030.

Resource availability

Lead contact. Further information about data and methods should be directed to and will be fulfilled by the lead contact, Zhenci Xu (xuzhenci@hku.hk).

Materials availability. This study did not generate unique materials.

Data availability. The SDG index of 285 Chinese cities during 2005–2016 can be found in the file of supplemental tables.

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AUTHOR CONTRIBUTIONS

H.X.: data curation, formal analysis, methodology, original draft. Z.X.: conceptualization, supervision, review and editing. J.R.: conceptualization, supervision, resources. Y.Z.: formal analysis, review and editing. R.L.: data curation, formal analysis. S.B.: methodology, software. L.Z.: formal analysis, review and editing. S.L: review and editing. C.K.M.L.: review and editing. J.L.: formal analysis, review and editing.

DECLARATION OF INTERESTS

The authors declare no competing interests.

SUPPLEMENTAL INFORMATION

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LEAD CONTACT WEBSITE

https://www.researchgate.net/profile/Zhenci-Xu-2.
https://www.polyu.edu.hk/ise/people/academic-staff/jz-ren/.

The Innovation, Volume *3*

Supplemental Information

Navigating Chinese cities to achieve sustainable development goals by 2030

Huijuan Xiao, Zhenci Xu, Jingzheng Ren, Ya Zhou, Ruojue Lin, Sheng Bao, Long Zhang, Shengfang Lu, Carman K.M. Lee, and Jianguo Liu

Tables of Contents

Details about the evaluation of the SDG index.

City-level sustainability of China has been evaluated in several studies in recent years; however, most studies presented a limited number of indicators considering only some aspects of sustainability (Table S 8),[1-3] which could not reflect the insights of the newly proposed 17 different SDGs and thus, could not monitor the progress of each SDG. In other words, our indicator system (61 indicators × 285 cities × 12 years) provides the most advanced and comprehensive SDG evaluation for Chinese cities and is an important improvement in the sustainability analysis of China. In this study, four interrelated steps for evaluating the SDG index incorporating 17 SDGs of Chinese cities are as follows:

Step 1: Indicator selection and data sources. We evaluated the SDG index (scores 0-100) of Chinese cities during 2005-2016 with a comprehensive, consistent, and comparable evaluation framework. Table S 1 shows indicators and corresponding data sources of the 17 SDGs. Our indicators were selected mainly based on the official list of global Sustainable Development Goal indicators proposed by the Union Nations, and supported by the study about SDGs evaluation of Chinese provinces and countries,[4,5] and reports from international institutions.[6,7] The study includes as many indicators with robust data as possible from these sources. In cases where indicators had data limitation problems, we chose alternative indicators based on the circumstance of Chinese cities and our understanding of targets shown in United Nations' official list of global Sustainable Development Goal indicators. Five criteria were used to determine alternative indicators for measuring SDG index: (1) Criteria 1 (Relevance): The indicators are the best related to a specific issue of the 169 targets under the 17 SDGs; (2) Criteria 2 (Coverage): The indicators can apply to a broad range of Chinese cities and can cover at least 95% of Chinese cities; (3)

Criteria 3 (Comparability): The indicators allow for direct comparison of performance across cities. In particular, the statistical calibre and method are consistent; (4) Criteria 4 (Timeliness): The indicators are time-series and updated periodically, such as monthly, annually, and every five years, which can ensure the updating of SDG index continuously. and (5) Criteria 5 (Data quality): Data are collected from reputable sources, such as international institutions, published papers, and national, regional, provincial, and city-level bureaus of statistics. All monetary indicators were transformed to the 2005 constant price based on the GDP index of each city. For some indicators, complete data for a particular year were missing. In such cases, we used the data of the nearest year or the average value of the nearest two years to substitute the missing value.[5] Under SDG 5 (Gender equality), 'Ratio of female to male illiteracy rate' and 'Ratio of female to male with a high school diploma' are available for 2005, 2010, and 2015 based on China's census and sample survey. For the other years, the official statistical bureau only provides the illiteracy rate for provinces and the four municipal cities (Beijing, Shanghai, Tianjin, and Chongqing). This is mainly because China is a vast and populous country and conducting a census every year is time-consuming and costly. The population survey system implemented by China's statistical departments includes the decennial population census in years ending with 0, the 1% population sample survey during the inter-censual years ending with 5, and the annual population change sample survey at the national and provincial levels in the rest years. Therefore, we deducted the city-level missing data for these two indicators based on the changing trend at the provincial level.

Step 2: Upper bound selection. The upper bound indicates the target of an indicator that is expected to be achieved by 2030.[4] The upper bound for each indicator is determined using a five-step decision tree, as mentioned in our previous study.[5] (1) For indicators that have been used in

current studies,[4-6] we took these upper bounds as reference. (2) Using the absolute quantitative thresholds described in targets to set the upper bound, such as 'universal access to water' and 'full gender equality'. (3) In a case where no explicit description of the SDG target exists, the principle of 'leave no one behind' mentioned by the Union Nations is adopted to determine the upper bound. (4) where science-based targets exist that must be achieved by 2030 or later, these are adopted to set 100% as upper bound (5) for the other indicators, the study determines the upper bound by taking the mean value of the top 20 performers.

Step 3: Rescale the data of each indicator via normalization. After obtaining the upper bound of each indicator, the study rescaled the data with 0 scores describing worst performance and 100 scores denoting the optimum performance to make them comparable. The benefit-type and cost-type indicators can be rescaled as follows:[4,5]

$$Y_{ijk} = 100 \times \frac{Y_{ijk}^{0} - Lower\ bound\left(Y_{ijk}^{0}\right)}{Upper\ bound\left(Y_{ijk}^{0}\right) - Lower\ bound\left(Y_{ijk}^{0}\right)} \quad (1)$$

where i, j, and k indicate the city, SDG, and indicator, respectively. Y_{ijk}^{0} is the raw data value of indicator k under SDG j for city i. Y_{ijk} is the normalized value after rescaling. To remove the effect of extreme values, which can skew the results of a composite index, the Handbook on constructing composite indicators: methodology and user guide presented by OECD recommends censoring the data in the bottom 2.5th percentile as the minimum value for normalization. We applied this approach to the lower bound and censored data at this level. Any value which is larger than the upper bound scores 100, while values below the lower bound score 0.

The above equation is only applicable to benefit-type and cost-type of indicators but not medium-type indicators.[4,5] The medium-type indicator suggests the best performance of this indicator is a specific value instead of the largest or the smallest value (e.g., the ratio of female to male with a high school diploma with 1 as best performance). In this study, we proposed a normalization method that can be used to normalize the medium-type indicators, as follows:

$$Y_{ijk} = 100 \times \left(1 - \frac{\left| Y_{ijk}^{0} - Upper\ bound\left(Y_{ijk}^{0} \right) \right|}{Max\left(Upper\ bound\left(Y_{ijk}^{0} \right) \text{-} Min\left(Y_{ijk}^{0} \right),\ Max\left(Y_{ijk}^{0} \right) - Upper\ bound\left(Y_{ijk}^{0} \right) \right)} \right) \tag{2}$$

where $Max\left(Y_{ijk}^{0}\right)$ and $Min\left(Y_{ijk}^{0}\right)$ are the maximum value at the 1.25th percentile and the minimum value at the 1.25th percentile of the raw data, respectively. Any value which is equal to the upper bound scores 100. In the condition that $\frac{\left| Y_{ijk}^{0} - Upper\ bound\left(Y_{ijk}^{0} \right) \right|}{Max\left(Upper\ bound\left(Y_{ijk}^{0} \right) \text{-} Min\left(Y_{ijk}^{0} \right),\ Max\left(Y_{ijk}^{0} \right) - Upper\ bound\left(Y_{ijk}^{0} \right) \right)} > 1$, the value scores 0.

Step 4: Aggregate the indicators within and across SDGs. To aggregate the indicator scores of each SDG, the study adopted the arithmetic mean by treating each indicator equally, as follows:

$$Y_{ij}\left(N_{ij}, Y_{ijk} \right) = \sum_{k=1}^{N_{ij}} \frac{1}{N_{ij}} Y_{ijk} \tag{3}$$

where Y_{ij} is the score of SDG j for city i, and N_{ij} is the number of indicators for SDG j for city i. A city's overall SDG index is evaluated based on the following equation:

$$Y_i\left(N_i, Y_{ij}, Y_{ijk}\right) = \sum_{i=1}^{N_i} \frac{1}{N_i}_i \sum_{k=1}^{N_{ij}} \frac{1}{N_{ij}} Y_{ijk} \quad (4)$$

SDG index signifies a city's sustainability, ranging from 0 (the worst) to 100 (the target). Y_i is the SDG index score for city i, and N_i is the number of SDGs for each city (in the case of non-coastal cities, N_i =16, and in the case of coastal cities, N_i =17) (see Supplemental information for details). All SDGs were weighted equally to convey the importance of integrated solutions that equally address all 17 SDGs.[4,5] Consistent with the previous research, there is no a priori reason to give one measure greater weight than another.[4,5] The equal weighting ($\frac{1}{N_i}$) is also consistent with the spirit that all countries need to achieve all 17 SDGs through integrated strategies.[4,5]

The sample cities in our study were categorized into two types, that is, non-resource-based cities and resource-based cities (see Table S 2). Resource-based cities are those whose leading industries involve the exploitation and processing of various natural resources.[8] In general, there are 170 non-resource-based cities and 115 resource-based cities (see Table S 2). Yichun-HLJ and Yichun-JX mean the city in Heilongjiang province and Jiangxi province, respectively. Yulin-SX and Yulin-GX respectively denote the city in Shaanxi province and Guangxi province. Suzhou-JS and Suzhou-AH indicate the city in Jiangsu province and Anhui province, respectively. Taizhou-JS and Taizhou-ZJ denote the city in Jiangsu province and Zhejiang province, respectively. Fuzhou-FJ and Fuzhou-JX indicate the city in Fujian province and Jiangxi province, respectively.

SDG 14 (life below water) aims to promote the sustainability of conservation and usage of the oceans, seas, and marine resources, so we measured the performance of SDG 14 only for 53 coastal cities in China. The coastal city list is based on the China Marine Statistical Yearbook, as shown

in Table S 4. In general, there are 232 non-coastal cities and 53 coastal cities in this study, which were measured by 16 goals and 17 goals, respectively. The list of cities not included in the evaluation because of insufficient data can be found in Table S 3. There are 12 cities excluded from the analysis, among which one is a resource-based city (Bijie city), while the rest are non-resource-based cities (Table S 3). One reason that led to missing data during the study period was the changes of administrative divisions. There are a total of 24 Chinese cities that had administrative changes during 2006-2016, as shown in Table S 5. Among them, 12 cities that have not been recorded in reputable sources due to administrative changes were deleted, including Chaohu, Bijie, Tongren, Sansha, Haidong, Shigatse, Chamdo, Danzhou, Linzhi, Tulufan, Shannan, and Hami. For the rest of the 12 cities, they were adjusted based on the county-level data. If the county-level data were not available, the value was adjusted based on the trend of the city's corresponding province.

Sensitivity analysis of SDG index

To test the sensitivity of the SDG index to different values of indicators, we considered a widely used index to measure the degree of sensitivity:[9] $S_{ijk} = \left(\Delta Y_i / Y_i\right) \Big/ \left(\Delta Y_{ijk}^0 / Y_{ijk}^0\right)$ where ΔY_i is the differences of the SDG index for city i between the original and modified conditions due to the change of Y_{ijk}^0.[6] ΔY_{jki}^0 is the differences of the data value of the indicator k under SDG j between the original and modified conditions. If S_{ijk} is large, the SDG index is more sensitive to the value change of an individual indicator. The modified condition is that we increased the value of an indicator in 2016 by 10%. The sample cities used for the sensitivity analysis are randomly chosen from 3 ranges regarding city rank, that is [1st, 95th], [96th, 190th], and [191st, 285th]. In

each range, we chose two cities. These cities are Xiangtan, Zhengzhou, Shijiazhuang, Wuhai, Chifeng, and Yangquan corresponding to the rank range. As shown in Figure S2 in the supplemental information, we found that the sensitivity of the SDG index to value changes of an indicator is very small (all are less than 0.08), suggesting a 10% increase in the original value of the indicator can only change 0.8% of the SDG index. In view of this, we believe that the SDG index is not sensitive to the change of the value of indicators.

Relationship between natural resource dependence and the SDG index.

This study used Spearman's correlation analysis to explore the relationship between natural resource dependence and the SDG index of 285 Chinese cities. Spearman's correlation analysis is a nonparametric rank statistic method, which can measure the relationship between two variables,[10] and has been widely used in many studies.[11,12] This study used the share of employees of mining industry in the total employees to measure the natural resource dependence, which was collected from the China City Statistical Yearbook and has been adopted in many studies.[13,14] The mining industry includes many subsectors closely related to natural resources, such as coal mining, ferrous metals mining, and non-metallic ore mining. We conducted Spearman's correlation analysis year by year. All results show that the SDG index of Chinese cities was negatively correlated with natural resource dependence (Table S 11).

