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Evaluating China's urbanization trajectory: an overextension or still in progress?

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China's urbanization has undergone a transformative journey since the initiation of the reform and opening-up policy in 1978, catalyzing economic growth while profoundly impacting its ecological and demographic landscapes. This study offers a systematic evaluation of China's urbanization trajectory over the past 4 decades through the development of an indicator system encompassing three key dimensions: population urbanization, land urbanization, and economic urbanization. Using the entropy method for weight assignment, the analysis reveals a consistent upward trend in China's comprehensive urbanization, with occasional sharp increases. Although population urbanization influences the overall index, land urbanization has outpaced both population and economic urbanization, indicating a pronounced dependence on land resources. This trend poses a potential risk of unsustainable urban growth if left unaddressed. The findings indicate that to achieve sustainable urban development, China must prioritize balancing the interplay between population and land, moving away from land-dependent strategies, and adopting a more balanced approach to urbanization. The quantitative analysis provides key insights into this imbalance, indicating that policies should integrate land use planning with population dynamics to promote holistic urban growth. Future research should investigate the long-term socio-economic and environmental impacts of land-centric urbanization and propose innovative strategies to guide China towards a sustainable urban future.

KEYWORDS

urbanization dimensions, comprehensive evaluation, sustainable development, urban growth, China

1 Introduction

Urbanization, a crucial step towards modernization, leads to the concentration of populations in urban areas, thereby generating substantial economic demand, particularly in sectors including housing and employment (Liang and Yang, 2019). This agglomeration stimulates domestic demand through increased consumption and investment, and also drives industrial development (Zheng, 2010). Over the past decades, China's burgeoning urban population and the real estate sector have accentuated urbanization's role in amplifying domestic demand (Han et al., 2022). Urbanization creates higher-income job opportunities, attracting a large influx of rural labor to cities, thereby alleviating rural poverty and unemployment (Tan et al., 2016; Chen et al., 2019). Additionally, it attracts foreign investment, bolstering economic development and facilitating urban industrial

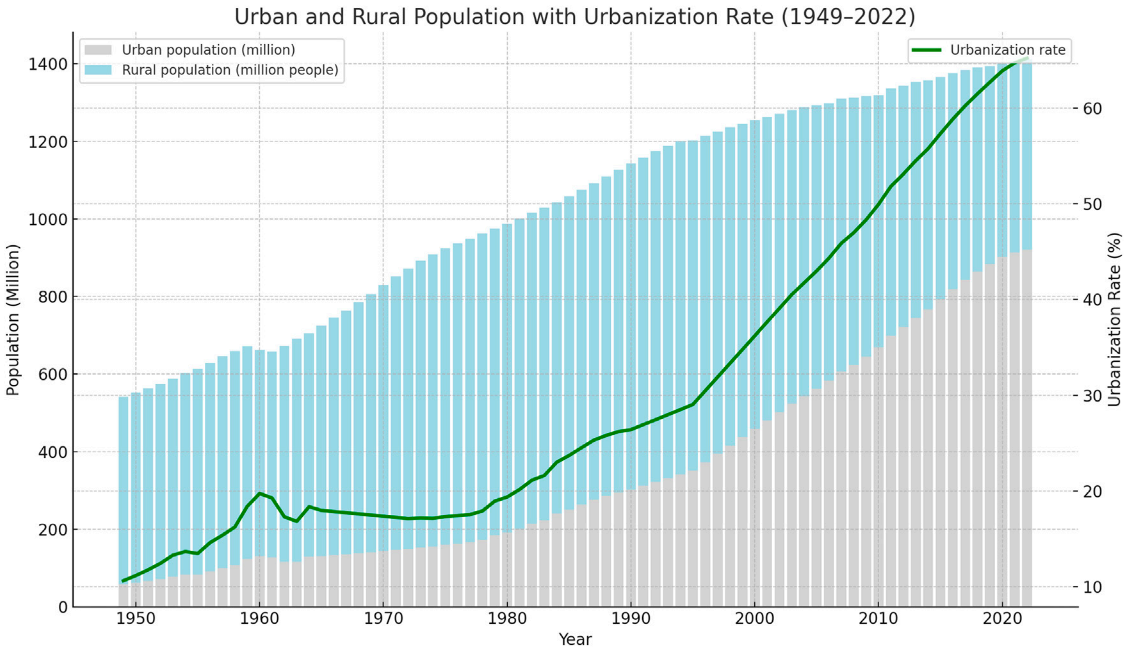

FIGURE 1
Number of urban and rural population, and urbanization rate in China (1949-2022). Data from National Bureau of Statistics of China.

growth and job creation (Bai et al., 2012). As urbanization intensifies, urban infrastructure and public services improve concurrently, enhancing living standards (Wu et al., 2024).

In 1949, China's urbanization rate was 10.64% (National Bureau of Statistics of China, 2022). Initial growth was hindered by factors such as the 1950 Land Reform Law and a planned economic system that prioritized industrial development over urban expansion, restricting rural-to-urban migration (Chan, 1992). The implementation of the Reform and Opening-Up Policy in 1978 represented a major shift from a centrally planned economy to a more market-oriented system (Naughton, 2007). This policy primarily focused on economic growth through land-focused urbanization and industrial expansion. It facilitated rural-to-urban migration by relaxing population movement restrictions, allowing a large influx of rural labor into urban areas and transforming China's social and economic landscape (Zhang and Song, 2003). As illustrated in Figure 1, China's urbanization began with a modest phase before transitioning into a period of rapid growth.

China's urbanization has undergone a rapid and profound transformation, characterized by economic, spatial, and demographic shifts (Zhang and Song, 2003). Unlike the gradual urbanization observed in Western countries, China's process has been largely policy-driven, leading to rapid and large-scale urban growth (Long et al., 2009). This rapid urban growth has contributed to the development of urban infrastructure and services, elevating living standards for many (Zhang, 2017). The urbanization drive has brought numerous benefits, from increasing rural laborers' income through urban employment to bolstering the nation's economic trajectory (Wang et al., 2021). Research indicates that rural laborers migrating to urban areas often experience a considerable increase in income. This increase is due to access to more diverse employment opportunities, which has been critical in reducing poverty levels (Meng et al., 2023). Furthermore, the concentration of population and industries in urban centers has enabled efficient resource allocation, fostering an environment conducive to innovation and higher productivity (Li and Zhang, 2020). The expansion of urban areas has also been associated with marked improvements in public services, including healthcare, education, and transportation infrastructure (Zhao K. et al., 2022).

