CHEMICAL ENGINEERING TRANSACTIONS
VOL. 106, 2023
A publication of AIDIC
The Italian Association of Chemical Engineering
Online at www.cetjournal.it
Guest Editors: Jeng Shiun Lim, Nor Alafiza Yunus, Peck Loo Kiew, Hon Huin Chin

ISBN 979-12-81206-05-2; **ISSN** 2283-9216
DOI: 10.3303/CET23106001

Measurement of China's Modernization Level, Dynamic Evolution of Distribution, and Analysis of Regional Differences Based on the Concept of Sustainable Development

Xiaofei Chu, Wenlong Li*

Business School of Henan University of Science and Technology, Luoyang, Henan 471000,China
wenlong0629@163.com

This study aims to explore the modernization level, dynamic distribution, and regional disparities of China from 2006 to 2020. Based on the concept of sustainable development and the concept of modernization in China, an evaluation index system for modernization is constructed. The improved CRITIC method is employed to calculate the weights of each index, and a modernization index model is used to characterize the level of modernization. The kernel density estimation method and the Dagum Gini coefficient are then applied to analyse the dynamic distribution and regional disparities of modernization across provinces in China. The research findings indicate that the modernization level has significantly improved at the national and regional levels during the observed period. However, different regions and provinces have experienced varying growth rates in modernization, highlighting significant spatial disparities. China's modernization level exhibits a pattern where provinces along the southeastern coastal line serve as the starting point and extend towards the inland regions, with the level of modernization decreasing as the distance from the coastline increases. Moreover, polarization phenomena are observed in the central and eastern regions.

1. Introduction

From the 1950s onwards, the Asia-Pacific region witnessed the emergence of the third wave of global modernization, marking a significant worldwide revolution. As countries pursued economic growth, the modernization process began to unfold. Nonetheless, as modernization enters a new phase, the imbalance and unsustainability associated with it have emerged as major challenges for all nations. These issues not only contradict the principles of social justice but also impact the stability and long-term development of economies. Sustainable development is an intricate system that encompasses not just the influence of economic, social, and environmental indicators, but also the temporal aspect of current and future generations. China, being a highly modernized country in the Asia-Pacific region, has emerged as a favored destination for scholars conducting research on modernization. Hence, with sustainable development in mind, researching China's methods for transitioning to modernization, measuring the level of modernization, and analyzing gaps between levels of modernization is important. Sharma and Bandyopadhyay (2022) proposed a generic methodological framework for sustainability assessment that incorporates interval indicator scores to identify appropriate options. Razavi et al. (2019) analyzed population behavioral issues by creating population density maps using kernel density estimates. Wei and Miao (2023) analyzed regional differences in water-energy-food (W-E-F) stress through Dagum Gini coefficient decomposition. By studying the literature, this paper finds that there are fewer studies on modernization measurement and most of them stay at the level of theoretical analysis and qualitative analysis of how to promote modernization and development, lacking empirical analysis. This paper aims to establish an indicator system based on the concept of sustainable development to measure China's modernization level and that of its provinces. The temporal and spatial differences in modernization are then analyzed using the kernel density map and the Dagum Gini coefficient method. These studies can offer valuable policy recommendations for the country's modernization, support the scientific evaluation of modernization progress, and broaden the scope of modernization research to some extent.

Paper Received: 9 October 2023; Revised: 07 November 2023; Accepted: 28 November 2023
Please cite this article as: Chu X., Li W., 2023, Measurement of China's Modernization Level, Dynamic Evolution of Distribution, and Analysis of Regional Differences Based on the Concept of Sustainable Development, Chemical Engineering Transactions, 106, 1-6 DOI:10.3303/CET23106001

2. Indicator system and research methodology

2.1 Indicator system

Starting from the concept of sustainable development, this paper constructs the indicator system from the three aspects of ecologically sustainable development, economically sustainable development and socially sustainable development, and gradually decomposes into 14 secondary indicators. In terms of economic development, factors such as the quality of economic development, the state of the industrial structure and the dynamics of economic development are considered; in terms of social development, factors such as the size and growth of the population, and the related state of health care and education, as well as the process of urbanization and the employment of the workforce are taken into account; and in terms of the ecological environment, factors such as the capacity of the environment or its carrying capacity need to be taken into account.

The weights are calculated from the improved CRITIC method, Shuheng et al. (2023) show that the improved CRITIC method effectively avoids the problem of weight changes caused by conflicting value ranges of indicators, and its evaluation results are more consistent with the actual situation. The details are shown in the Table 1.