Our results show that abundant natural resources do not necessarily bring the expected development achievement.[15,16] Large-scale exploitation and processing of natural resources inevitably could result in heavy reliance on resource-related activities, such as coal and oil mining,

metal mining, and lumbering. The boom of resource-based sectors could cause the 'Dutch disease' and shrink the development of manufacturing sectors.[17] Further, other important factors for long-term economic growth (e.g. human capital, technological innovation, and capital investment) could be excluded, thus, impeding the development of high value-added sectors, which is considered as an important transmission mechanism of the resource curse.[18,19] Some economic, social, and environmental problems could occur if regions overly depend on the exploitation of natural resources.[20-22] The economic problems include slow economic growth and the unbalanced industry structure.[15,16,23] Natural resources are limited and increasingly depleted natural resources could bring about a substantial number of employees losing jobs and leaving their home region for better employment and living conditions.[24] Additionally, exploitation activities could cause damage the environment and ecosystems. For example, vegetation is an important part of the environment but may be subjected to a disturbance in areas close to coal mines and mine subsidence may occur.[20] These activities can also produce solid wastes, water pollutants, air pollutants, and CO_2 emissions.[25,26] Tailings are generated in large amounts in mining cities, and it is one of the largest and most dangerous sources of solid wastes.[27] The above-mentioned problems regarding the economy, society, and environment jointly result in a relatively low SDG index for some cities which overly rely on natural resources.

An alternative way to conduct an adjacency-based iteration forecasting model.

If the score of an SDG in period t_0 is zero ($Y_{lj}^{t_0}$ =0), we can't obtain the past growth rate (g_{lj}^{t}) in step 1 of the adjacency-based iteration forecasting model since the denominator in a fraction

cannot be zero. Therefore, we provide an alternative way to do the simulation, that is using the past annual growth volume ($v_{lj}^{t} = \frac{Y_{lj}^{t} - Y_{lj}^{t_0}}{t - t_0}$).

Step 1: Estimate the past annual growth volume. The past annual growth volume from period t_0 to t of SDG j of city l (v_{lj}^{t}) can be obtained, as follows:

$$v_{lj}^{t} = \frac{Y_{lj}^{t} - Y_{lj}^{t_0}}{t - t_0} \tag{5}$$

Step 2: Construct the matrix of distance in sustainability. This step is the same as before, so we do not show details here.

Step 3: Determine the future growth volume in the next period based on an adjacent city.

$$v_{ij}^{t+1} \in \left[\min_{1 \le l \le M} (v_{lj}^{t} \,|\, d_{il}^{t} \le \alpha), \max_{1 \le l \le M} (v_{lj}^{t} \,|\, d_{il}^{t} \le \alpha) \right] \tag{6}$$

where v_{ij}^{t+1} indicates the growth volume regarding SDG j of city i for the next period. v_{ij}^{t+1} is ranging from $\min_{1 \le l \le M} (v_{lj}^{t} \,|\, d_{il}^{t} \le \alpha)$ to $\max_{1 \le l \le M} (v_{lj}^{t} \,|\, d_{il}^{t} \le \alpha)$. There are 285 cities (including itself) that can be treated as adjacent cities for city i and we set a threshold (α) to screen out cities with a relatively large difference in sustainability. α is in the range of 0 to 100, which is the key parameter to designing different scenarios. For example, $\alpha = 0$ means only the city with the same sustainability in all SDGs can be included in the adjacent city list, and at least one city (itself) can be regarded as a adjacent city for city i. $\alpha = 100$ means that all cities can be treated as adjacent cities for city i, even if they are diametrically different in sustainability. Then, we chose the

maximum of the average annual growth volume regarding SDG j within the adjacent city list for city i, that is $v_{ij}^{t+1} = \max_{1 \le l \le M} (v_{lj}^{t} \,|\, d_{il}^{t} \le \alpha)$. This setting indicates, in the next period, that city i will learn from the growth path of the most fast-growing city with similar sustainable development in economy, society, and environment.

Step 4: Simulate the scores of an SDG of a city in the next period.

$$Y_{ij}^{t+1}\left(v_{ij}^{t+1}, Y_{ij}^{t}\right) = Y_{ij}^{t} + v_{ij}^{t+1} \tag{7}$$

Y_{ij}^{t+1} and Y_{ij}^{t} respectively indicate the scores of the SDG j of city i in period $t+1$ and t. For cities whose SDGs would reach 100 before 2030, the score of the SDG j would remain constant at 100 since then. The SDG index is the weighted average of the scores of all SDGs in period $t+1$.

Step 5: Iterate from step 1 to step 4 up to 2030. This step is the same as before, so we do not show details here.

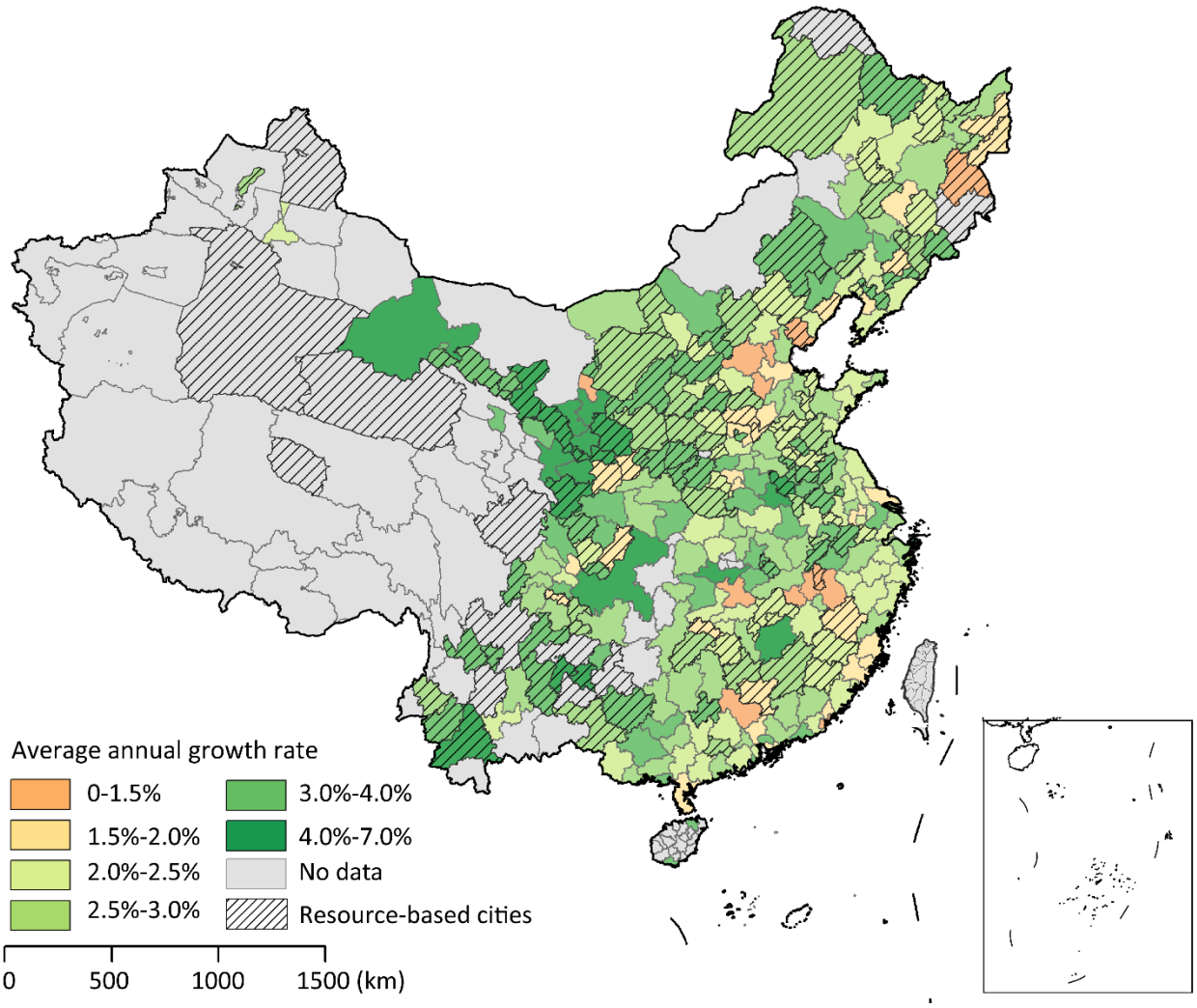

Figure S 1. Average annual growth rate of the SDG index of Chinese cities during 2005-2016. There are a total of 115 resource-based cities (the area with gridlines) and 170 non-resource-based cities (the areas without gridlines) shown on the map. Their average annual growth rate in the SDG index was 2.69% during 2005–2016, ranging from 1.05% (Mudanjiang, Heilongjiang province) to 5.96% (Baiyin, Gansu province).

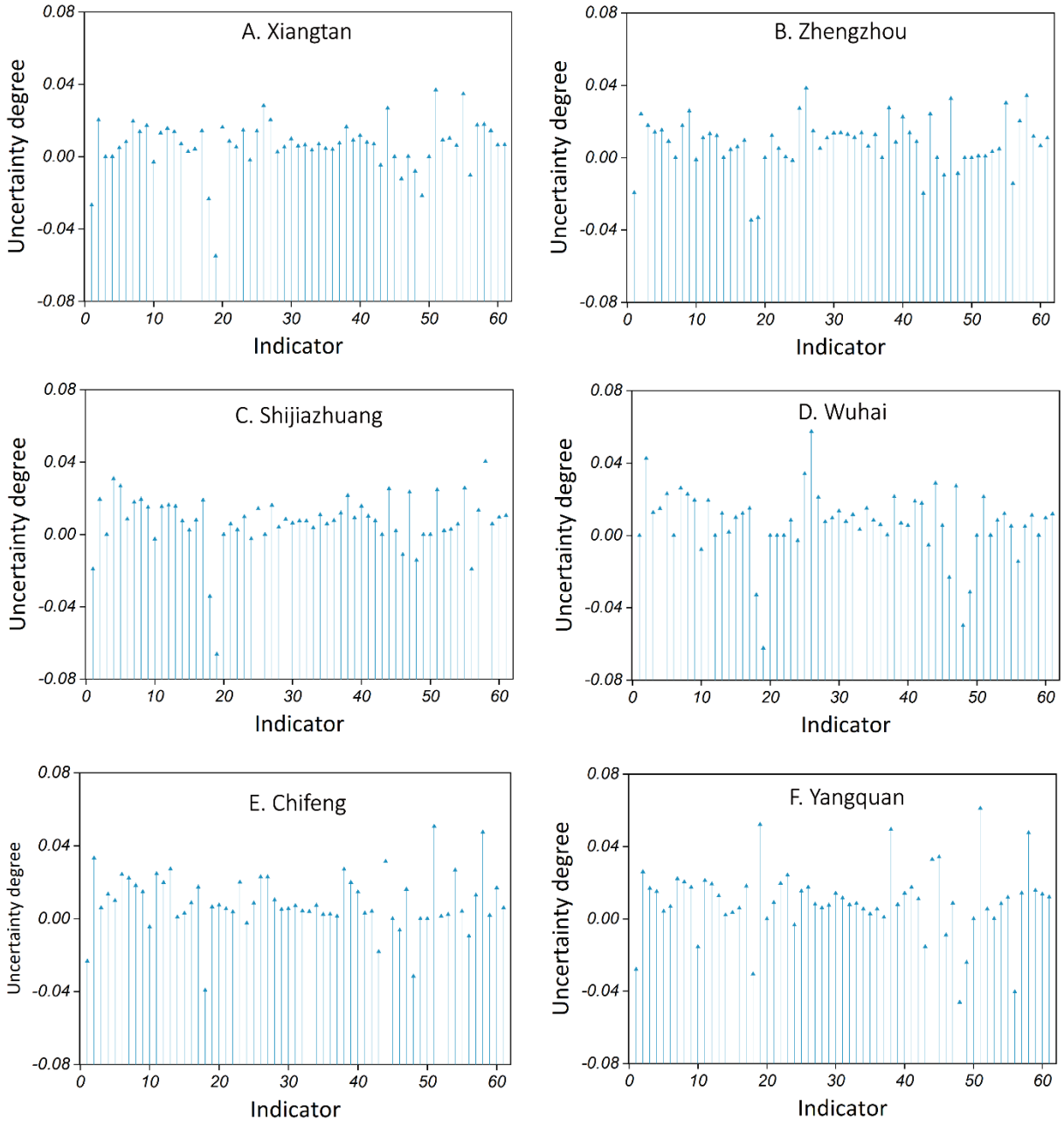

Figure S 2. Uncertainty degree of SDG index to changes in each indicator. The horizontal axis suggests the indicator number, and the description of indicator corresponding to each number is shown in Table S1. A total of 61 indicators are included in uncertainty analysis. The vertical axis suggests the uncertainty degree due to a 10% increase in the original value of each indicator.

Table S 1. Indicators and data sources of 17 SDGs.