Despite its merits, China's urbanization journey faces several challenges. The emphasis on land development and industrial growth resulted in limited *per capita* water and land resources, a decline in arable land, and environmental degradation (Song et al., 2018; Lin and Zhu, 2018). Urban sprawl contributed to the "heat island effect", increasing local temperatures and affecting biodiversity (Cui and Shi, 2012; Chapman and Hall, 2022). Rapid urbanization also created a mobile populace often residing in poor living conditions, leading to issues of integration and identity (Wang B. et al., 2022; Chen and Tang, 2023). Urbanization's repercussions are not limited to China. For instance, in Bangladesh, urbanization has resulted in declining groundwater levels, accentuating the scarcity of public water resources (Alam et al., 2006). Similarly, in Mexico City, rapid urban growth has led to severe air pollution and the over-extraction of groundwater, causing subsidence and infrastructure damage (Ríos-Sánchez et al., 2024). In African cities such as Lagos, Nigeria, unplanned urban expansion has resulted in inadequate waste management and increased flood risk, posing risks to public health and the environment (Idowu and Zhou, 2021). These challenges underscore the need for a strategic shift in urbanization policy, specifically towards more sustainable land use, improved social inclusion, and enhanced environmental management.

In response, China introduced the New Urbanization Plan (2014–2020), representing a major policy shift toward a more holistic and sustainable approach to urban development (State Council of China, 2014). This plan emphasizes integrating rural migrants into urban life by granting them access to public services, housing, and legal rights (a process often referred to as "citizenization"), alongside improving urban living standards and promoting environmentally sustainable land use. Unlike the earlier Reform and Opening-Up Policy, which primarily focused on economic growth through land-centric urbanization, the New Urbanization Plan addresses the social and environmental challenges arising from previous urbanization models (Chen et al., 2016). It prioritizes social inclusion, urban-rural integration, and sustainability as key elements of China's current urbanization framework (Chu, 2020). The New Urbanization Plan signifies a strategic move toward sustainable urban development, aligning with the United Nations' Sustainable Development Goals (SDGs) that advocate for inclusive, safe, resilient, and sustainable cities (Yigitcanlar and Teriman, 2015; Zhang et al., 2022). This approach acknowledges the multifaceted nature of urbanization, necessitating a comprehensive strategy that integrates demographic, spatial, and economic dimensions. It also demonstrates an increasing emphasis on the importance of environmental sustainability and social equity in urban policy (Cai et al., 2021).

The concept of urbanization is viewed from different academic perspectives. Demographically, it is perceived as the ongoing shift in population distribution from rural to urban settings (Kuznets, 1955). Geographers emphasize spatial dimensions, focusing on the conversion of agricultural land to urban use and urban spatial expansion (Bai et al., 2012; Liang et al., 2019). Economists delve into the changes in industrial structures and workforce dynamics, highlighting the economic ramifications (Liang and Yang, 2019). These diverse interpretations underscore the multifaceted nature of urbanization, requiring comprehensive approaches that encompass demographic, spatial, and economic dimensions. Given this complexity, the indicators chosen to measure urbanization often vary based on research priorities, including metrics such as population density, land use patterns, or economic transformations (Cao et al., 2021; Chen et al., 2022).

While numerous studies have explored China's urbanization, there are still gaps in the literature. Existing research often focuses on singular aspects, such as economic or demographic changes, lacking comprehensive multi-dimensional analyses that integrate population, land, and economic urbanization (Liu H. et al., 2014). Moreover, there is a lack of studies that systematically incorporate both international standards, such as ISO 37120 and the UN-Habitat City Prosperity Index (CPI), and China's national standard GB/T 36,749-2018, to evaluate urbanization from both global and local perspectives. In recent years, China's urbanization has entered a new phase, marked by the development of smart cities, urban renewal projects, and the implementation of new urbanization strategies (Wang et al., 2023). Despite these advancements, several contemporary challenges persist, including the need for hukou system reform to enhance social equity (Tian et al., 2022), managing ecological sustainability (Cai et al., 2021), and the growing rural-urban divide (Hung, 2022). These challenges have sparked academic debate regarding the sustainability of China's urban expansion and the effectiveness of hukou reform and other policy measures in fostering balanced urbanization (Zhang et al., 2020). By addressing these issues, our study aims to provide insights contributing to ongoing debates and guide the development of more sustainable urban policies in China.

To address these gaps, this study constructs a comprehensive urbanization index that combines these frameworks, offering a detailed understanding of China's urbanization trajectory. By integrating key elements from ISO 37120, the UN-Habitat CPI, and China's GB/T 36,749-2018, we adopt a holistic approach to evaluating urbanization, incorporating both global and local perspectives. ISO 37120 offers globally accepted indicators covering population, economic performance, and infrastructure development (International Organization for Standardization, 2018). The CPI evaluates productivity, infrastructure, quality of life, environmental sustainability, and social inclusion (UN-Habitat, 2016), integrating aspects critical to land urbanization. GB/T 36,749-2018 aligns urbanization with China's specific development goals, integrating economic growth with social welfare and environmental sustainability (Standardization Administration of the People's Republic of China, 2018). While ISO 37120 and the CPI offer a global outlook, GB/T 36,749-2018 incorporates local factors, such as China's unique land use policies and economic development strategies. Together, these frameworks facilitate a balanced assessment of population, land, and economic urbanization, effectively capturing the dynamics at both international and domestic levels.

The research questions guiding this study are as follows: 1) How can a comprehensive urbanization index effectively represent the multidimensional aspects of China's urbanization? 2) What key trends and patterns in China's urbanization process emerge through the analysis of this index? 3) How can the insights derived from the index inform strategies for sustainable urban development in China?

To address these questions, we developed a comprehensive urbanization index that combines a range of indicators, encompassing economic performance, land use, and demographic transitions. This index functions as a quantitative tool designed to identify temporal trends in China's urbanization trajectory. By offering a holistic framework, the index enhances the understanding of urbanization, linking it to broader socio-economic and environmental contexts.

This study aims to contribute to the academic discourse on urbanization by providing a novel, data-driven evaluation of China's urbanization trajectory. The development of an integrated urbanization index, incorporating economic, spatial, and demographic dimensions, serves as a robust analytical tool for understanding the complexity of China's urbanization. This index highlights the interconnectedness of various influencing factors, while also generating insights that can assist policymakers in addressing urban challenges and promoting sustainable growth.