Table 1: China's modernization indicator system

Level 1 indicators	Level 2 indicators	Indicator properties	Unit of measure	Weights
Ecological sustainability indicators	rate of forest cover	+	%	9.00%
	thermal power generation	-	BkW/h	8.00%
Economic sustainability indicators	GDP per capita	+	CNY	7.00%
	Per capita disposable income	+	CNY	7.00%
	R&D investment intensity	+	%	5.00%
	Value added of tertiary sector as a share of GDP	+	%	6.00%
	Final consumption as a share of GDP	+	%	6.00%
Social sustainability indicators	Patents granted per 10,000 people	+	Pcs	10.00%
	Urban-registered unemployment rate	-	%	7.00%
	Inbound tourism arrivals	+	10,000 people	7.00%
	Doctors per 1,000 population	+	Pcs	5.00%
	Per capita investment in education	+	CNY	8.00%
	Per capita expenditure on old-age insurance	+	CNY	7.00%

2.2 Regional division

Prior to the spatial characterization, in order to scientifically reflect the modernization and development of different regions of China, the economic regions of China are now divided into four major regions: eastern, central, western and northeastern. As shown in the Table 2.

Table 2: Regional division

Regional	Ground
Eastern	Tianjin, Hebei, Shanghai, Jiangsu, Zhejiang, Fujian, Shandong, Guangdong and Hainan.
Central	Shanxi, Anhui, Jiangxi, Henan, Hubei, and Hunan.
Western	Inner Mongolia, Guangxi, Chongqing Municipality, Sichuan, Guizhou, Yunnan, Tibet, Shaanxi, Gansu, Qinghai, Ningxia, and Xinjiang.
Northeast	Liaoning, Jilin and Heilongjiang.

2.3 Methodology

2.3.1 Index calculation

The formula for the modernization composite index is as Eq(1):

$$F = Z * W = \begin{bmatrix} f_1 \\ f_2 \\ \vdots \\ f_{20} \end{bmatrix} \quad (1)$$

Where Z represents the index matrix of each index, and W represents the weight moment of each index. The composite index in year t is f_t， $f_t = \sum_{j=1}^{14} Z_{tj} * w_j$, Z_{tj} is the index of the jth indicator in year t, w_j is the weight of each indicator in j, and f_t is the modernization in year t.

2.3.2 Dagum Gini coefficient and its decomposition

The Gini coefficient is a measure of the extent of regional disparities. Dagum (1997) first defined the following inter-group Gini coefficient, which were calculated using the Eq(2) and Eq(3):

$$G_{jh} = \frac{\sum_{i=1}^{nj} \sum_{r=1}^{nh} |y_{ji} - y_{hr}|}{n_j n_h (\overline{y_i} + \overline{y_h})} \quad (2)$$

where j and h are the numbers of two specific regions, n_j and n_h represent the number of provinces in the corresponding regions, $y_{ji}$and y_{hr} represent the modernization indices of the ith province in region j and the rth province in region h, respectively, and $\overline{y_i}$ and $\overline{y_h}$ represent the mean value of modernization of all provinces in the corresponding regions.

$$G = \sum_{j=1}^{k} G_{jj} P_j S_j + \sum_{j=1}^{k} \sum_{h \neq j} G_{jh} P_j S_h D_{jh} + \sum_{j=1}^{k} \sum_{h \neq j} G_{jh} P_j S_h (1 - D_{jh}) \quad (3)$$

where $P_j = {}^{n_j}/_{n}$ represents the ratio of the number of provinces n_j in region j to the sample size n, and $S_h = {}^{n_h \overline{y_h}}/_{n\bar{y}}$ represents the ratio of the modernization index of region h to the modernization index of all regions in the sample. G is the Gini coefficient.

2.3.3 Kernel density estimate

Kernel density estimation is an important nonparametric estimation method. Specifically, the kernel density profile of the modernization index for region J is generated by Eq(4):

$$F_i(y) = \frac{1}{n_j h} \sum_{i=1}^{nj} K\left(\frac{y_{ji} - y}{h}\right) \quad (4)$$

where K(•)represents the kernel density function, which describes the weights of all sample points y_{ji} in the y-neighborhood, and h represents the window width of the kernel density estimation.

3. Results

3.1 Trends in China's Modernization Index and Subsystem Index

To easily see the development trend of China's modernization index and sub-system index, this section will be dimensionless modernization index and sub-system index, and Figure 1 shows the development trend of China's modernization index as well as the three sub-system indices from 2006 to 2020. Due to space constraints, the raw data are not shown and can be requested from the authors if needed.