No.	Target	Indicator	Unit	Data source
			Goal 1. No poverty	
1	Target 1.3	Ratio of unemployed person to total population	%	The China City Statistical Yearbook & City-level statistical yearbooks
2	Target 1.a	Total government spending on essential services per capita	10000 Yuan/person	The China Statistical Yearbook for Regional Economy & City-level statistical yearbooks & Provincial statistical yearbooks
			Goal 2. Zero hunger	
3	Target 2.3	Total power of agricultural machinery per cultivated land	W.h/m2	The China Statistical Yearbook for Regional Economy & City-level statistical yearbooks & Provincial statistical yearbooks
4	Target 2.3	Grain yield per cultivated land	Tonnes/m2	The China Statistical Yearbook for Regional Economy & City-level statistical yearbooks & Provincial statistical yearbooks
5	Target 2.4	Irrigated area per cultivated land	%	The China Statistical Yearbook for Regional Economy & City-level statistical yearbooks & Provincial statistical yearbooks
6	Target 2.a	Government expenditure on agriculture, forestry, and water conservancy per capita	1000 Yuan/person	The China Statistical Yearbook for Regional Economy & City-level statistical yearbooks & Provincial statistical yearbooks
			Goal 3. Good health and well-being	
7	Target 3.8	Number of beds of hospitals and health centers per capita	Units/person	The China City Statistical Yearbook & City-level statistical yearbooks
8	Target 3.8	Ratio of employees of health, social, security and social welfare to total population	%	The China City Statistical Yearbook & City-level statistical yearbooks
9	Target 3.c	Ratio of doctors to total population	%	The China City Statistical Yearbook & City-level statistical yearbooks
10	Target 3.9	Volume of industry sulphur dioxide per capita	Tonnes/person	The China City Statistical Yearbook & City-level statistical yearbooks
			Goal 4. Quality education	
11	Target 4.1	Student–teacher ratio of regular secondary schools	-	The China Statistical Yearbook for Regional Economy & City-level statistical yearbooks & Provincial statistical yearbooks
12	Target 4.1	Student–teacher ratio of primary schools	-	The China Statistical Yearbook for Regional Economy & City-level statistical yearbooks & Provincial statistical yearbooks
13	Target 4.3	Student–teacher ratio of regular higher education institutions	-	The China Statistical Yearbook for Regional Economy & City-level statistical yearbooks & Provincial statistical yearbooks

14	Target 4.3	Ratio of students enrollment in high schools to total population	%	The China City Statistical Yearbook & City-level statistical yearbooks
15	Target 4.6	Collection of public libraries per 100 persons	Pieces/person	The China City Statistical Yearbook & City-level statistical yearbooks
16	Target 4.a	Government expenditure on education per capita	Yuan/person	The China City Statistical Yearbook & City-level statistical yearbooks & Provincial statistical yearbooks
17	Target 4.c	Ratio of teacher to total population	%	The China City Statistical Yearbook & City-level statistical yearbooks
		Goal 5. Gender equality		
18	Target 5.c	Ratio of female to male with a high school diploma	-	China's national population census in 2010 & China national population sample survey in 2005 and 2015 & National and provincial statistical yearbooks in the years except 2005, 2010, and 2015
19	Target 5.c	Ratio of female to male illiteracy rate	-	China's national population census in 2010 & China national population sample survey data in 2005 and 2015 & National and provincial statistical yearbooks in the years except 2005, 2010, and 2015
		Goal 6. Clean water and sanitation		
20	Target 6.1	Water coverage rate	%	The China Urban Construction Statistical Yearbook & City-level statistical yearbooks
21	Target 6.2	Number of latrines per capita	Units/person	The China Urban Construction Statistical Yearbook & City-level statistical yearbooks
22	Target 6.3	Ratio of waste water centralized treated of sewage work	%	The China City Statistical Yearbook & City-level statistical yearbooks
23	Target 6.4	Water consumption for residential use per capita	Tonne/person	The China City Statistical Yearbook & City-level statistical yearbooks
24	Target 6.4	Water consumption per GDP	Tonnes/10000 Yuan	The China City Statistical Yearbook & Provincial statistical yearbooks
		Goal 7. Affordable and clean energy		
25	Target 7.1	Gas coverage rate	%	The China Urban Construction Statistical Yearbook & City-level statistical yearbooks
26	Target 7.1	Electricity consumption per capita	Kwh/person	The China City Statistical Yearbook & City-level statistical yearbooks
		Goal 8. Decent work and economic growth		
27	Target 8.1	Annual growth rate of real GDP per capita	%	The China City Statistical Yearbook & City-level statistical yearbooks & Provincial statistical yearbooks

28	Target 8.3	Ratio of persons employed in private enterprises and self-employed individuals to total employed persons	%	The China City Statistical Yearbook & City-level statistical yearbooks
29	Target 8.4	Retail sales of consumer goods per capita	10000 Yuan/person	The China City Statistical Yearbook & City-level statistical yearbooks & Provincial statistical yearbooks
30	Target 8.5	Ratio of employed persons to total population	%	The China City Statistical Yearbook & City-level statistical yearbooks
31	Target 8.10	Ratio of loans of national banking system to GDP	%	The China City Statistical Yearbook & City-level statistical yearbooks
32	Target 8.10	Ratio of employed persons in financial Intermediation to total population	%	The China City Statistical Yearbook & City-level statistical yearbooks
		Goal 9. Industry, innovation, and infrastructure		
33	Target 9.1	Ratio of passenger traffic to total population	Passenger volume/person	The China City Statistical Yearbook & The China Transportation Statistical Yearbook & City-level statistical yearbooks
34	Target 9.2	Ratio of employed persons of manufacturing sectors to total employed persons	%	The China City Statistical Yearbook & City-level statistical yearbooks
35	Target 9.5	Research and development expenditure as a proportion of GDP	%	The China City Statistical Yearbook & City-level statistical yearbook & Provincial statistical yearbooks
36	Target 9.5	Ratio of persons employed in scientific research, technical service and geologic prospecting to total population	%	The China City Statistical Yearbook & City-level statistical yearbook & Provincial statistical yearbooks
37	Target 9.b	Patents per capita	Units/person	State Intellectual Property Office of China
		Goal 10. Reduced inequalities		
38	Target 10.2	Ratio of employees of health, social, security and social welfare to unemployed persons	employees/person	The China City Statistical Yearbook & City-level statistical yearbooks & provincial statistical yearbooks
39	Target 10.4	Wages as a proportion of GDP	%	The China City Statistical Yearbook & City-level statistical yearbooks & provincial statistical yearbooks
40	Target 10.4	Social safety net and employment effort expenditure per unemployed person	%	The China Statistical Yearbook for Regional Economy & The China City Statistical Yearbook & City-level statistical yearbooks
		Goal 11. Sustainable cities and communities		
41	Target 11.2	Number of public transportation vehicles per 10000 persons	Units/10000 persons	The China City Statistical Yearbook & City-level statistical yearbooks

42	Target 11.3	Living area per capita	Square meters/person	The China City Statistical Yearbook & The China Urban Construction Statistical Yearbook & City-level statistical yearbooks
43	Target 11.6	Concentration of PM2.5	μg/m3	Socioeconomic Data and Applications Center (SEDAC): A Data Center in NASA's Earth Observing System Data and Information System (EOSDIS) (Hosted by CIESIN at Columbia University)
44	Target 11.7	Ratio of green covered areas to completed area	%	The China City Statistical Yearbook & City-level statistical yearbooks
Goal 12. Responsible consumption and production				
45	Target 12.4	Ratio of consumption wastes treated	%	The China City Statistical Yearbook & City-level statistical yearbooks
46	Target 12.4	Wastewater discharged per capita	Cubic meters/person	The China Urban Construction Statistical Yearbook & City-level statistical yearbooks
47	Target 12.5	Ratio of industrial solid wastes comprehensively utilized	%	The China City Statistical Yearbook & City-level statistical yearbooks
Goal 13. Climate change				
48	Target 13.2	CO_2 emissions intensity	Tonnes/10000 Yuan	The data of CO_2 emissions are sourced from existing study[28] & The China City Statistical Yearbook & Provincial statistical yearbooks
49	Target 13.2	CO_2 emissions per capita	Million tonnes/10000 persons	The data of CO_2 emissions are sourced from existing study[28] & The China City Statistical Yearbook & Provincial statistical yearbooks
Goal 14. Life below water				
50	Target 14.1	Volume of industrial waste discharged directly into the sea	%	The China Marine Statistical Yearbook
51	Target 14.3	Ratio of waste water centralized treated of sewage work	%	The China City Statistical Yearbook & City-level statistical yearbooks
Goal 15. Life on land				
52	Target 15.1	Forest coverage rate	%	NASA's Earth Observing System Data and Information System
53	Target 15.1	Wetland coverage rate	%	NASA's Earth Observing System Data and Information System
54	Target 15.a	Government expenditure on agriculture, forestry, and water conservancy as a proportion of GDP	%	The China Statistical Yearbook for Regional Economy & City-level statistical yearbooks & Provincial statistical yearbooks
Goal 16. Peace, justice, and strong institutions				

55	Target 16.6	Governance efficiency	-	Methods: Slacks-Based Data Envelopment Analysis Measure; Inputs and Outputs can be found in Table S **6**; The details of the evaluation process have been shown in our previous work.[8]
56	Target 16.6	Tax burden of enterprises	%	The China City Statistical Yearbook & City-level statistical yearbooks
		Goal 17. Partnerships for the goals		
57	Target 17.1	Proportion of domestic budget funded by domestic taxes	%	The China Statistical Yearbook for Regional Economy & City-level statistical yearbooks & Provincial statistical yearbooks
58	Target 17.1	Share of public finance income to GDP	%	The China City Statistical Yearbook & City-level statistical yearbooks & Provincial statistical yearbooks
59	Target 17.3	Ratio of health, education, and R&D spending to GDP	%	The China City Statistical Yearbook & City-level statistical yearbooks & Provincial statistical yearbooks
60	Target 17.3	Share of foreign direct investments to GDP	%	The China City Statistical Yearbook & City-level statistical yearbooks & Provincial statistical yearbooks
61	Target 17.6	Share of subscribers of Internet services to total population	%	The China City Statistical Yearbook & City-level statistical yearbooks

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Table S 2. City list and categorization of 285 Chinese cities.

No.	City	City type	No.	City	City type	No.	City	City type
1	Wuhai	Resource-based	96	Liupanshui	Resource-based	191	Dezhou	Non-resource-based
2	Fushun	Resource-based	97	Anshun	Resource-based	192	Liaocheng	Non-resource-based
3	Fuxin	Resource-based	98	Qujifng	Resource-based	193	Binzhou	Non-resource-based
4	Panjin	Resource-based	99	Baoshan	Resource-based	194	Heze	Non-resource-based
5	Liaoyuan	Resource-based	100	Zhaotong	Resource-based	195	Zhengzhou	Non-resource-based
6	Baishan	Resource-based	101	Lijiang	Resource-based	196	Kaifeng	Non-resource-based
7	Hegang	Resource-based	102	Pu'er	Resource-based	197	Anyang	Non-resource-based
8	Shuangyashan	Resource-based	103	Lincang	Resource-based	198	Xinxiang	Non-resource-based
9	Yichun-HLJ	Resource-based	104	Baoji	Resource-based	199	Xuchang	Non-resource-based
10	Qitaihe	Resource-based	105	Xianyang	Resource-based	200	Luohe	Non-resource-based
11	Huaibei	Resource-based	106	Weinan	Resource-based	201	Shangqiu	Non-resource-based
12	Tongling	Resource-based	107	Yan'an	Resource-based	202	Xinyang	Non-resource-based
13	Jingdezhen	Resource-based	108	Yulin-SX	Resource-based	203	Zhoukou	Non-resource-based
14	Pingxiang	Resource-based	109	Jinchang	Resource-based	204	Zhumadian	Non-resource-based
15	Xinyu	Resource-based	110	Wuwei	Resource-based	205	Wuhan	Non-resource-based
16	Zaozhuang	Resource-based	111	Zhangye	Resource-based	206	Shiyan	Non-resource-based
17	Jiaozuo	Resource-based	112	Pingliang	Resource-based	207	Yichang	Non-resource-based
18	Puyang	Resource-based	113	Qingyang	Resource-based	208	Xiangyang	Non-resource-based
19	Huangshi	Resource-based	114	Longnan	Resource-based	209	Jingmen	Non-resource-based
20	Shaoguan	Resource-based	115	Karamay	Resource-based	210	Xiaogan	Non-resource-based
21	Luzhou	Resource-based	116	Beijing	Non-resource-based	211	Jingzhou	Non-resource-based
22	Tongchuan	Resource-based	117	Tianjin	Non-resource-based	212	Huanggang	Non-resource-based
23	Baiyin	Resource-based	118	Shijiazhuang	Non-resource-based	213	Xianning	Non-resource-based
24	Shizuishan	Resource-based	119	Qinhuangdao	Non-resource-based	214	Suizhou	Non-resource-based
25	Tangshan	Resource-based	120	Baoding	Non-resource-based	215	Changsha	Non-resource-based
26	Handan	Resource-based	121	Cangzhou	Non-resource-based	216	Zhuzhou	Non-resource-based
27	Xingtai	Resource-based	122	Langfang	Non-resource-based	217	Xiangtan	Non-resource-based
28	Zhangjiakou	Resource-based	123	Hengshui	Non-resource-based	218	Yueyang	Non-resource-based