The findings of this study carry important practical implications. For policymakers, the index provides a foundation for developing balanced urbanization strategies that harmonize economic growth, environmental sustainability, and social equity. Specifically, the index can guide the optimization of land use, enhance social welfare policies, and support the implementation of sustainable urban planning practices. For researchers, the methodological

TABLE 1 Comprehensive urbanization evaluation indicator system.

Subsystem	Indicator	Indicator coding	Unit	Data source
Population Urbanization	Urban population proportion	PU_1	%	China Statistical Yearbook
	Urban core population	PU_2	10,000 people	China Urban Construction Statistical Yearbook
	Urban core population density	PU_3	people/km^2	National Data Platform
Land Urbanization	Number of cities	LU_1	number	China City Statistical Yearbook
	Size of built-up area	LU_2	km^2	National Data Platform
	Amount of urban construction land	LU_3	km^2	National Data Platform
Economic Urbanization	Ratio of employment in secondary and tertiary industries	EU_1	%	China Statistical Yearbook
	GDP share of secondary and tertiary industries	EU_2	%	China Statistical Yearbook
	GDP *per capita*	EU_3	Chinese Yuan	China Statistical Yearbook

framework presented in this study can be applied to other rapidly urbanizing contexts, facilitating comparative analyses and the formulation of evidence-based policies. Furthermore, our findings offer a valuable reference for other rapidly urbanizing nations, emphasizing the importance of a balanced approach that integrates economic, social, and environmental objectives in urban development.

2 Methods

The core of this study's urbanization assessment centers around three key dimensions: Population Urbanization, Land Urbanization, and Economic Urbanization. These dimensions capture the complex and multifaceted nature of China's urbanization, including demographic shifts, land use changes, and economic transformation. By structuring the evaluation around these three dimensions, the study facilitates meaningful comparisons with international standards and captures the unique characteristics of China's urbanization process.

To conduct this evaluation, the study constructs subsystems for each dimension and applies the entropy weight method to assign weights to the indicators within each subsystem. This approach ensures that the contribution of each dimension is objectively quantified (Zhu et al., 2020), enabling a balanced and nuanced analysis of urbanization across mainland China.

The study covers the period from 1981 to 2016, a 36-year span that encompasses key phases in China's urbanization trajectory, from early reforms to rapid economic growth and urban expansion. This period allows for a thorough analysis of long-term trends and the diversity of regional socio-economic conditions, while excluding data from Hong Kong, Macau, and Taiwan.

2.1 Urbanization evaluation indicator system

Based on an analysis of urbanization components and a review of research, we have formulated an urbanization evaluation indicator system (Table 1). This system comprises three subsystems: Population Urbanization Subsystem, Land Urbanization Subsystem, and Economic Urbanization Subsystem. Each subsystem includes specific indicators that reflect different aspects of urbanization.

2.1.1 Population urbanization subsystem

Population urbanization refers to the migration of rural populations to urban areas, which increases the proportion of urban residents. This process is a fundamental characteristic of urbanization and is crucial is crucial for transforming industrial and employment structures (Li et al., 2018). Migration from rural to urban regions is a primary manifestation of urbanization, as it directly increases the urban population share (Dociu and Dunarintu, 2012). This migration trend is widely recognized as a key factor in population urbanization (Sun et al., 2017).

In this study, the population urbanization subsystem is evaluated through three key indicators.

- Urban population proportion (PU_1): This indicator measures the percentage of the total population living in urban areas, reflecting population concentration. This fundamental metric, used by the National Bureau of Statistics of China (NBS) to report urbanization levels, is calculated by dividing the urban population by the total population and expressing the result as a percentage. In this context, "urban population" refers to residents living in urban areas, rather than individuals registered under the hukou (household registration) system (Chu, 2020). However, while the urban population proportion is a useful indicator, it has limitations in capturing the full complexity of urbanization, particularly in the context of new urbanization and sustainable development. First, this metric does not account for critical factors such as changes in the industrial structure that drive urban economies, the availability of public services and infrastructure required to support the urban population and environmental sustainability, which is essential for long-term urban development. Because it focuses solely on population concentration, the NBS metric risks providing an incomplete picture of urbanization by overlooking these crucial aspects. Therefore, relying solely on this indicator may not provide a comprehensive evaluation of urbanization, especially in regions where urban growth is influenced by factors beyond population migration (Gu et al., 2012).

- Urban core population (PU_2): This indicator reflects the population residing in the core or built-up areas of a city. It provides insights into the population concentration in urban centers, which typically include city centers and adjacent urbanized areas (Zhao et al., 2009). These areas are characterized by dense populations, advanced industries, and well-established infrastructure. An increase in the urban core population suggests growing centralization of economic and social functions within the city, reinforcing the urban agglomeration effect (Fang and Yu, 2017).
- Urban core population density (PU_3): This indicator measures the number of residents per square kilometer within the urban core. It assesses the efficiency of land use and the city's capacity to accommodate population growth (Liu et al., 2018). Urban core population density is calculated by dividing the total urban core population (including temporary residents) by the area of the urban core. Higher population density is often associated with efficient land use and economic vitality but can also present challenges in urban management and infrastructure provision (Ewing and Hamidi, 2015). Therefore, population density is a critical indicator of urbanization quality.

2.1.2 Land urbanization subsystem

Land urbanization reflects the spatial transformation of urban areas, including city growth, spatial expansion, and increased urban density (Deng et al., 2015). A direct result of land urbanization is the conversion of agricultural land into urban land, which supports manufacturing, real estate, and infrastructure development. The transformation of land from rural to urban use—including industrial, residential, and infrastructure purposes—is one of the core processes of urbanization (Deng et al., 2010). The land urbanization subsystem captures the speed, scope, and efficiency of urban expansion, analyzing changes in built-up areas and urban construction land. It also highlights land resource demands and their impact on the ecological environment, making rational land use a key component of sustainable urban development (Liu Y. et al., 2014).

In this study, the land urbanization subsystem is evaluated through three key indicators.