From the figure, the development trend of China's modernization composite index as well as the three subsystem indices is steadily increasing. From the perspective of the composite index, from 2006-2020, China's modernization composite index has been growing, from 25.73 in 2006 to 43.64 in 2020, an increase of 69.59%, indicating that China's modernization development has been moving forward steadily. The economic, social, and ecological indices are the same as the composite index, all of which have increased steadily over time. Among them, the economic index rose from 9.79 to 15.74, an increase of 60.7%, indicating that over the past fifteen years, the Chinese government has focused on economic development, continuously raised the income of its residents, and taken sustainable economic development as a national development strategy, and has made great achievements. The social index rose from 8.85 to 20.61, an increase of 132%, indicating that in recent years China has focused on the coordination of the industrial structure and the development of people's livelihoods, constantly striving to achieve common prosperity, popularize education, and promote the protection of people's livelihoods, which has further promoted China's modernization and development. The ecological index rose from 7.08 to 7.28, an increase of 2.7%, with large fluctuations in the process of rising, as can be seen from the raw data of the indicator, the fluctuation of the ecological index is caused by the increase of thermal power generation. China's economy is so large that it inevitably fails to consider the big picture of economic development and does not comprehensively consider ecological sustainable development in the process of

development, so if China wants to promote high-quality development and modernization, it needs to give more consideration to ecologically sustainable development in the next step of development, such as increasing research and development of new energy sources, and using new energy sources to substitute for thermal power generation as a means of improving China's ecological development.

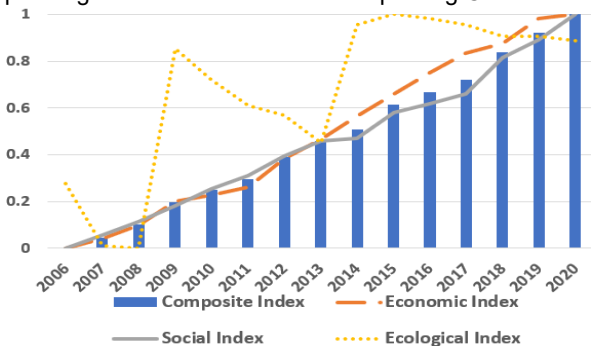

Figure 1: Trends in China's modernization index and subsystem index, 2006-2020

3.2 Spatial distribution of the modernization index

In order to show the spatial distribution of the modernization index of some provinces in China, this paper selects the modernization index of each province in 2020 to make a spatial distribution map for analysis, as shown in the Figure 2.

According to the spatial distribution map of the modernization index of Chinese provinces in 2020, the following conclusions can be seen: firstly, the modernization level of Chinese provinces is characterized by an obvious spatial distribution phenomenon, which is mainly characterized by the provinces along the southeastern coastline as the starting point, extending inland, and the further away from the coastline, the lower their modernization level; secondly, the difference in modernization between the two provinces with the largest gap is as high as 54.46, indicating that there are large differences in modernization between provinces..

China's modernization level tends to begin in the southeastern coastal provinces and gradually decrease as the distance from the coastline increases. This pattern can be attributed to two primary factors. Firstly, the coastal areas enjoy maritime advantages and have convenient transportation resources, which facilitate foreign trade activities for the eastern provinces. Secondly, the eastern region serves as a testing ground for various national reforms before they are implemented in the central and western regions.

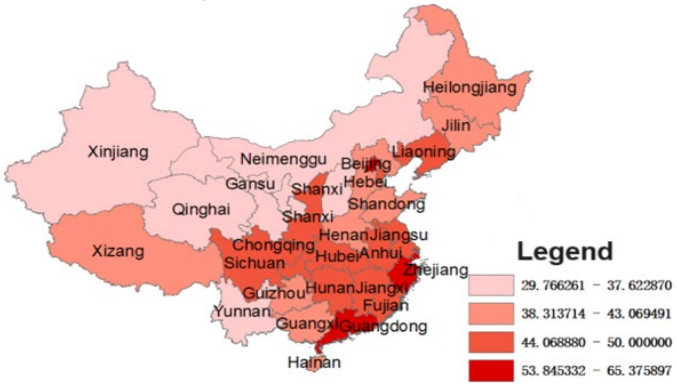

Figure 2: Spatial distribution of modernization in selected provinces in China in 2020

3.3 Analysis of regional differences

Table 3 shows the Gini coefficients of China's modernization level from 2006 to 2020, where Gw denotes the within-group Gini coefficient, Gb denotes the between-group Gini coefficient, and Gt denotes the coefficient of hypervariable density. The Gini coefficient of China's modernization level shows a steady downward trend. From 0.138 in 2006 to 0.088 in 2020, a decrease of 0.05. The decrease is 36.23%, with an average annual decrease of 2.41%. On the whole, the spatial gap in China's modernization level has generally been narrowing over the past fifteen years, but there are still obvious gaps in modernization levels between regions and provinces, so governments at all levels should continue to speed up the implementation of balanced modernization development in a high-quality and efficient manner.