29	Chengde	Resource-based	124	Taiyuan	Non-resource-based	219	Changde	Non-resource-based
30	Datong	Resource-based	125	Hohhot	Non-resource-based	220	Zhangjiajie	Non-resource-based
31	Yangquan	Resource-based	126	Tongliao	Non-resource-based	221	Yiyang	Non-resource-based
32	Changzhi	Resource-based	127	Bayannur	Non-resource-based	222	Yongzhou	Non-resource-based
33	Jincheng	Resource-based	128	Ulanqab	Non-resource-based	223	Huaihua	Non-resource-based
34	Shuozhou	Resource-based	129	Shenyang	Non-resource-based	224	Guangzhou	Non-resource-based
35	Jinzhong	Resource-based	130	Dalian	Non-resource-based	225	Shenzhen	Non-resource-based
36	Yuncheng	Resource-based	131	Dandong	Non-resource-based	226	Zhuhai	Non-resource-based
37	Xinzhou	Resource-based	132	Jinzhou	Non-resource-based	227	Shantou	Non-resource-based
38	Linfen	Resource-based	133	Yingkou	Non-resource-based	228	Foshan	Non-resource-based
39	Lvliang	Resource-based	134	Liaoyang	Non-resource-based	229	Jiangmen	Non-resource-based
40	Baotou	Resource-based	135	Tieling	Non-resource-based	230	Zhanjiang	Non-resource-based
41	Chifeng	Resource-based	136	Chaoyang	Non-resource-based	231	Maoming	Non-resource-based
42	Erdos	Resource-based	137	Changchun	Non-resource-based	232	Zhaoqing	Non-resource-based
43	Hulunbuir	Resource-based	138	Siping	Non-resource-based	233	Huizhou	Non-resource-based
44	Anshan	Resource-based	139	Baicheng	Non-resource-based	234	Meizhou	Non-resource-based
45	Benxi	Resource-based	140	Harbin	Non-resource-based	235	Shanwei	Non-resource-based
46	Huludao	Resource-based	141	Qiqihar	Non-resource-based	236	Heyuan	Non-resource-based
47	Jilin	Resource-based	142	Jiamusi	Non-resource-based	237	Yangjiang	Non-resource-based
48	Tonghua	Resource-based	143	Suihua	Non-resource-based	238	Qingyuan	Non-resource-based
49	Songyuan	Resource-based	144	Shanghai	Non-resource-based	239	Dongguan	Non-resource-based
50	Jixi	Resource-based	145	Nanjing	Non-resource-based	240	Zhongshan	Non-resource-based
51	Daqing	Resource-based	146	Wuxi	Non-resource-based	241	Chaozhou	Non-resource-based
52	Mudanjiang	Resource-based	147	Changzhou	Non-resource-based	242	Jieyang	Non-resource-based
53	Heihe	Resource-based	148	Suzhou-JS	Non-resource-based	243	Nanning	Non-resource-based
54	Xuzhou	Resource-based	149	Nantong	Non-resource-based	244	Liuzhou	Non-resource-based
55	Suqian	Resource-based	150	Lianyungang	Non-resource-based	245	Guilin	Non-resource-based
56	Huzhou	Resource-based	151	Huai'an	Non-resource-based	246	Wuzhou	Non-resource-based
57	Huainan	Resource-based	152	Yancheng	Non-resource-based	247	Beihai	Non-resource-based
58	Maanshan	Resource-based	153	Yangzhou	Non-resource-based	248	Fangchenggang	Non-resource-based
59	Chuzhou	Resource-based	154	Zhenjiang	Non-resource-based	249	Qinzhou	Non-resource-based

60	Suzhou-AH	Resource-based	155	Taizhou-JS	Non-resource-based	250	Guigang	Non-resource-based
61	Bozhou	Resource-based	156	Hangzhou	Non-resource-based	251	Yulin-GX	Non-resource-based
62	Chizhou	Resource-based	157	Ningbo	Non-resource-based	252	Laibin	Non-resource-based
63	Xuancheng	Resource-based	158	Wenzhou	Non-resource-based	253	Chongzuo	Non-resource-based
64	Sanming	Resource-based	159	Jiaxing	Non-resource-based	254	Haikou	Non-resource-based
65	Nanping	Resource-based	160	Shaoxing	Non-resource-based	255	Sanya	Non-resource-based
66	Longyan	Resource-based	161	Jinhua	Non-resource-based	256	Chongqing	Non-resource-based
67	Ganzhou	Resource-based	162	Quzhou	Non-resource-based	257	Chengdu	Non-resource-based
68	Yichun-JX	Resource-based	163	Zhoushan	Non-resource-based	258	Deyang	Non-resource-based
69	Zibo	Resource-based	164	Taizhou-ZJ	Non-resource-based	259	Mianyang	Non-resource-based
70	Dongying	Resource-based	165	Lishui	Non-resource-based	260	Suining	Non-resource-based
71	Jining	Resource-based	166	Hefei	Non-resource-based	261	Neijiang	Non-resource-based
72	Tai'an	Resource-based	167	Wuhu	Non-resource-based	262	Leshan	Non-resource-based
73	Laiwu	Resource-based	168	Bengbu	Non-resource-based	263	Meishan	Non-resource-based
74	Linyi	Resource-based	169	Anqing	Non-resource-based	264	Yibin	Non-resource-based
75	Luoyang	Resource-based	170	Huangshan	Non-resource-based	265	Bazhong	Non-resource-based
76	Pingdingshan	Resource-based	171	Fuyang	Non-resource-based	266	Ziyang	Non-resource-based
77	Hebi	Resource-based	172	Lu'an	Non-resource-based	267	Guiyang	Non-resource-based
78	Sanmenxia	Resource-based	173	Fuzhou-FJ	Non-resource-based	268	Zunyi	Non-resource-based
79	Nanyang	Resource-based	174	Xiamen	Non-resource-based	269	Kunming	Non-resource-based
80	Ezhou	Resource-based	175	Putian	Non-resource-based	270	Yuxi	Non-resource-based
81	Hengyang	Resource-based	176	Quanzhou	Non-resource-based	271	Xi'an	Non-resource-based
82	Shaoyang	Resource-based	177	Zhangzhou	Non-resource-based	272	Hanzhong	Non-resource-based
83	Chenzhou	Resource-based	178	Ningde	Non-resource-based	273	Ankang	Non-resource-based
84	Loudi	Resource-based	179	Nanchang	Non-resource-based	274	Shangluo	Non-resource-based
85	Yunfu	Resource-based	180	Jiujiang	Non-resource-based	275	Lanzhou	Non-resource-based
86	Baise	Resource-based	181	Yingtan	Non-resource-based	276	Jiayuguan	Non-resource-based
87	Hezhou	Resource-based	182	Ji'an	Non-resource-based	277	Tianshui	Non-resource-based
88	Hechi	Resource-based	183	Fuzhou-JX	Non-resource-based	278	Jiuquan	Non-resource-based
89	Zigong	Resource-based	184	Shangrao	Non-resource-based	279	Dingxi	Non-resource-based
90	Panzhihua	Resource-based	185	Jinan	Non-resource-based	280	Xining	Non-resource-based

91	Guangyuan	Resource-based	186	Qingdao	Non-resource-based	281	Yinchuan	Non-resource-based
92	Nanchong	Resource-based	187	Yantai	Non-resource-based	282	Wuzhong	Non-resource-based
93	Guang'an	Resource-based	188	Weifang	Non-resource-based	283	Guyuan	Non-resource-based
94	Dazhou	Resource-based	189	Weihai	Non-resource-based	284	Zhongwei	Non-resource-based
95	Ya'an	Resource-based	190	Rizhao	Non-resource-based	285	Urumqi	Non-resource-based

Table S 3. 12 Chinese cities that are excluded in evaluation.

No.	City	Province	City type
1	Sansa	Hainan	Non-resource-based city
2	Danzhou	Hainan	Non-resource-based city
3	Bijie	Guizhou	Resource-based city
4	Tongren	Guizhou	Non-resource-based city
5	Lasa	Tibet	Non-resource-based city
6	Shigatse	Tibet	Non-resource-based city
7	Changdu	Tibet	Non-resource-based city
8	Linzhi	Tibet	Non-resource-based city
9	Shannan	Tibet	Non-resource-based city
10	Haidong	Qinghai	Non-resource-based city
11	Tulufan	Xinjiang	Non-resource-based city
12	Hami	Xinjiang	Non-resource-based city

Table S 4. 53 coastal cities in China.

No.	City	Province	No.	City	Province
1	Tianjin	Tianjin	28	Qingdao	Shandong
2	Tangshan	Hebei	29	Dongying	Shandong
3	Qinhuangdao	Hebei	30	Yantai	Shandong
4	Cangzhou	Hebei	31	Weifang	Shandong
5	Dalian	Liaoning	32	Weihai	Shandong
6	Dandong	Liaoning	33	Rizhao	Shandong
7	Jinzhou	Liaoning	34	Binzhou	Shandong
8	Yingkou	Liaoning	35	Guangzhou	Guangdong
9	Panjin	Liaoning	36	Shenzhen	Guangdong
10	Huludao	Liaoning	37	Zhuhai	Guangdong
11	Shanghai	Shanghai	38	Shantou	Guangdong
12	Nantong	Jiangsu	39	Jiangmen	Guangdong
13	Lianyungang	Jiangsu	40	Zhanjiang	Guangdong
14	Yancheng	Jiangsu	41	Maoming	Guangdong
15	Hangzhou	Zhejiang	42	Huizhou	Guangdong
16	Ningbo	Zhejiang	43	Shanwei	Guangdong
17	Wenzhou	Zhejiang	44	Yangjiang	Guangdong
18	Jiaxing	Zhejiang	45	Dongguan	Guangdong
19	Shaoxing	Zhejiang	46	Zhongshan	Guangdong
20	Zhoushan	Zhejiang	47	Chaozhou	Guangdong
21	Taizhou	Zhejiang	48	Jieyang	Guangdong
22	Fuzhou	Fujian	49	Beihai	Guangxi
23	Xiamen	Fujian	50	Fangchenggang	Guangxi
24	Putian	Fujian	51	Qinzhou	Guangxi

25	Quanzhou	Fujian	52	Haikou	Hainan
26	Zhangzhou	Fujian	53	Sanya	Hainan
27	Ningde	Fujian			

Table S 5. Changes of administrative divisions of prefecture-level cities in China, 2006-2016. The information was collected from Ministry of Civil Affairs of the People's Republic of China.

No.	City	Province	Change year	Official document
1	Urumqi	Xinjiang	2007	The State Council 2007/No.65
2	Baoji	Shaanxi	2008	The State Council 2008/No.77
3	Xianyang	Shaanxi	2008	The State Council 2008/No.77
4	Chaohu	Anhui	2011	The State Council 2011/No.84
5	Hefei	Anhui	2011	The State Council 2011/No.84
6	Wuhu	Anhui	2011	The State Council 2011/No.84
7	Maanshan	Anhui	2011	The State Council 2011/No.84
8	Bijie	Guizhou	2011	The State Council 2011/No.130
9	Tongren	Guizhou	2011	The State Council 2011/No.131
10	Sansha	Hainan	2012	Announcement from the Ministry of Civil Affairs of China
11	Haidong	Qinghai	2013	The State Council 2013/No.23
12	Shigatse	Tibet	2014	The State Council 2014/No.79
13	Chamdo	Tibet	2014	The State Council 2014/No.143
14	Tongling	Anhui	2015	The State Council 2015/No.181
15	Anqing	Anhui	2015	The State Council 2015/No.181
16	Huainan	Anhui	2015	The State Council 2015/No.206
17	Liuan	Anhui	2015	The State Council 2015/No.206
18	Danzhou	Henan	2015	The State Council 2015/No.41
19	Linzhi	Tibet	2015	The State Council 2015/No.51
20	Tulufan	Xinjiang	2015	The State Council 2015/No.52
21	Shannan	Tibet	2016	The State Council 2016/No.8
22	Hami	Xinjiang	2016	The State Council 2016/No.9
23	Chengdu	Sichuan	2016	The State Council 2016/No.78
24	Ziyang	Sichuan	2016	The State Council 2016/No.78

Table S 6. Input and output selection for governance efficiency indicator.