- Number of cities (LU_1): This indicator reflects the breadth of urbanization by capturing the increase in the total number of cities, indicating whether new cities are established, or existing towns are upgraded. The increase in the number of cities directly reflects the national urbanization strategy and is typically accompanied by infrastructure investment, economic development, and population concentration (Sun et al., 2020). Cities in China are classified into prefecture-level and county-level cities, including municipalities, sub-provincial cities, and county-level cities, but excluding counties.
- Size of built-up area (LU_2): This indicator measures the total area of urban built-up regions, representing areas that have undergone substantial development and have access to public utilities and infrastructure. In core cities, this includes contiguous developed areas as well as dispersed urbanized districts. For cities with multiple towns, the built-up area encompasses multiple developed regions connected by urban infrastructure. The size of the built-up area, measured in square kilometers, reflects the extent of urban development and expansion (Seto et al., 2011).
- Amount of urban construction land (LU_3): This indicator, expressed in square kilometers, measures the total area allocated for urban construction. It includes land designated for residential use, public administration, commercial services, industrial use, logistics, transportation, utilities, and green spaces. The amount of construction land reflects the demand for land resources during different stages of urban development, providing insights into the speed of urban expansion and its relationship with land resource management (Long et al., 2014).

2.1.3 Economic urbanizaion subsystem

Economic urbanization reflects the evolution of industrial structure during urbanization. Kuznets (1955) described this transition as the shift from an agriculture-based economy to one dominated by industry and subsequently by services. This subsystem captures the process of economic transformation and urban areas' contribution to economic growth. Economic vitality drives urban development, propelled by the expansion of industrial and service sectors, which promote urban modernization. By analyzing employment structures, industrial composition, and *per capita* economic output, we can assess how urbanization contributes to economic growth and social wellbeing. The economic urbanization subsystem is crucial for evaluating whether a city can sustain and develop its economy independently.

In this study, the economic urbanization subsystem is evaluated through three key indicators.

- Ratio of employment in secondary and tertiary industries (EU_1): This indicator reflects the transition from an agriculture-based economy to one dominated by industry and services. As urbanization progresses, more labor shifts from agriculture to industry and services, indicating economic modernization and industrial upgrading (Cai and Wang, 2010).
- GDP share of secondary and tertiary industries (EU_2): This indicator measures the contribution of non-agricultural industries to GDP. It reflects the role of industrial and service sectors in driving economic development and serves as a key indicator of economic modernization (Chen et al., 2011). As urbanization progresses, the GDP share of these sectors increases, indicating a shift from agriculture to modern industry and services.
- GDP *per capita* (EU_3): This indicator is calculated by dividing GDP by the total population. It is a key measure of economic development and the quality of life of urban residents. The growth of GDP *per capita* reflects the economic benefits of urbanization, as one of the ultimate goals of urbanization is to improve residents' living standards (He et al., 2016).

2.1.4 Data source

Data for constructing the urbanization index were collected from multiple authoritative sources. Specifically, data for the proportion of the urban population, the share of secondary and tertiary sector employment, and the share of secondary and tertiary sectors in GDP were obtained from the China Statistical Yearbook. Data on urban population and the number of cities were obtained from the China Urban Construction Statistical Yearbook and the China City Statistical Yearbook. Data on population density, built-up area, and urban construction land area were sourced from the National Data Platform, available at https://data.stats.gov.cn/index.htm, published by the National Bureau of Statistics. These data sources were chosen for their reliability and comprehensive coverage across all regions of China, ensuring consistency in the evaluation of urbanization.

2.2 Comprehensive urbanization development index

The comprehensive urbanization development index (UI) is calculated by combining the population, land, and economic urbanization indices through a weighted formula. The formula is as follows:

$$UI = p * PUI + l * LUI + e * EUI$$

Where:

UI represents the composite urbanization development index, and PUI, LUI and EUI represent the population urbanization index, land urbanization index, and economic urbanization index, respectively. The coefficients p, l, and e are the relative weights assigned to each subsystem, determined using the entropy method, which objectively assigns weights based on data variability.

Each subsystem index is calculated by aggregating its key indicators, which have been standardized using Min-Max normalization to ensure comparability across different units and scales.

The population urbanization index (PUI) is defined as:

$$PUI = p_1 * PU_1' + p_2 * PU_2' + p_3 * PU_3'$$

where PU_1', PU_2' and PU_3' are the normalized values of the key population urbanization indicators, and p_1, p_2 and p_3 represent their respective weights, determined using the entropy method.

Similarly, the land urbanization index (LUI) and economic urbanization index (EUI) are calculated as:

$$LUI = l_1 * LU_1' + l_2 * LU_2' + l_3 * LU_3'$$

$$EUI = e_1 * EU_1' + e_2 * EU_2' + e_3 * EU_3'$$

where l_1, l_2, l_3, e_1, e_2, and e_3 represent the weights of corresponding indicators within each subsystem, determined through the entropy method.

2.3 Entropy weight method

To calculate the weight coefficients ($p, l, e, p_1, p_2, p_3, l_1, l_2, l_3, e_1, e_2$ and e_3), the entropy weight method is employed. This method enhances the objectivity of the evaluation by deriving weights from the variability and distribution trends in the data (Zou et al., 2006). While methods such as the Analytic Hierarchy Process (AHP) and conventional weighted average methods are commonly used (Shi et al., 2017; Du et al., 2021), they rely on expert judgment, introducing subjectivity into the weighting process. The AHP is a structured technique for organizing and analyzing complex decisions, using a multi-level hierarchical structure to compare elements pairwise and derive priority scales. Conventional weighted average methods, on the other hand, assign weights based on expert opinions or predefined criteria, which can introduce bias. In contrast, objective weighting methods, such as the entropy method, calculate weights based purely on data, minimizing personal bias. The entropy method, introduced by Shannon (1948), assigns weights by examining the variability of historical data, uncovering hidden information in the dataset, such as patterns or trends that may not be immediately apparent but are crucial for determining the importance of each indicator. By focusing on the dispersion of variables, the entropy method provides more reliable weight calculations than subjective methods by reducing bias and providing a consistent, data-driven basis for assigning weights. It increases the differentiation among indicators, making it easier to distinguish the importance of different indicators. Therefore, this study employs the entropy method to calculate the weights of various indicators in the urbanization system, ensuring a robust and data-driven approach to evaluation.