In terms of the contribution rate of the sources of differences, the contribution rate of interregional differences is consistently much higher than that of intraregional differences and hypervariable density differences during the observation period, with the contribution rate of interregional differences consistently remaining above 50 per cent during the observation period, while the contribution rates of intraregional differences and hypervariable density are relatively similar. This shows that the most important source of overall spatial variation in modernization levels is interregional variation, the second is intraregional variation and the third is hypervariable density.

Table 3: Dagum Gini Coefficient and Contribution Rate Results

Year	Gini coefficient in total	Contribution rate（%）					
		Gw	Gb	Gt	Gw	Gb	Gt
2006	0.138	0.036	0.081	0.022	25.72%	58.72%	15.56%
2007	0.146	0.036	0.091	0.019	24.79%	62.35%	12.86%
2008	0.150	0.036	0.097	0.017	23.82%	64.58%	11.60%
2009	0.153	0.035	0.103	0.015	22.84%	67.07%	10.09%
2010	0.155	0.034	0.106	0.014	22.03%	68.64%	9.34%
2011	0.153	0.033	0.107	0.013	21.33%	70.11%	8.57%
2012	0.148	0.032	0.101	0.015	21.61%	68.22%	10.16%
2013	0.146	0.032	0.101	0.014	21.52%	68.86%	9.63%
2014	0.135	0.030	0.093	0.013	21.84%	68.54%	9.62%
2015	0.127	0.029	0.083	0.015	22.62%	65.25%	12.13%
2016	0.124	0.028	0.078	0.017	22.95%	63.52%	13.53%
2017	0.115	0.026	0.074	0.015	23.02%	64.29%	12.69%
2018	0.108	0.025	0.068	0.015	23.41%	63.08%	13.51%
2019	0.103	0.025	0.063	0.015	24.09%	61.18%	14.73%
2020	0.088	0.021	0.057	0.010	23.77%	64.83%	11.40%

3.4 Dynamic evolution analysis

Figure 3a to 3d depicts the dynamic evolution of the distribution of the modernization level in China's eastern, central, western and northeastern regions, respectively, over the observation period. First of all, in terms of distribution position, the interval of change of the distribution curves of the four regions shifted to the right very obviously, indicating that the modernization level of the four regions showed an upward trend in general. Second, in terms of distribution patterns, the width of the main peaks in the eastern and central regions narrows, indicating a narrowing of the absolute difference in modernization of the provinces within these two regions, while the opposite is true for the western and northeastern regions. Afterwards, from the perspective of the extension of the distribution, all of the eastern regions show the phenomenon of right side trailing, indicating that the gap between the provinces with higher modernization levels in this eastern region and the average level of modernization in the region is widening; while the rest of the regions show a slight left side trailing phenomenon, indicating that the gap between the provinces with low modernization levels in these regions and the average level is widening. Finally, in terms of polarization phenomena, the eastern, central and western regions have shown a trend towards bipolarity or multipolarity, while the north-eastern region has been on a unipolar trend.

In terms of China as a whole, Figure 3e depicts the dynamic evolution of China as a whole. It is not difficult to see that the distribution curve and the change interval of China as a whole within the observer are shifting to the right, and the height of its main peak shows an evolutionary process of a small decline followed by a rebound, but the width of the curve has a small expansion, which indicates that there is a clear regional upward trend of the national modernization level as a whole, but the absolute difference has expanded, and the growth rate of the modernization level of some provinces has not reached the average level. At the same time, it can be clearly observed from the figure that there is a serious trailing phenomenon on the right side of the curve of the national modernization level, but the length of the trailing is getting shorter and shorter as time goes by, which indicates that there is still a certain gap between the national average modernization level and the provinces with higher modernization levels, but the number of these provinces is decreasing. It is not difficult to understand that although China's modernization level has improved significantly with the rapid economic and social development in recent years, it is difficult for provinces with low modernization levels to catch up quickly with those with high modernization levels in a short period of time due to the obvious heterogeneity of factors affecting changes in modernization levels and growth rates among different provinces or regions. The gap between the two is likely to persist for a certain period of time.