	Variable	Unit	Description	Data source
Input	Public finance expenditure	100 million yuan	Public finance expenditure, including expenditure for science, technology, education, social security, transport, and welfare	The China City Statistical Yearbook & City-level statistical yearbooks & Provincial statistical yearbooks
Input	Land	sq. km	Area of land used for urban construction	The China City Statistical Yearbook & City-level statistical yearbooks & Provincial statistical yearbooks
Output	Education	-	Education level=6×P+12×S+16×H P: the number of students enrolled in primary schools S: the number of students enrolled in secondary schools H: the number of students enrolled in institutions of higher education Note: the weighted values (6, 12, and 16) are set based on the length of school years	The China City Statistical Yearbook & City-level statistical yearbooks & Provincial statistical yearbooks
Output	Infrastructure	10 thousand square meters	Area of paved city roads	The China City Statistical Yearbook & City-level statistical yearbooks & Provincial statistical yearbooks
Output	Healthcare	Persons	The number of doctors	The China City Statistical Yearbook & City-level statistical yearbooks & Provincial statistical yearbooks
Output	Technology	-	The innovation performance is evaluated through innovation outputs, such as invention patents, utility patents, and design patents	The data are source from existing study.[29]

Table S 7. SDG index of Chinese cities from 2005 to 2016.

No.	City	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	Average	Rank in 2016
1	Beijing	57.28	59.71	63.52	63.17	67.43	69.38	70.13	71.90	71.97	71.88	72.40	73.12	67.66	2
2	Tianjin	49.27	50.06	53.86	56.06	57.03	57.69	60.12	61.18	62.36	63.67	64.10	65.31	58.39	14
3	Shijiazhuang	39.81	40.28	41.18	41.83	42.67	43.73	43.38	45.38	46.11	46.16	48.41	49.72	44.05	137
4	Tangshan	41.71	41.06	42.39	43.85	45.28	46.75	45.04	47.17	46.83	46.11	47.19	47.58	45.08	186
5	Qinhuangdao	46.09	45.35	46.23	47.07	48.84	49.21	48.46	49.63	52.36	54.44	56.19	57.68	50.13	43
6	Handan	33.14	32.89	33.52	35.22	36.86	37.95	37.01	38.16	39.85	39.67	40.83	40.76	37.15	280
7	Xingtai	32.45	33.04	34.46	35.21	36.84	38.32	36.90	38.54	41.28	41.62	43.07	43.17	37.91	268
8	Baoding	35.92	34.85	35.63	37.40	37.50	39.55	38.27	39.74	39.86	39.96	42.12	42.24	38.59	275
9	Zhangjiakou	30.57	30.83	32.34	34.23	35.88	37.46	36.95	38.67	39.04	38.96	40.31	40.87	36.34	279
10	Chengde	35.01	33.99	35.06	37.44	38.74	40.16	39.62	42.08	42.35	42.39	43.94	45.46	39.69	235
11	Cangzhou	39.67	39.29	40.05	41.59	43.00	44.93	43.75	44.34	45.53	45.99	47.61	48.57	43.69	157
12	Langfang	40.15	38.95	40.52	41.91	42.84	44.13	43.34	44.50	44.54	44.20	44.82	46.46	43.03	210
13	Hengshui	36.34	35.04	35.03	36.31	38.48	40.65	39.73	41.63	43.30	43.96	41.80	42.38	39.55	274
14	Taiyuan	46.01	44.56	45.54	46.27	46.10	49.55	53.43	56.53	57.64	56.79	59.24	57.72	51.61	41
15	Datong	29.05	29.26	31.24	30.58	33.36	34.50	36.11	38.76	39.45	41.44	42.61	43.29	35.80	266
16	Yangquan	35.70	34.11	35.26	37.07	36.64	40.26	42.85	44.23	43.45	41.83	44.57	44.40	40.03	251
17	Changzhi	34.25	31.49	34.31	35.96	38.05	39.07	40.71	42.38	43.61	44.09	44.88	44.56	39.45	248
18	Jincheng	31.22	33.32	38.02	37.62	36.26	37.93	41.22	43.43	45.68	46.38	44.67	43.12	39.91	269
19	Shuozhou	30.78	29.49	31.11	30.88	32.49	34.63	35.45	37.98	38.85	40.13	41.29	39.78	35.24	282
20	Jinzhong	32.90	30.82	34.23	34.91	36.94	37.55	40.87	41.94	43.19	45.32	44.81	46.00	39.12	227
21	Yuncheng	29.40	31.44	33.51	36.94	36.93	39.59	42.56	43.59	45.13	43.60	42.98	42.85	39.04	272
22	Xinzhou	27.15	26.98	28.90	29.87	32.91	35.35	36.12	38.18	40.84	42.10	41.55	39.78	34.98	283
23	Linfen	29.05	26.30	29.11	30.13	29.70	33.32	36.42	37.77	38.95	39.00	39.38	39.34	34.04	284
24	Lvliang	29.71	29.33	32.85	32.77	32.74	32.94	34.00	36.30	37.46	37.39	38.40	39.05	34.41	285
25	Hohhot	37.33	37.58	39.40	40.24	41.66	42.20	43.91	46.30	46.53	46.66	48.58	48.51	43.24	160
26	Baotou	35.90	36.80	38.80	38.65	39.39	41.36	43.26	43.71	43.30	44.38	47.31	47.49	41.70	191
27	Wuhai	34.32	38.09	38.32	39.85	42.47	43.40	43.81	43.92	43.71	44.83	49.38	51.66	42.81	98

28	Chifeng	30.33	29.89	30.68	32.08	34.73	35.74	38.07	39.15	39.31	38.65	41.36	43.00	36.08	271
29	Tongliao	30.61	31.63	32.98	33.40	37.16	36.99	39.24	40.77	40.56	41.51	43.15	45.22	37.77	239
30	Erdos	34.60	33.89	37.04	36.50	38.87	42.76	44.96	45.27	43.03	42.70	43.44	46.26	40.78	218
31	Hulunbuir	31.81	31.31	32.27	33.15	34.42	36.26	38.80	40.57	41.11	39.51	43.05	43.22	37.12	267
32	Bayannur	33.85	34.08	36.34	37.12	37.45	39.34	40.68	41.58	44.14	44.32	46.08	46.82	40.15	202
33	Ulanqab	30.65	32.33	33.55	33.63	34.27	34.17	34.35	37.99	39.99	40.59	41.10	43.09	36.31	270
34	Shenyang	42.88	42.72	45.37	47.63	48.98	50.37	52.69	55.35	55.68	54.68	54.57	55.96	50.57	49
35	Dalian	46.45	45.47	49.40	51.08	52.11	52.50	53.62	55.33	55.38	55.07	54.90	58.63	52.50	37
36	Anshan	33.04	33.27	35.38	37.07	38.54	42.04	43.01	44.92	45.10	45.67	45.17	46.07	40.77	225
37	Fushun	39.31	39.19	42.01	41.36	43.60	43.70	43.75	45.79	47.61	47.80	46.05	47.42	43.97	192
38	Benxi	36.20	36.70	40.56	41.25	43.67	44.08	45.20	47.74	48.11	48.62	47.83	51.07	44.25	112
39	Dandong	40.24	41.75	42.63	43.17	43.45	45.65	51.11	51.65	53.15	53.73	51.71	52.78	47.58	80
40	Jinzhou	38.42	38.63	42.64	43.82	45.38	45.57	48.90	51.08	51.10	50.16	50.01	50.23	46.33	127
41	Yingkou	42.96	42.95	45.40	46.70	46.87	48.00	49.66	51.55	51.23	51.54	50.62	51.36	48.24	102
42	Fuxin	34.27	34.79	36.97	37.46	40.31	42.56	43.90	44.72	44.41	45.38	45.61	46.30	41.39	216
43	Liaoyang	38.61	37.23	42.07	41.35	45.14	47.18	47.56	48.88	48.63	48.99	47.14	49.00	45.15	148
44	Panjin	43.50	44.20	46.32	47.18	50.43	51.34	51.96	54.00	54.18	54.48	53.68	54.19	50.46	62
45	Tieling	31.24	34.31	37.33	37.95	39.17	41.30	42.72	44.84	44.76	44.91	44.30	44.81	40.64	245
46	Chaoyang	31.32	31.77	34.87	35.44	37.41	39.47	41.21	45.08	44.48	42.14	43.06	43.65	39.16	262
47	Huludao	39.83	39.53	39.90	40.70	41.11	43.12	43.30	47.45	47.31	47.73	45.64	47.40	43.58	193
48	Changchun	43.78	43.52	44.49	45.40	44.52	46.05	47.04	48.64	49.39	50.95	52.61	53.66	47.50	71
49	Jilin	37.76	40.05	42.44	42.06	42.16	43.00	43.13	44.53	44.84	46.64	47.29	47.55	43.45	188
50	Siping	34.07	34.91	36.57	36.94	37.53	39.69	39.43	40.72	41.75	41.39	44.40	45.48	39.41	234
51	Liaoyuan	35.74	35.34	38.90	38.22	41.63	44.33	43.09	44.46	46.15	45.59	47.05	47.91	42.37	179
52	Tonghua	41.23	40.16	42.34	42.12	44.10	45.99	45.78	48.20	50.96	51.80	54.60	55.68	46.91	51
53	Baishan	35.33	36.16	41.04	40.97	42.23	43.84	47.63	45.40	45.39	45.48	49.15	52.28	43.74	86
54	Songyuan	34.81	36.43	39.08	39.45	41.02	41.83	41.38	42.87	43.70	44.26	45.46	46.38	41.39	213
55	Baicheng	36.94	39.48	43.73	42.42	41.91	40.16	41.27	42.59	43.99	45.65	47.95	49.87	43.00	132
56	Harbin	40.57	41.63	43.27	43.45	45.29	46.69	49.34	52.02	51.99	52.99	51.61	53.69	47.71	69
57	Qiqihar	35.42	34.99	36.68	35.97	39.30	41.14	40.38	46.15	42.52	43.50	41.71	45.59	40.28	230

58	Jixi	38.30	37.71	41.22	41.64	44.92	44.60	45.79	48.16	43.75	46.71	44.49	47.57	43.74	187
59	Hegang	36.08	35.56	37.61	38.27	41.29	43.39	43.71	44.56	45.51	46.84	45.33	48.53	42.22	159
60	Shuangyashan	38.55	39.51	41.30	40.93	44.49	42.38	40.68	41.58	41.25	42.52	45.83	46.65	42.14	205
61	Daqing	37.00	36.75	38.17	42.26	42.57	44.13	46.26	47.36	46.17	48.19	45.84	48.17	43.57	171
62	Yichun-HLJ	36.95	37.15	40.02	39.93	42.68	44.89	44.69	46.41	46.08	44.34	45.99	47.79	43.08	183
63	Jiamusi	35.70	36.20	39.20	40.28	40.67	41.56	45.57	46.92	46.20	46.60	45.86	48.19	42.75	168
64	Qitaihe	35.79	38.25	40.26	38.24	40.01	42.06	41.63	45.69	46.04	45.33	45.72	47.16	42.18	199
65	Mudanjiang	41.34	41.18	41.80	42.50	44.56	44.59	45.80	46.53	45.70	44.56	43.50	46.37	44.04	215
66	Heihe	32.07	33.91	33.19	37.60	41.31	43.61	43.17	46.46	47.15	47.25	46.52	48.45	41.72	161
67	Suihua	34.94	33.07	34.39	35.73	37.69	38.88	38.80	41.19	40.73	41.53	41.32	44.09	38.53	258
68	Shanghai	50.86	52.87	55.21	58.74	60.00	61.53	63.44	65.69	65.95	66.31	67.04	68.67	61.36	9
69	Nanjing	50.10	52.30	52.98	55.38	56.01	55.98	57.40	59.62	61.82	61.75	63.21	64.50	57.59	17
70	Wuxi	46.82	46.50	47.67	49.08	50.10	52.10	53.16	55.28	57.01	57.10	57.90	59.00	52.64	30
71	Xuzhou	38.05	37.02	39.41	40.23	40.91	40.61	41.78	43.87	45.84	46.15	48.38	48.87	42.59	151
72	Changzhou	47.01	45.54	48.21	50.00	50.55	52.26	52.04	55.00	56.39	56.49	57.57	58.38	52.45	38
73	Suzhou-JS	43.82	42.93	48.62	50.22	51.64	53.01	55.51	58.93	61.52	62.92	63.27	64.56	54.75	16
74	Nantong	45.57	44.83	44.40	47.72	47.92	48.05	48.92	51.07	53.70	53.54	55.45	54.78	49.66	57
75	Lianyungang	41.53	43.20	45.23	46.67	46.91	47.65	46.95	49.96	50.21	51.89	54.33	54.73	48.27	58
76	Huai'an	39.02	39.52	42.18	43.58	44.07	44.95	45.81	49.26	50.38	50.64	51.58	52.12	46.09	90
77	Yancheng	41.64	40.98	43.97	43.68	43.92	42.89	43.92	46.54	48.07	49.96	51.71	52.66	45.83	83
78	Yangzhou	41.19	41.39	41.66	43.64	43.61	44.16	45.50	47.76	49.79	49.99	51.61	52.19	46.04	88
79	Zhenjiang	42.36	42.22	44.80	46.50	47.35	48.29	49.04	52.33	54.46	54.86	56.03	56.54	49.57	48
80	Taizhou-JS	41.64	41.80	42.34	44.14	44.22	44.81	44.25	46.52	48.72	49.12	50.69	51.88	45.84	94
81	Suqian	34.37	36.97	38.16	41.40	41.98	41.40	42.72	45.34	47.50	47.79	49.63	49.75	43.09	136
82	Hangzhou	53.24	54.56	57.26	59.73	61.86	64.60	65.73	66.48	68.36	69.59	71.77	72.32	63.79	4
83	Ningbo	47.00	45.01	48.89	51.29	51.74	53.56	55.89	55.24	58.03	59.22	60.64	63.59	54.17	19
84	Wenzhou	44.95	44.19	47.25	47.91	49.95	52.32	52.87	54.22	56.15	56.55	59.60	58.88	52.07	32
85	Jiaxing	44.92	43.89	47.22	48.66	49.23	51.24	51.87	52.21	54.70	54.83	56.20	57.44	51.03	44
86	Huzhou	45.15	43.94	47.36	48.97	49.60	50.88	52.20	52.35	54.37	53.67	56.20	57.71	51.03	42
87	Shaoxing	46.65	45.25	49.26	48.91	49.46	51.19	51.71	51.59	54.31	55.54	57.54	58.68	51.67	35