The steps of the entropy weight method are as follows:

2.3.1 Data normalization

To ensure comparability between different indicators that may have varying units and scales, the Min-Max normalization method is applied. This step scales the data of each indicator into the range of [0, 1], allowing for fair comparisons across different metrics. The normalization formula is:

$$X_{it}' = \frac{X_{it} - X_{min}}{X_{max} - X_{min}}$$

Where:

X_{it} represents the value of the i-th indicator in year t (from 1981 to 2016).

X_{min} and X_{max} are the minimum and maximum values of the i-th indicator over the entire period.

X_{it}' is the normalized value for the i-th indicator in year t.

This ensures that all indicators are dimensionless and lie within a comparable range, thus removing any bias introduced by differing magnitudes of data.

2.3.2 Calculation of proportions

For each year, the proportion P_{it} of the i-th indicator relative to the total of that indicator across all years is calculated using the following formula:

$$P_{it} = \frac{X_{it}'}{\sum_{t=1981}^{2016} X_{it}'}$$

Where:

P_{it} represents the proportion of the i-th indicator in year t relative to the entire study period (1981-2016).

This step identifies the relative contribution of each indicator in each year, enabling the evaluation of its variability over time.

2.3.3 Entropy calculation

The entropy value E_i for each indicator is calculated to measure the degree of uncertainty or disorder in the data across the study period. The entropy is computed using the following formula:

$$E_i = -k * \sum_{t=1981}^{2016} P_{it} * \ln P_{it}, 0 \le E_i \le 1$$

Where:

k $= \frac{1}{\ln(36)}$ is a normalization constant, as the study spans 36 years (1981-2016).

P_{it} is the proportion of the i-th indicator in year t.

E_i is the entropy value for the i-th indicator, which reflects the degree of dispersion in the indicator over time. A higher entropy value indicates that the indicator is more uniformly distributed across the years, while a lower entropy value suggests greater concentration or variability in certain years.

2.3.4 Calculation of divergence coefficients

The divergence d_i for each indicator is calculated as:

$$d_i = 1 - E_i$$

The divergence coefficient d_i reflects the amount of useful information provided by each indicator. Indicators with greater variability contribute more to the urbanization index, as they offer more insight into changes over time.

2.3.5 Weight calculation

The weight w_i for each indicator is then determined based on its divergence coefficient. The weight is computed using the following formula:

$$w_i = \frac{d_i}{\sum_{i=1}^{m} d_j}$$

Where:

w_i is the weight assigned to the i-th indicator.

m is the total number of indicators within the subsystem.

The sum of the weights across all indicators within each subsystem equals 1, ensuring that each indicator's contribution is proportional to its divergence.

2.3.6 Subsystem index calculation

Once the weights for each indicator within the three subsystems (Population, Land, and Economic Urbanization) have been determined, the annual subsystem index for each year is calculated as the weighted sum of the normalized values of the corresponding indicators. For example, the Population Urbanization Index PUI for year t is calculated as:

$$PUI_t = \sum_{i=1}^{m} \left(w_i * X'_{it} \right)$$

Where:

X'_{it} is the normalized value of the i-th indicator for year t.

w_i is the weight assigned to the i-th indicator.

PUI_t is the population urbanization index for year t.

This same procedure is applied to calculate the Land and Economic Urbanization indices in a similar manner.

2.3.7 Calculation of the comprehensive urbanization development index

Finally, the comprehensive urbanization development index (UI) for each year is calculated by taking a weighted sum of the three subsystem indices: Population, Land, and Economic Urbanization. The formula for the comprehensive index is:

$$UI_t = p * PUI_t + l * LUI_t + e * EUI_t$$

Where:

p, l, and e are the weights of the Population, Land, and Economic Urbanization subsystems, respectively, determined using the entropy method.

PUI_t , I_t , and EUI_t are the subsystem indices for year t.

By applying the entropy method, we ensure that the comprehensive urbanization index for each year from 1981 to 2016 is calculated in a robust and data-driven manner, reflecting the dynamic and multi-dimensional nature of urbanization in mainland China.

3 Results

3.1 Descriptive statistics of urbanization indicators

Based on the data presented in Table 2, we analyzed the descriptive statistics of urbanization indicators over a 36-year period from 1981 to 2016. These statistics provide a comprehensive overview of China's national urbanization process, reflecting changes across three key subsystems. The time-based analysis is critical for understanding the evolution of urbanization at the national level and offers insights into the overall urban growth dynamics in China.

Population Urbanization: The coefficient of variation (CoV) for "urban core population density" (PU_3) is 0.85, indicating notable variability in population concentration within urban areas during the observed period. This variability reflects changes in urban population distribution as rural-to-urban migration intensified, leading to increased urban core density. In contrast, the "urban population proportion" (PU_1) has a lower CoV of 0.32, indicating a more consistent national trend of population urbanization over time. These findings emphasize the growing population concentration in urban centers, which has important implications for urban infrastructure development and public service demands.

Land Urbanization: Both the "size of built-up area" (LU_2) and the "amount of urban construction land" (LU_3) exhibited considerable expansion over the 36-year period. The mean size of built-up areas is 25,211.48 km^2 with a standard deviation of 14,168.85 km^2, indicating a substantial variability and an overall increase in the spatial footprint of urban areas. Similarly, the amount

TABLE 2 Descriptive statistics of urbanization indicators.

Subsystem	Indicator	Sample	Mean	SD	CoV
Population Urbanization	Urban population proportion	36	35.86	11.50	0.32
	Urban core population	36	32,014.30	7,273.56	0.23
	Urban core population density	36	1,010.40	861.19	0.85
Land Urbanization	Number of cities	36	559.44	146.46	0.26
	Size of built-up area	36	25,211.48	14,168.85	0.56
Economic Urbanization	Amount of urban construction land	36	24,811.45	14,359.63	0.58
	Ratio of employment in secondary and tertiary industries	36	0.50	0.12	0.23
	GDP share of secondary and tertiary industries	36	0.82	0.08	0.10
	GDP *per capita*	36	14,071.42	16,265.69	1.16