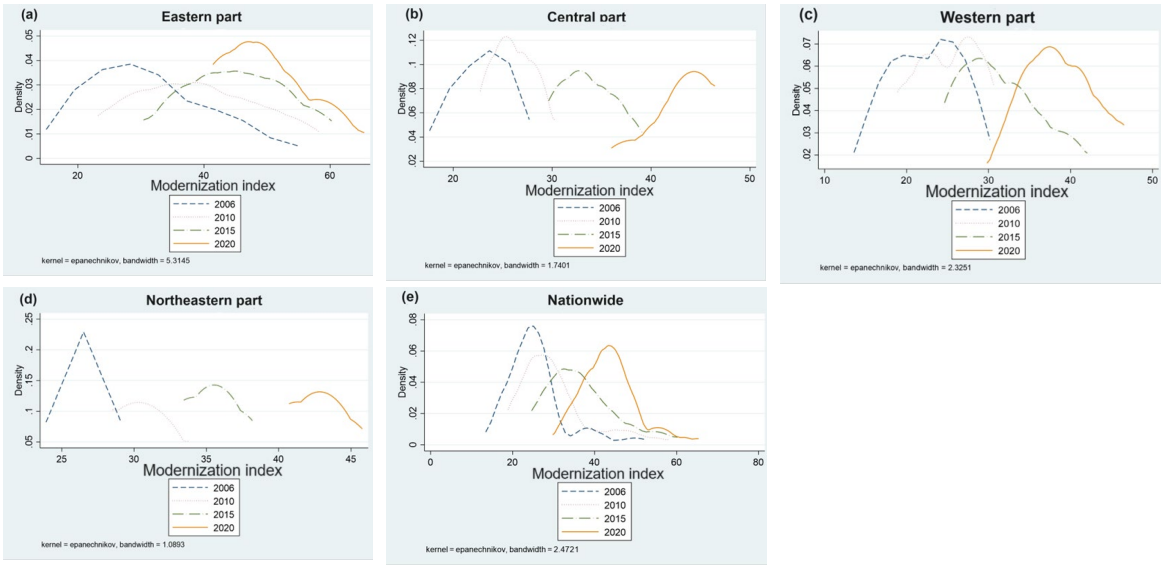

Figure 3: Kernel density map of (a)eastern part;(b) Central part;(c) Western part;(d) Northeastern part;(e) Nationwide

4. Conclusions and Suggestions

Firstly, in terms of the duration of observation, the level of modernization has significantly increased both nationally and in the four main regions. However, the rate of growth in the modernization index has varied, resulting in distinct spatial disparities between regions and provinces. Secondly, analyzing the absolute difference in the kernel density map, the distribution curves of the modernization level exhibit dissimilarities in terms of the center location, shape, flexibility, polarization, and other characteristics between the entire country and the four major regions. Thirdly, considering the relative differences indicated by the Gini coefficient, both China as a whole and the four main regions have experienced a decline in their respective coefficients over time.

In the pursuit of China's modernization, it is crucial to acknowledge and address the substantial spatial disparity in the distribution of modernization levels among regions and provinces. Additionally, the Chinese Government ought to prioritize and allocate more policy support to the underdeveloped central and western regions, compensating for their regional disadvantages with policy advantages. Finally, to promote the progress of these less developed areas, they should utilize their labor and natural resources to attract industries from more advanced regions. This will enhance their own development potential and speed up their modernization process.

Acknowledgments

The authors thank the support of Dr. Qiuting Li.

References

Razavi M., Yazdi S.H., Taherinia H.A., 2019, Crowd analysis using Bayesian Risk Kernel Density Estimation, Engineering Applications of Artificial Intelligence, 82, 282-293.

Sharma P., Bandyopadhyay S., 2022, Sustainability Assessment Framework Incorporating Interval Parameters, Chemical Engineering Transactions, 94, 715-720.

Shuheng Z., Yiyu C., Yinjun M., 2023, Using improved CRITIC method to evaluate thermal coal suppliers, Scientific Reports,13, 195.

Wei X., Miao H., 2023, Characteristics, regional differences, and influencing factors of China's water-energy-food (W-E-F) pressure: evidence from Dagum Gini coefficient decomposition and PGTWR model, Environmental Science and Pollution Research International, 30(24), 66062-66079.