88	Jinhua	42.80	42.27	44.04	45.50	46.24	47.42	47.97	47.98	50.72	51.88	53.13	54.00	47.83	64
89	Quzhou	42.06	42.76	44.63	45.13	46.91	48.09	48.31	47.81	50.22	50.51	52.79	53.46	47.72	72
90	Zhoushan	46.15	44.98	51.96	51.53	55.81	57.52	59.37	60.05	62.66	64.74	66.93	69.35	57.59	8
91	Taizhou-ZJ	45.25	45.41	48.36	49.22	50.23	51.57	52.19	52.89	55.57	56.28	57.93	58.66	51.96	36
92	Lishui	43.43	41.35	47.62	47.33	49.04	48.67	49.74	49.20	52.15	52.49	54.63	55.14	49.23	54
93	Hefei	45.80	46.33	47.15	48.40	48.26	50.51	50.50	51.66	54.64	56.30	57.43	57.22	51.18	45
94	Wuhu	41.80	40.79	44.47	45.76	46.81	49.36	48.74	51.79	54.10	55.22	56.79	57.98	49.47	39
95	Bengbu	37.90	38.42	40.08	42.94	43.65	46.05	48.34	49.23	52.65	53.38	53.91	53.38	46.66	73
96	Huainan	37.28	39.19	41.56	40.68	41.65	43.41	44.11	46.08	47.22	47.05	47.83	49.29	43.78	145
97	Maanshan	41.26	41.28	41.66	44.15	43.80	44.99	46.54	49.34	50.65	50.25	52.01	52.47	46.53	85
98	Huaibei	35.52	36.47	38.69	39.42	41.86	44.14	45.61	47.18	48.96	49.93	49.31	49.78	43.90	135
99	Tongling	41.28	41.78	41.75	43.68	43.35	45.53	46.32	48.49	50.27	51.66	53.17	55.18	46.87	53
100	Anqing	38.48	39.23	39.50	40.85	41.71	42.14	42.71	44.86	48.32	48.82	51.47	50.92	44.08	115
101	Huangshan	38.08	39.17	42.77	44.65	45.54	47.68	49.31	50.87	52.41	54.07	54.54	55.76	47.90	50
102	Chuzhou	36.28	38.46	41.70	41.79	42.24	44.01	47.46	47.06	50.04	50.47	51.05	51.61	45.18	99
103	Fuyang	30.25	30.54	32.10	34.98	35.42	37.36	40.58	41.13	44.50	45.56	47.98	48.18	39.05	169
104	Suzhou-AH	32.15	33.28	33.74	36.23	36.93	39.27	39.01	40.45	42.90	44.66	47.09	47.99	39.48	176
105	Lu'an	34.34	35.77	39.33	39.67	44.04	45.73	47.43	48.85	50.27	51.03	53.27	52.16	45.16	89
106	Bozhou	30.36	32.25	36.19	38.92	38.21	40.91	41.43	41.96	45.53	47.53	47.19	48.41	40.74	162
107	Chizhou	38.58	40.29	42.62	43.35	44.07	46.13	47.30	49.27	52.02	53.22	54.54	54.92	47.19	56
108	Xuancheng	37.88	39.42	42.71	44.03	43.81	47.98	49.82	48.73	55.16	53.77	54.72	55.09	47.76	55
109	Fuzhou-FJ	51.58	51.18	49.92	52.70	54.89	54.47	56.69	58.14	59.21	59.18	60.52	61.46	55.83	24
110	Xiamen	56.23	55.23	61.06	60.83	62.91	63.53	63.50	64.69	65.40	66.30	67.79	70.39	63.15	5
111	Putian	43.20	41.80	43.00	43.72	47.85	47.80	48.28	51.73	51.21	50.54	51.46	53.10	47.81	78
112	Sanming	39.09	37.09	40.06	39.56	43.64	43.44	44.62	46.84	47.77	47.86	49.43	49.91	44.11	131
113	Quanzhou	42.11	42.46	43.63	42.49	47.32	45.83	46.69	48.62	49.70	49.58	50.57	51.40	46.70	101
114	Zhangzhou	39.76	38.22	39.82	39.28	41.77	42.01	42.89	44.65	45.32	45.30	46.76	49.64	42.95	138
115	Nanping	40.09	38.82	41.79	41.27	44.77	45.21	45.36	47.05	47.84	47.07	48.51	49.02	44.73	147
116	Longyan	36.88	36.47	39.21	39.28	43.64	42.05	44.73	44.76	45.69	45.40	47.62	47.27	42.75	197
117	Ningde	39.44	40.86	44.91	41.73	46.96	48.65	50.30	52.71	53.61	53.70	53.43	53.86	48.35	67

118	Nanchang	50.02	50.22	51.43	50.41	50.56	51.08	51.96	54.07	58.13	55.36	57.10	58.84	53.27	33
119	Jingdezhen	44.20	41.87	44.10	44.64	47.72	48.29	50.48	50.39	49.37	49.78	50.30	50.94	47.67	113
120	Pingxiang	41.01	41.74	45.18	43.75	43.95	46.04	47.38	49.44	50.45	50.09	51.52	53.31	46.99	75
121	Jiujiang	38.69	40.20	42.51	44.98	44.90	45.87	46.99	51.93	51.06	51.28	54.51	53.01	47.16	79
122	Xinyu	39.39	37.99	40.00	44.37	43.43	45.53	47.38	48.28	47.27	48.54	50.45	51.52	45.35	100
123	Yingtan	36.46	36.90	36.71	38.30	40.93	41.55	43.83	45.19	46.05	46.71	49.84	50.46	42.75	121
124	Ganzhou	35.05	35.20	38.64	37.32	38.42	39.33	39.27	41.72	42.24	43.46	47.23	48.18	40.50	170
125	Ji'an	32.55	34.84	37.59	38.74	42.02	42.71	42.09	43.16	46.19	47.71	50.16	50.42	42.35	123
126	Yichun-JX	38.49	39.12	41.35	42.51	43.31	42.32	44.18	45.03	45.79	46.51	48.59	48.33	43.79	164
127	Fuzhou-JX	38.78	38.33	39.91	39.78	41.25	42.62	43.35	47.37	48.06	48.23	49.85	50.73	44.02	119
128	Shangrao	41.18	41.57	42.39	43.09	42.12	43.13	45.05	44.88	45.07	47.00	46.73	47.53	44.14	189
129	Jinan	44.97	46.47	46.35	48.33	49.08	50.93	52.45	54.41	55.99	57.46	59.52	60.18	52.18	27
130	Qingdao	47.45	48.69	45.60	49.48	51.33	51.40	53.52	55.23	55.91	57.34	58.76	59.24	52.83	29
131	Zibo	39.24	41.84	42.31	42.75	43.51	44.67	46.59	48.16	48.82	49.47	51.20	50.89	45.79	116
132	Zaozhuang	31.53	37.94	37.13	39.08	40.08	41.87	40.55	42.52	44.00	44.36	45.24	45.52	40.82	233
133	Dongying	41.15	44.16	44.25	44.61	46.95	48.04	49.53	51.55	51.47	52.83	54.14	53.92	48.55	66
134	Yantai	41.53	44.27	44.52	44.41	46.34	48.29	49.12	50.66	51.41	52.72	52.14	54.23	48.30	61
135	Weifang	39.46	40.68	42.04	43.71	45.42	45.88	47.79	49.24	51.70	51.50	51.54	51.87	46.74	95
136	Jining	36.67	37.66	38.41	39.76	40.69	41.21	41.01	44.04	45.29	45.29	46.66	46.21	41.91	220
137	Tai'an	37.35	39.17	39.36	39.94	40.79	41.92	42.63	43.48	44.85	44.96	46.59	46.47	42.29	209
138	Weihai	48.88	51.29	51.07	52.51	54.28	57.71	58.48	60.14	61.65	63.67	65.24	65.45	57.53	13
139	Rizhao	39.74	42.96	42.70	42.75	42.59	45.61	45.80	47.19	47.68	48.41	49.69	50.29	45.45	124
140	Laiwu	40.98	43.90	44.93	44.95	45.44	47.26	48.17	49.65	50.94	50.51	51.62	52.01	47.53	93
141	Linyi	33.55	36.52	37.25	38.33	40.72	41.16	41.90	43.11	45.20	45.68	45.06	45.69	41.18	228
142	Dezhou	35.14	36.97	37.24	38.55	39.03	40.19	42.68	43.48	45.42	45.81	46.67	46.46	41.47	211
143	Liaocheng	36.66	36.96	37.65	39.50	39.99	40.44	41.38	43.34	44.82	44.58	45.58	44.36	41.27	254
144	Binzhou	38.04	41.07	40.66	43.48	44.68	47.09	48.90	50.60	50.64	51.55	53.45	52.12	46.86	91
145	Heze	32.16	38.08	38.92	38.68	40.43	40.71	41.22	42.02	42.98	43.20	44.63	44.09	40.59	257
146	Zhengzhou	39.80	39.59	42.24	42.38	46.05	47.67	50.07	50.92	52.47	54.88	58.30	58.79	48.60	34
147	Kaifeng	36.30	35.42	36.67	37.28	38.87	38.97	39.08	40.73	45.13	45.66	48.42	48.19	40.89	167

148	Luoyang	33.78	32.51	33.39	35.52	36.35	36.38	37.44	40.07	43.98	45.63	46.96	47.92	39.16	177
149	Pingdingshan	34.62	35.01	36.17	37.07	38.78	37.81	37.73	40.52	42.28	42.01	43.07	44.39	39.12	253
150	Anyang	35.33	34.84	35.90	36.87	38.28	38.60	39.38	38.92	40.49	40.74	43.29	43.32	38.83	265
151	Hebi	36.84	36.67	38.24	40.39	41.29	41.47	42.03	44.70	47.10	47.86	49.94	51.21	43.15	109
152	Xinxiang	35.52	37.25	38.54	40.68	42.11	41.59	41.41	43.09	44.05	44.27	44.48	45.32	41.53	238
153	Jiaozuo	37.14	34.69	37.12	38.32	40.09	40.58	42.50	42.17	43.86	44.33	46.86	47.82	41.29	181
154	Puyang	39.90	37.19	38.64	41.51	42.51	41.02	40.09	41.68	44.88	45.53	46.90	47.51	42.28	190
155	Xuchang	36.17	36.72	35.17	37.36	38.87	37.42	37.73	39.42	41.58	43.07	43.34	44.22	39.26	256
156	Luohe	41.70	42.47	44.04	44.38	44.02	46.58	45.60	46.83	48.46	50.01	50.98	50.87	46.33	117
157	Sanmenxia	33.86	33.10	35.19	37.14	37.59	37.57	39.97	42.02	44.72	46.21	45.47	48.29	40.10	165
158	Nanyang	32.11	31.69	32.69	33.91	34.80	35.74	36.79	37.16	38.98	40.41	43.08	43.77	36.76	261
159	Shangqiu	33.64	33.88	35.20	36.54	37.04	37.11	37.42	39.07	41.34	42.78	44.63	45.19	38.65	240
160	Xinyang	35.89	36.57	37.88	40.59	41.86	42.48	42.21	45.13	45.14	46.06	46.00	46.55	42.20	207
161	Zhoukou	30.74	32.34	32.19	34.61	34.26	35.86	36.46	38.59	41.28	42.37	43.40	43.42	37.13	264
162	Zhumadian	32.30	33.56	34.87	36.27	37.46	39.77	39.17	40.74	43.84	43.37	45.47	47.61	39.54	185
163	Wuhan	45.61	46.00	48.06	50.46	53.14	55.29	57.44	59.84	61.74	61.79	64.38	65.04	55.73	15
164	Huangshi	36.80	38.09	39.22	39.93	41.18	41.17	42.99	45.94	48.52	48.54	49.36	51.23	43.58	108
165	Shiyan	36.93	40.30	42.49	43.09	45.35	44.26	47.28	48.24	49.16	50.26	50.93	52.67	45.91	82
166	Yichang	38.02	37.41	40.32	40.14	42.89	43.89	44.75	46.92	47.93	50.82	52.15	52.58	44.82	84
167	Xiangyang	39.76	40.11	41.46	41.98	44.43	42.86	44.55	46.77	46.91	48.42	50.54	50.25	44.84	126
168	Ezhou	36.76	37.92	37.98	41.57	45.48	44.06	46.49	48.38	49.86	53.34	53.51	54.59	45.83	60
169	Jingmen	40.61	41.26	43.17	43.97	44.19	44.61	45.96	47.49	48.84	50.78	52.24	52.27	46.28	87
170	Xiaogan	35.01	35.05	36.25	37.09	38.49	39.77	40.87	44.81	44.16	45.55	47.10	48.02	41.01	174
171	Jingzhou	30.82	32.91	37.00	37.34	38.75	39.36	38.97	41.23	40.65	42.08	44.43	48.74	39.36	155
172	Huanggang	36.05	35.57	37.16	38.97	40.90	38.80	40.30	44.19	45.00	47.12	47.76	48.78	41.72	153
173	Xianning	35.47	36.37	39.06	38.60	41.74	43.58	44.97	47.75	47.98	49.36	51.64	53.78	44.19	68
174	Suizhou	39.17	40.17	42.14	42.22	45.20	47.04	47.45	48.15	49.97	51.28	53.54	53.11	46.62	77
175	Changsha	48.08	49.32	49.75	51.72	54.18	56.06	55.97	57.53	58.48	59.10	61.76	63.00	55.41	20
176	Zhuzhou	41.44	41.71	41.88	43.43	43.80	46.04	47.63	50.26	49.96	52.47	54.35	55.24	47.35	52
177	Xiangtan	42.93	42.41	43.54	45.35	45.73	47.46	47.48	49.66	50.20	51.79	52.73	54.70	47.83	59