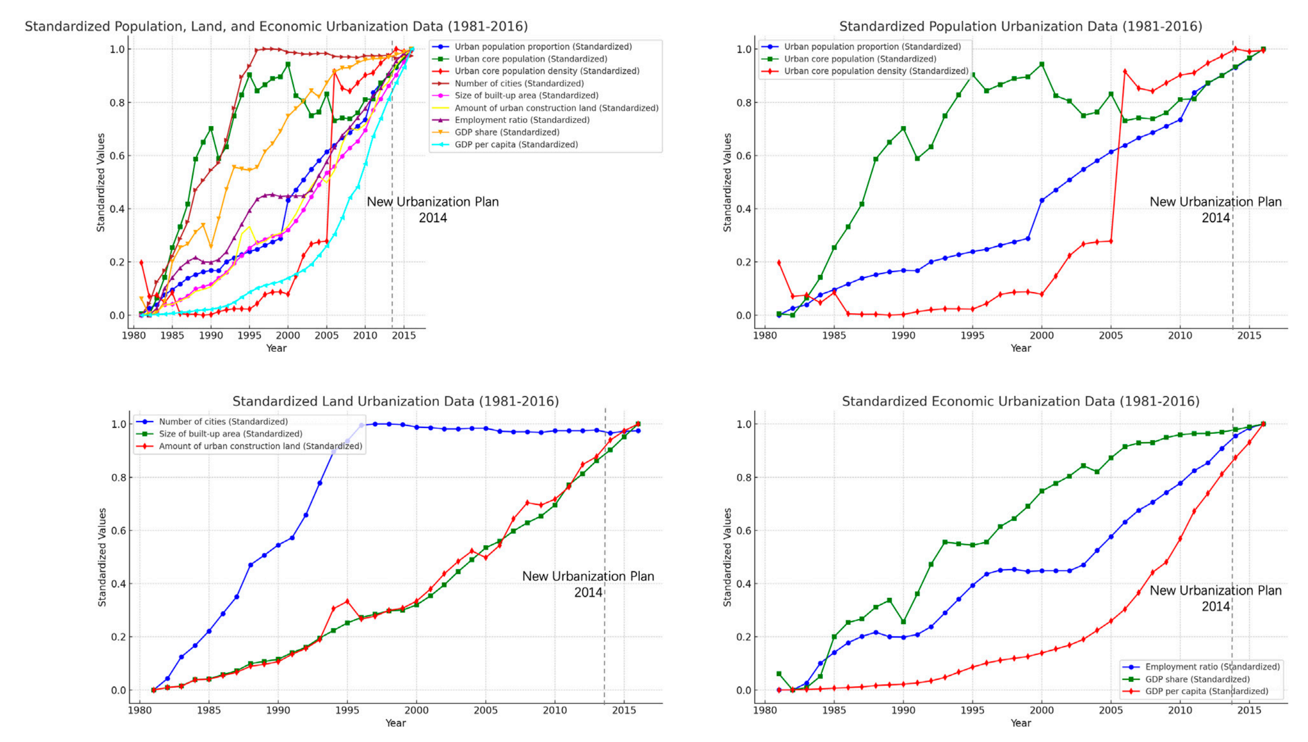

FIGURE 2
Standardized urbanization data comparison (1981-2016).

of urban construction land averages 24,811.45 km^2 with a CoV of 0.58, reflecting substantial and variable land consumption for urban development over time. Meanwhile, the “number of cities” (LU_1) remained relatively stable, with a mean of 559.44 and a CoV of 0.26. This suggests that while new cities were established, land urbanization was primarily driven by the expansion of existing cities rather than the creation of entirely new ones. This reflects China’s national urbanization strategy focused on intensifying development within current urban areas.

Economic Urbanization: The “employment ratio in secondary and tertiary industries” (EU_1) has a relatively low CoV of 0.23, indicating a steady and uniform transition of the labor force from agriculture to industry and services at the national level. The “GDP share of secondary and tertiary industries” (EU_2) also demonstrates stability with a CoV of 0.10, reflecting the growing contribution of these sectors to national economic output. The most pronounced variability is observed in “GDP *per capita*” (EU_3), with a CoV of 1.16, indicating substantial changes in national economic productivity over time. This highlights the uneven pace of economic growth during the urbanization process, particularly following the economic reforms initiated in the 1980s, which spurred rapid increases in GDP but also led to fluctuations in *per capita* economic output.

In summary, the descriptive statistics in Table 2 not only provide a quantitative overview of urbanization but also offer longitudinal insights into China's urbanization process from 1981 to 2016. These data capture the evolving nature of population movement, land use, and economic transformation at the national level. The inclusion of key metrics such as mean, standard deviation, and coefficient of variation quantifies the magnitude and variability of changes over time, enhancing our understanding of how urbanization has shaped the country's development. The high CoV in certain indicators, such as urban core population density and GDP *per capita*, underscores notable temporal fluctuations in urbanization, reflecting the dynamic and rapid changes experienced during China's modernization efforts. These statistics are crucial for evaluating the long-term sustainability of urban growth and the economic impacts of urbanization, informing future policy decisions at the national level.

3.2 Temporal trends in urbanization subsystems

To facilitate comparison, all values in the Urbanization Evaluation Indicator System were standardized. Based on the standardized data, we observed distinct trends across population, land, and economic urbanization from 1981 to 2016 (Figure 2). While all three dimensions exhibit notable growth, their developmental trajectories differ. These trends underscore the critical role of China's reform and opening-up policies in advancing urbanization to a new stage.

Land urbanization experienced the most rapid and early development, marked by sharp increases in urban construction land, built-up areas, and the number of cities from the 1980s to the early 2000s. In contrast, population urbanization exhibited a more gradual and consistent rise, with notable acceleration after 2005, reflecting China's policies promoting urban migration and urban development. Economic urbanization demonstrated steady growth throughout the period, with accelerated increases in GDP *per capita* and the share of secondary and tertiary industries after 2005, indicating China's transition toward a service-based economy.

3.2.1 Population urbanizaion subsystem

The population urbanization subsystem includes the urban population proportion, the urban core population, and the urban core population density.

- Urban Population Proportion: This indicator exhibited steady growth from the early 1980s, reflecting gradual urban migration. After 2005, a marked acceleration was observed. This aligns with China's intensified focus on urbanization policies aimed at accommodating rural migrants through expanded infrastructure (Cai et al., 2020). By 2016, this indicator had nearly doubled compared to the 1980s, signifying a substantial increase in the urban population nationwide.
- Urban Core Population: Similar to the urban population proportion, this indicator exhibited a gradual increase with a notable surge post-2005. The growth was driven by improvements in living conditions and the expansion of urban services, attracting more individuals to cities (Wu and Zhang, 2007). A brief deceleration occurred after 2006, likely due to limitations in housing and infrastructure, followed by a resurgence after 2008.
- Urban Core Population Density: This indicator provides insight into the concentration of population within urban cores over time. Population density rose steadily, accelerating after 2005 in line with increased urban migration. While this trend signifies urban growth, it also presents challenges for urban infrastructure, necessitating a balance between growing populations and adequate services and living conditions (Chen et al., 2016).

3.2.2 Land urbanization subsystem

The land urbanization subsystem is characterized by the number of cities, the size of built-up areas, and the amount of urban construction land.

- Number of Cities: The rapid increase in the number of cities from the early 1980s through the 1990s reflects China's urban expansion driven by industrialization and the need to accommodate new urban residents (Liu H. et al., 2014). After 2000, the growth rate slowed, indicating that the initial phase of rapid urban expansion had leveled off.
- Size of Built-Up Areas: Similar to the growth in the number of cities, the size of built-up areas expanded rapidly during the 1990s, reflecting noticeable investment in infrastructure development. After 2014, this indicator stabilized, marking China's transition toward more efficient land use as promoted by the New Urbanization Plan (Chu, 2020).
- Amount of Urban Construction Land: The expansion of urban construction land peaked in the 1990s, aligning with China's emphasis on industrialization and infrastructure development. Post-2014, growth in this area slowed, indicating a shift toward more regulated land use and strategic urban planning, moving from extensive expansion to sustainable development (Chu, 2020).

3.2.3 Economic urbanization subsystem

The economic urbanization subsystem includes the GDP *per capita*, the GDP share of secondary and tertiary industries, and the employment ratio in secondary and tertiary industries.

- Ratio of Employment in Secondary and Tertiary Industries: Starting from a low base in the early 1980s, this indicator saw substantial growth after the 1990s as China transitioned from an agrarian economy to one focused on industry and services. By 2016, a noticeable proportion of the urban workforce was employed in these sectors, reflecting the increasing reliance of urban economies on secondary and tertiary industries.
- GDP Share of Secondary and Tertiary Industries: This indicator exhibited a consistent rise, especially after the 1990s, as China's economy shifted from agriculture to manufacturing and services. By 2016, secondary and tertiary industries had become the dominant contributors to national GDP, underscoring China's economic transformation.
- GDP per Capita: The most noticeable growth in this indicator occurred after 2000, with sharp increases driven by China's integration into the global economy. This period of rapid

TABLE 3 Weight of urbanization subsystems and indicators.

Subsystem and weights	Indicator	Weights within subsystem	System-level weights	Rank
Population Urbanization 0.41	Urban population proportion	0.29	0.119	2
	Urban core population	0.19	0.078	8
	Urban core population density	0.52	0.213	1
Land Urbanization 0.29	Number of cities	0.29	0.084	7
	Size of built-up area	0.35	0.102	6
	Amount of urban construction land	0.36	0.104	5
Economic Urbanization 0.30	Ratio of employment in secondary and tertiary industries	0.39	0.117	3
	GDP share of secondary and tertiary industries	0.25	0.075	9
	GDP *per capita*	0.36	0.108	4

economic growth was supported by industrialization and the gradual shift toward a service-based economy. By 2016, China's GDP *per capita* had risen considerably, reflecting the success of economic reforms and urban development policies.

The standardized data analysis reveals distinct trends in population, land, and economic urbanization. Land urbanization led in the early years, driven by the expansion of infrastructure and industrial growth. Population urbanization gained momentum after 2005, facilitated by policies promoting urban migration and development of services. Economic urbanization, while steady, experienced accelerated growth post-2005, reflecting China's shift toward a service-based economy. By 2014, the introduction of the New Urbanization Plan further synchronized these subsystems, fostering a more balanced and sustainable urbanization trajectory (Chen et al., 2016). This shift is evident in the convergence of the population, land, and economic urbanization indices, indicating a more integrated approach to urban development. As China continues to urbanize, maintaining this balance will be crucial for ensuring sustainable growth and addressing challenges associated with urban infrastructure and services.

3.3 Weight distribution

The entropy method applied in this study reveals noticeable disparities in the weight distribution across the three key urbanization subsystems: population, land, and economic (Table 3). In the entropy weight method, an indicator's weight reflects its relative importance based on the variability of the data. A weight of 1 would indicate that an indicator fully determines the outcome of a subsystem, while a weight of 0 would mean the indicator has no influence on the subsystem.

Within the population urbanization subsystem, urban core population density holds the highest weight (0.52), indicating its pivotal role in capturing the intensity of population concentration in urban areas. This result highlights the significant impact of rural-to-urban migration on China's urban density patterns. In contrast, urban population proportion, while traditionally important for measuring urbanization, carries a lower weight (0.29), suggesting that this indicator may not fully reflect the nuances of population distribution within urban centers.

In the land urbanization subsystem, the amount of urban construction land (0.36) and the size of built-up area (0.35) emerge as the most influential indicators. These findings emphasize the critical importance of land development and urban expansion in China's urbanization strategy. Conversely, the number of cities (0.29) plays a relatively smaller role, implying that urban growth in China has primarily been driven by the expansion of existing cities rather than the establishment of new ones. This aligns with the national urbanization focus on intensifying land use in existing urban areas.

In the economic urbanization subsystem, the ratio of employment in secondary and tertiary industries (0.39) ranks as the most influential indicator, reflecting China's structural shift from agriculture to industrial and service-based employment. This transition has been a key driver of economic urbanization, closely followed by GDP *per capita* (0.36), which underscores the role of economic growth in urban development. The lower weight of GDP share of secondary and tertiary industries (0.25) suggests that while the contribution of these sectors to the overall economy is important, the restructuring of the workforce has had a more direct effect on urbanization trends.