178	Hengyang	36.83	37.08	39.33	39.98	39.82	41.41	42.13	40.91	42.26	44.42	45.13	47.01	41.36	200
179	Shaoyang	34.62	35.10	36.91	37.66	39.50	39.61	39.52	39.86	42.71	43.05	46.23	47.22	40.17	198
180	Yueyang	42.90	42.74	42.88	43.21	46.70	47.09	45.75	48.10	47.39	47.14	48.60	49.78	46.02	134
181	Changde	35.60	37.72	40.16	41.05	43.58	43.12	43.30	46.38	47.17	47.39	50.34	50.65	43.87	120
182	Zhangjiajie	38.04	41.04	40.61	43.34	43.40	43.01	42.82	44.79	46.08	47.09	50.63	51.17	44.34	111
183	Yiyang	41.82	41.00	41.86	43.50	45.57	45.79	45.67	48.97	47.87	48.43	52.51	53.96	46.41	65
184	Chenzhou	36.04	33.93	35.38	37.19	38.92	39.78	40.72	41.69	43.41	44.34	45.83	47.69	40.41	184
185	Yongzhou	36.37	35.99	40.89	40.38	42.00	42.06	41.08	43.41	45.37	46.86	47.83	48.99	42.60	149
186	Huaihua	35.07	35.35	38.94	38.87	39.15	40.31	39.52	45.01	45.12	43.75	44.40	47.31	41.07	194
187	Loudi	37.79	38.07	40.04	37.68	40.89	41.01	42.09	43.71	43.35	43.79	42.20	44.57	41.27	247
188	Guangzhou	55.31	52.76	58.25	60.62	58.77	59.11	60.98	62.43	62.73	64.11	66.46	67.14	60.72	11
189	Shaoguan	37.58	37.77	37.46	36.85	37.98	40.66	43.09	41.66	43.56	43.88	45.93	45.65	41.01	229
190	Shenzhen	59.86	58.91	60.85	63.49	67.00	66.35	66.18	66.62	70.54	71.43	72.72	72.50	66.37	3
191	Zhuhai	53.70	55.65	56.44	60.34	63.86	65.66	68.59	69.25	71.66	72.65	75.03	75.73	65.71	1
192	Shantou	43.69	43.38	43.15	44.41	47.11	46.55	46.91	47.79	49.01	50.04	52.97	51.28	47.19	104
193	Foshan	46.34	43.02	48.75	50.91	52.69	54.23	56.48	56.41	59.23	59.47	61.75	61.58	54.24	23
194	Jiangmen	40.70	37.50	43.60	40.40	46.56	49.14	50.09	51.24	52.24	52.72	52.91	52.07	47.43	92
195	Zhanjiang	37.54	36.47	37.88	38.72	41.06	41.25	42.47	42.48	44.57	45.25	46.94	46.61	41.77	206
196	Maoming	35.17	34.19	34.83	36.14	36.15	35.66	38.65	39.36	39.84	43.02	44.09	46.11	38.60	223
197	Zhaoqing	38.27	36.55	41.51	38.96	41.83	44.00	45.49	47.22	47.01	47.55	50.21	47.91	43.88	178
198	Huizhou	44.79	40.99	43.81	43.95	47.65	48.97	51.21	53.35	55.30	56.21	58.72	60.53	50.46	26
199	Meizhou	35.45	35.87	38.71	37.93	38.92	40.38	39.35	42.84	44.36	45.95	48.08	48.01	41.32	175
200	Shanwei	35.42	36.83	38.02	37.80	42.83	44.34	46.60	47.47	48.04	49.74	50.23	49.55	43.91	139
201	Heyuan	37.47	39.58	40.62	41.38	43.58	45.33	45.45	45.80	45.24	46.79	51.20	51.26	44.48	106
202	Yangjiang	36.18	35.75	38.50	38.44	39.02	41.71	41.46	46.05	47.99	46.07	48.13	49.30	42.38	143
203	Qingyuan	38.51	37.37	36.21	36.81	41.10	40.40	39.71	41.17	42.31	42.85	43.15	44.25	40.32	255
204	Dongguan	50.27	48.81	52.65	56.84	57.36	63.65	62.82	63.41	66.63	68.71	70.98	70.10	61.02	6
205	Zhongshan	54.59	54.61	53.37	56.54	57.49	60.99	64.05	64.62	65.16	64.80	66.33	68.19	60.90	10
206	Chaozhou	40.67	37.94	41.77	40.59	42.46	43.92	48.04	46.55	48.06	47.86	48.95	48.63	44.62	156
207	Jieyang	36.10	37.92	39.23	38.89	40.01	42.16	42.92	42.98	40.74	41.63	43.26	45.53	40.95	232

208	Yunfu	35.66	35.94	38.13	36.59	39.98	41.10	41.59	42.75	44.56	45.39	47.86	46.91	41.37	201
209	Nanning	36.56	39.09	43.17	43.34	44.27	44.49	45.46	47.29	47.82	49.61	51.63	53.33	45.51	74
210	Liuzhou	37.18	35.08	39.44	38.98	41.59	42.18	43.08	45.38	45.43	45.44	47.74	49.53	42.59	141
211	Guilin	38.93	38.82	41.21	43.08	43.74	44.06	44.83	46.09	47.57	48.40	50.93	51.72	44.95	97
212	Wuzhou	35.93	35.62	40.44	37.68	39.26	41.25	42.82	42.54	42.41	42.95	45.65	46.79	41.11	203
213	Beihai	35.55	36.23	40.48	41.11	42.96	44.77	47.58	48.60	48.47	50.06	50.48	52.71	44.92	81
214	Fangchenggang	37.25	37.42	41.57	38.33	37.06	41.21	42.00	45.67	47.02	48.37	48.59	50.83	42.94	118
215	Qinzhou	35.71	34.51	38.66	36.58	40.34	39.79	41.26	43.99	46.84	45.47	45.70	47.81	41.39	182
216	Guigang	32.84	32.45	34.24	33.28	33.69	36.82	37.31	39.94	40.82	40.26	43.28	44.55	37.46	249
217	Yulin-GX	35.24	34.42	34.70	35.41	37.40	40.58	40.29	42.90	43.43	43.99	45.00	46.11	39.96	224
218	Baise	33.33	31.97	34.20	33.15	34.10	36.18	38.68	39.97	39.03	41.51	43.29	44.40	37.48	252
219	Hezhou	33.16	33.22	33.22	31.96	39.05	40.66	40.66	39.78	42.92	42.73	46.69	47.31	39.28	195
220	Hechi	32.00	32.42	32.42	34.20	35.75	37.63	36.58	38.89	40.39	43.61	43.41	45.55	37.74	231
221	Laibin	28.87	29.25	33.08	34.69	35.84	36.83	38.92	41.13	40.00	40.61	39.96	41.34	36.71	278
222	Chongzuo	32.45	33.14	35.50	36.09	36.43	36.56	35.83	38.15	38.00	38.52	42.00	41.85	37.04	277
223	Haikou	47.73	49.97	48.20	52.95	57.22	58.60	63.29	62.73	64.67	65.41	65.90	66.65	58.61	12
224	Sanya	50.09	47.31	46.51	51.47	56.69	57.50	60.78	62.55	65.31	65.56	67.40	70.03	58.43	7
225	Chongqing	32.24	34.95	38.90	41.31	44.12	45.48	47.98	50.77	51.40	52.53	53.39	54.06	45.59	63
226	Chengdu	44.07	44.22	46.36	47.98	50.82	53.22	54.02	55.73	55.96	55.13	58.28	58.90	52.06	31
227	Zigong	37.88	35.35	37.63	39.13	39.50	39.45	42.92	42.34	43.34	43.77	45.02	45.37	40.98	236
228	Panzhihua	36.22	37.88	40.84	41.67	42.54	43.80	45.30	46.84	49.74	50.55	52.30	51.33	44.92	103
229	Luzhou	38.07	37.79	37.96	37.92	39.12	39.88	41.72	43.96	46.21	48.25	50.43	51.25	42.71	107
230	Deyang	35.15	34.45	38.37	38.84	40.86	41.46	43.73	45.41	46.01	46.84	47.62	46.43	42.10	212
231	Mianyang	35.87	36.07	41.18	39.36	42.58	42.29	44.97	45.85	47.27	49.28	50.82	51.19	43.89	110
232	Guangyuan	35.66	35.39	38.55	41.76	43.20	43.33	46.48	46.42	47.61	48.07	50.88	50.93	44.02	114
233	Suining	35.81	34.19	36.62	36.92	38.73	38.25	39.94	39.62	39.64	40.59	42.33	44.01	38.89	260
234	Neijiang	33.45	30.61	33.51	34.38	35.67	37.18	39.48	40.75	41.56	43.65	45.67	46.37	38.52	214
235	Leshan	35.88	36.92	39.34	40.16	41.79	42.03	43.24	44.67	45.93	46.55	48.28	48.23	42.75	166
236	Nanchong	37.04	34.05	38.47	38.44	38.66	39.18	39.91	41.88	42.63	43.43	45.76	46.52	40.50	208
237	Meishan	36.14	35.90	37.00	38.92	39.33	41.82	43.14	44.98	46.24	48.09	49.96	49.35	42.57	142

238	Yibin	34.98	34.61	38.12	39.73	41.85	42.03	44.22	45.56	45.53	44.71	46.67	46.70	42.06	204
239	Guang'an	31.33	31.40	35.26	35.20	37.20	38.44	39.12	41.57	42.25	43.66	45.26	45.01	38.81	242
240	Dazhou	37.92	36.97	39.20	40.86	40.48	41.07	41.01	40.56	42.54	42.74	43.97	44.71	41.00	246
241	Ya'an	37.64	38.09	37.94	39.83	41.37	41.26	45.23	49.98	49.13	50.96	53.92	53.66	44.92	70
242	Bazhong	33.29	33.61	36.75	37.33	41.19	42.59	44.75	46.12	47.95	48.27	48.80	48.96	42.47	150
243	Ziyang	35.70	37.05	38.84	40.09	41.81	42.30	42.33	43.28	45.15	46.05	46.30	44.54	41.95	250
244	Guiyang	43.00	42.42	45.63	46.91	48.46	51.47	52.87	55.25	59.01	60.74	62.84	64.06	52.72	18
245	Liupanshui	25.18	24.97	31.24	28.69	31.84	32.61	35.02	35.42	36.09	38.13	40.21	41.96	33.45	276
246	Zunyi	34.86	35.67	36.86	37.21	39.25	40.60	39.59	39.79	40.55	42.30	43.79	46.18	39.72	221
247	Anshun	26.48	28.43	32.87	30.16	33.44	37.73	39.19	41.33	42.62	44.81	47.34	48.54	37.74	158
248	Kunming	45.25	46.09	50.88	52.47	56.04	55.19	55.55	59.75	60.61	60.35	60.55	62.47	55.43	21
249	Qujing	31.50	30.77	34.30	31.72	37.79	37.33	36.73	38.80	40.64	42.56	44.85	45.33	37.69	237
250	Yuxi	39.61	41.14	44.41	42.58	45.79	45.76	45.94	45.04	46.51	48.76	51.19	50.26	45.58	125
251	Baoshan	35.99	34.53	37.64	37.40	37.92	40.53	41.76	45.71	46.58	47.27	48.15	47.28	41.73	196
252	Zhaotong	30.46	30.21	32.63	34.05	35.78	36.58	38.12	39.14	40.15	38.88	41.18	42.41	36.63	273
253	Lijiang	36.46	38.18	42.52	41.86	44.41	46.63	46.55	48.51	49.05	48.45	49.24	51.27	45.26	105
254	Pu'er	31.29	35.35	40.43	40.39	41.42	43.70	45.53	46.87	46.74	47.02	47.61	49.81	43.01	133
255	Lincang	33.93	34.84	38.68	38.04	36.18	39.91	41.39	45.00	45.26	46.65	47.34	50.12	41.44	128
256	Xi'an	46.30	46.98	49.43	51.22	52.00	53.00	55.21	57.52	58.53	58.30	60.79	61.09	54.20	25
257	Tongchuan	35.67	37.41	37.01	37.86	40.76	44.69	48.68	51.26	47.62	48.57	49.57	50.10	44.10	129
258	Baoji	39.93	40.21	41.88	42.07	42.18	42.84	45.34	45.83	46.89	47.09	47.52	48.09	44.16	172
259	Xianyang	36.58	36.07	36.57	38.36	38.84	39.05	39.82	42.59	42.85	42.91	43.60	43.60	40.07	263
260	Weinan	30.17	33.34	33.08	35.73	36.21	37.68	39.52	41.55	42.45	42.39	44.94	44.92	38.50	244
261	Yan'an	33.46	33.42	34.60	36.92	38.87	39.16	38.58	39.54	41.37	42.95	44.82	45.00	39.06	243
262	Hanzhong	34.03	34.87	37.58	41.64	40.89	41.94	43.52	46.46	47.26	47.92	49.14	49.54	42.90	140
263	Yulin-SX	28.27	26.20	30.19	31.74	34.84	38.78	36.91	37.23	38.84	39.59	40.69	40.39	35.30	281
264	Ankang	36.99	37.75	39.52	39.53	41.10	40.62	42.26	43.92	44.78	45.69	48.33	48.86	42.45	152
265	Shangluo	33.12	35.40	37.22	38.81	38.83	41.14	40.85	42.65	43.50	41.72	43.97	44.04	40.11	259
266	Lanzhou	41.23	42.09	43.25	43.34	45.79	46.71	48.22	51.25	53.75	54.98	56.14	57.18	48.66	46
267	Jiayuguan	40.78	43.06	43.14	46.20	47.19	47.72	47.27	49.58	51.73	51.58	53.48	57.76	48.29	40

268	Jinchang	32.69	33.75	35.53	37.17	38.45	41.71	41.37	41.05	44.50	45.52	47.35	49.30	40.70	144
269	Baiyin	26.06	26.46	29.28	29.74	33.26	37.07	38.15	40.23	44.42	45.15	47.35	49.23	37.20	146
270	Tianshui	29.13	31.35	34.70	36.97	39.18	39.49	40.84	41.86	42.73	43.08	45.68	46.23	39.27	219
271	Wuwei	31.20	31.96	33.98	34.83	38.74	41.04	40.57	42.75	45.23	46.50	49.57	50.43	40.57	122
272	Zhangye	34.18	32.33	37.24	38.43	41.15	41.43	43.06	45.43	47.03	45.99	49.58	51.84	42.31	96
273	Pingliang	26.50	25.94	29.53	32.41	33.00	34.23	34.39	38.60	40.61	43.68	44.28	46.00	35.76	226
274	Jiuquan	31.36	36.86	42.40	39.57	40.52	43.58	44.14	47.15	45.11	46.72	49.36	49.98	43.06	130
275	Qingyang	26.79	27.35	29.93	31.55	32.98	35.26	36.32	38.86	39.81	42.27	43.47	45.03	35.80	241
276	Dingxi	29.59	30.29	33.92	33.92	35.06	35.86	36.73	41.80	43.65	45.22	48.27	48.33	38.55	163
277	Longnan	27.40	27.78	29.61	32.24	32.19	34.26	37.31	39.30	40.73	43.22	45.88	47.87	36.48	180
278	Xining	39.70	41.26	43.36	44.63	43.97	45.46	49.80	52.17	51.70	53.94	54.86	56.66	48.13	47
279	Yinchuan	46.16	47.05	49.04	47.96	50.92	49.47	48.74	48.61	50.42	51.96	52.87	53.13	49.69	76
280	Shizuishan	32.77	34.60	39.95	41.04	42.41	42.74	42.35	45.52	46.30	46.35	46.80	46.14	42.25	222
281	Wuzhong	28.24	32.86	34.51	36.40	38.30	39.77	40.44	41.91	43.05	45.19	47.12	48.77	39.71	154
282	Guyuan	30.40	34.95	36.15	36.06	38.72	40.07	39.07	41.94	43.48	43.25	44.90	48.03	39.75	173
283	Zhongwei	25.62	29.24	30.68	32.50	35.69	36.72	38.18	42.24	43.30	42.83	45.24	46.27	37.38	217
284	Urumqi	49.22	51.58	49.51	50.94	51.35	52.59	54.69	56.02	56.66	58.05	60.98	61.66	54.44	22
285	Karamay	44.38	41.55	45.00	45.31	46.07	47.31	51.63	54.53	53.96	53.51	58.22	59.65	50.09	28

Table S 8. Summary of studies on sustainability evaluation of Chinese cities.

No.	Authors	Study periods	Case cities	No. of dimensions	No. of indicators	Main conclusions
1	Huang et al. (2016)[30]	1978-2012	10 provincial capitals of China	3	8	Chengdu, Xi'an, and Chongqing performed better regarding environmental and economic sustainability, but the remaining provincial cities are poor at economic sustainability
2	Van Dijk and Mingshun (2005)[31]	1994-2000	4 medium-size cities in China	3	22	Even though the performance of all case cities became better, three of them showed weak sustainability and one showed non-sustainability currently.

3	Sun et al. (2017)[32]	2000-2010	277 Chinese cities	3	22	The sustainability became better with the increase of city scale, accompanied by the decrease in energy intensity.
4	Fan and Qi (2010)[1]	2003-2006	30 provincial capitals of China	3	5	Although all case cities performed better regarding economic development and social equity, three of them had a worse urban environment.
5	Yi et al. (2021)[2]	2010-2018	19 first-tier cities in China	3	18	Sustainability of the case cities was not sufficiently good because only three of them had scores of sustainability larger than 0.5.
6	Deng et al. (2019)[33]	2005, 2010, 2015	4 large-size cities in China	4	18	The study presented an efficient method to carry out a snapshot sustainability assessment regarding urban built environment.
7	Cheng et al. (2022)[34]	2016	210 Chinese cities	3	24	The study constructed Inclusive Wealth Index and suggested that cities located in the eastern region of China have good performance in sustainability as well as larger capacities for sustainability, which is primarily driven by human capital.
8	Zeng et al. (2019)[3]	2016	55 coal cities in China	7	34	Most mature coal cities showed the characteristics of resource curse.

Table S 9. Major indicator and data gap in constructing the SDG index at the city scale.

SDG	Issue	Desired indicator
SDG 1	No poverty	1. Proportion of population covered by social protection floors/systems. (Global indicator framework A/RES/71/313 presented by United Nations Statistics Division). 2. Share of deaths, missing persons and directly affected persons attributed to disasters.[6]
SDG 2	Zero hunger	1. Prevalence of undernourishment.[6]
SDG 3	Good health and well-being	1. Maternal mortality rate. (Global indicator framework A/RES/71/313 presented by United Nations Statistics Division). 2. Neonatal mortality rate. (Global indicator framework A/RES/71/313 presented by United Nations Statistics Division). 3. Traffic deaths rate. (Global indicator framework A/RES/71/313 presented by United Nations Statistics Division).
SDG 4	Quality education	1. Mean years of schooling.[6] 2. Number of computers per school.[5]
SDG 5	Gender equality	1. Ratio of female to male labour force participation rate.[6] 2. Seats held by women as deputies to the National People's Congress. (Global indicator framework A/RES/71/313 presented by United Nations Statistics Division). 3. Percentage of women without jobs.[5]
SDG 6	Clean water and sanitation	1. Proportion of bodies of water with good ambient water quality. (Global indicator framework A/RES/71/313 presented by United Nations Statistics Division).
SDG 7	Affordable and clean energy	1. Renewable energy share in the total final energy consumption. (Global indicator framework A/RES/71/313 presented by United Nations Statistics Division).
SDG 8	Decent work and economic growth	1. Share of youth not in employment, education or training. (Global indicator framework A/RES/71/313 presented by United Nations Statistics Division).
SDG 9	Industry, innovation, and infrastructure	1. Number of scientific and technical journal articles.[6] 2. Patent applications accepted per million people.[5]
SDG 10	Reduced inequalities	1. Gini Coefficient.[6]
SDG 11	Sustainable cities and communities	1. Rooms per person.[4] 2. Percentage of urban population below minimum living guarantee.[5]
SDG 12	Responsible consumption and production	1. Municipal Solid Waste per capita.[6] 2. Hazardous waste generated per capita.[5]
SDG 13	Climate change	1. Imports of CO_2 emissions embodied in goods per capita.[6]

SDG 14	Life below water	1. Mean percentage area that is protected in marine sites important to biodiversity.[6] 2. Ocean Health Index.[6]
SDG 15	Life on land	1. Mean percentage area that is protected in terrestrial sites important to biodiversity.[6] 2. Mean percentage area that is protected in freshwater sites important to biodiversity.[6] 3. Red List Index of species survival. (Global indicator framework A/RES/71/313 presented by United Nations Statistics Division).
SDG 16	Peace, justice, and strong institutions	1. Share of prison population.[6] 2. Corruption Perception Index.[6]
SDG 17	Partnerships for the goals	1. Share of expenditure on social security and employment.[5]

Table S 10. Government documents at the national level that highlight the importance of resource-based cities.

No.	Government documents at the national level	Time
1	Several opinions on implementing the strategy of revitalizing northeast China and other old industrial bases.	Oct. 2003
2	Integrated solutions of population and development issues in resource-exhausted cities with a scientific outlook on development.	Aug. 2005
3	Planning outline for prospecting of replacement resource of national crisis mines (2004–2010).	Nov. 2006
4	Plan for revitalizing Northeast China	Aug. 2007
5	Notice on the list of the first batch of resource-exhausted cities	Mar. 2008
6	Some opinions of the State Council on promoting the sustainable development of resource-based cities	Dec. 2007
7	National planning of mineral resources (2008–2015).	Dec. 2008
8	Notice on the list of the second batch of resource-exhausted cities	Mar. 2009
9	Opinions of the State Council on further implementing the strategy of revitalizing the old industrial bases including Northeast China	Sept. 2009
10	Progress of the revitalization of Northeast China and other old industrial bases in 2009 and key arrangement in the next phase.	Sept. 2010
11	Notice on the list of the third batch of resource-exhausted cities	Nov. 2011
12	12th Five-Year Plan of the revitalization of Northeast China.	Mar. 2012
13	The national sustainable development plan of resource-based cities (2013–2020)	Nov. 2013
14	Opinions on several major policy measures to support the revitalization of Northeast China in the near future	Aug. 2014
15	Opinions on the comprehensive revitalization of Northeast China and other old industrial bases.	Apr. 2016
16	Three-Year rolling implementation plan for promoting the revitalization of Northeast China and other old industrial bases (2016–2018).	Aug. 2016
17	Implementation opinions on supporting industrial transformation and upgrading of old industrial cities and resource-based cities.	Sept. 2016
18	National plan of mineral resources (2016–2020).	Nov. 2016
19	Opinions on strengthening classification, guiding, and cultivating new drivers of transformation and development of resource-based cities.	Jan. 2017
20	Notice on supporting the construction of the first-batch demonstration zone for the transformation and upgrading of old industrial cities and resource-based cities.	Apr. 2017
21	Implementation opinions on accelerating the construction of green mines	May 2017

22	Reply of the State Council on approving to build a national innovation demonstration zone of sustainable development in Taiyuan City.	Feb. 2018
23	Implementation plan for supporting high-quality development of industrial transformation and upgrading demonstration zones in old industrial cities and resource-based cities in the 14th Five-Year Plan	Nov. 2021

Table S 11. Relationship between resource dependence and SDG index of Chinese cities. * p < 0.1, ** p < 0.05, *** p < 0.01.

Year	Spearman's correlation coefficient
2005	-0.440***
2006	-0.426***
2007	-0.433***
2008	-0.417***
2009	-0.426***
2010	-0.427***
2011	-0.399***
2012	-0.412***
2013	-0.432***
2014	-0.417***
2015	-0.444***
2016	-0.444***
2005-2016	-0.440***

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