At the subsystem level, population urbanization holds the greatest overall weight (0.41), followed by economic urbanization (0.30) and land urbanization (0.29). This distribution underscores the centrality of population dynamics in China's urbanization process, especially the increased concentration of people in urban areas due to rapid rural-to-urban migration (Chan, 2010). Historically, China's urbanization strategy placed substantial emphasis on land expansion, which resulted in challenges such as the insufficient integration of new urban residents—often referred to as "new citizens"—into essential social services and healthcare systems (He et al., 2016). However, the shift towards prioritizing population urbanization reflects a growing recognition of the need for more comprehensive urban planning strategies that not only

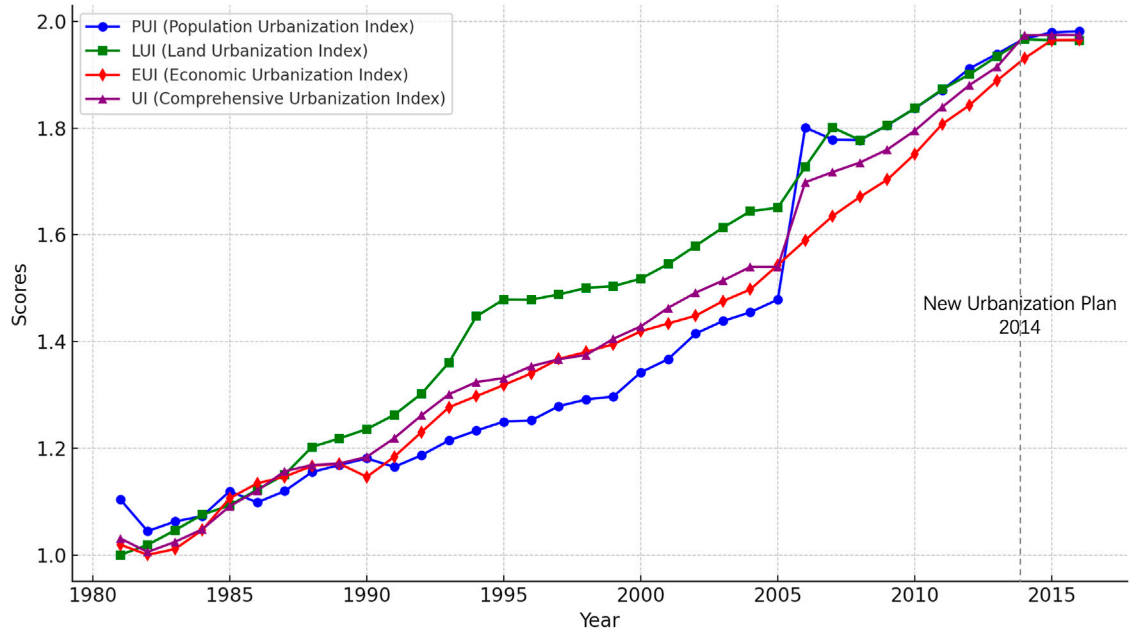

FIGURE 3
Development status and trend of urbanization in China.

account for physical expansion but also address the social and economic integration of urban populations (Chu, 2020).

3.4 Divergence in population, land, and economic urbanization

The data depicted in Figure 3 illustrate the divergent developments of population, land, and economic urbanization indices, providing a clear reflection of China's urbanization trajectory from 1981 to 2016. Although the PUI (Population Urbanization Index), LUI (Land Urbanization Index), and EUI (Economic Urbanization Index) all exhibit consistent growth, the rates of increase vary markedly. LUI shows rapid expansion in the early stages, especially between 1981 and the mid-1990s, outpacing both population and economic urbanization. This indicates that early in China's urbanization process, the focus was primarily on land development and infrastructure expansion (Deng et al., 2008).

China's Reform and Opening-Up policy in 1979 catalyzed a wave of urbanization. From the early 1980s to the mid-1990s, land urbanization surged ahead of population and economic growth. This divergence highlights China's priority during that period: expanding urban infrastructure to accommodate the anticipated influx of rural migrants and support industrialization (Lin, 2002). While land expansion was swift, the slower increase in the PUI and EUI suggests a lag between land development and the social and economic benefits that followed. This gap between land urbanization and the other two indices underscores the challenges of unbalanced development, which created a mismatch between the capacity of urban areas and the needs of incoming populations.

Around 2005, a significant shift occurs as the PUI experiences a marked rise, contributing to accelerated growth in the Comprehensive Urbanization Index (UI). The steep increase in PUI after 2005 reflects the critical role of population growth in driving overall urbanization. Although a brief deceleration in population growth occurred after 2006, the resurgence in 2008 helped align PUI more closely with LUI and EUI. This alignment post-2008 suggests a more synchronized development across the three dimensions of urbanization, indicating that China had begun to address the earlier imbalance between land, population, and economic growth.

Economic Urbanization (EUI) also plays a central role in China's urbanization process, particularly through its steady growth. The gradual rise in EUI during the 1980s and 1990s reflects China's industrialization efforts, which were key to job creation and urban infrastructure development. Following 2005, EUI accelerated alongside PUI, driven by increased urban population growth and the demand for services, housing, and infrastructure. By 2014, economic urbanization was fueled more by technological innovation and a shift toward service-based industries, marking China's transition to a more advanced economy. The stability of the EUI after 2014 further emphasizes the role of economic development as a foundation for both population and land urbanization.

In 2014, China's New Urbanization Plan was introduced, focusing on sustainable and quality-driven urban development. This policy is reflected in the narrowing gaps between the PUI, LUI, and EUI post-2014. The more synchronized growth of these indices indicates a shift toward a balanced urbanization model, where economic growth is more tightly coupled with population needs and efficient land use. The narrowing gap between EUI and the other indices after 2014 demonstrates the success of this strategy in creating a more cohesive and sustainable urbanization process.

4 Discussion

4.1 Land urbanization: the competitive nexus of land resources

China's rapid land urbanization is closely tied to the "urban sprawl" strategy, resulting in unchecked urban expansion and consistent city growth (Wang Z. et al., 2022). This trend is largely driven by administrative decisions rather than genuine market demand (Zhang and Wang, 2018). Over the years, the Chinese government's pro-urbanization stance, coupled with policies promoting urban expansion, has incentivized local governments to prioritize land urbanization for economic growth and tax revenue (Wei and Ye, 2014). This has led to accelerated land consumption, as evidenced by the substantial increase in the amount of urban construction land (mean 24,811.45 km^2, CoV 0.58) and the size of built-up areas (mean 25,211.48 km^2, CoV 0.56). These figures underscore the rapid pace of urban land development observed in this study. Furthermore, our results indicate that land urbanization experienced the most rapid and early development among the three subsystems, marked by sharp increases in urban construction land and built-up areas from the 1980s to the early 2000s.

This emphasis on land urbanization, however, is not without consequences. While these expansion efforts have contributed to economic growth, they have also led to environmental degradation. As supported by existing literature, the over-allocation of land resources to real estate and infrastructure development has resulted in land degradation and environmental harm, such as increased energy consumption and biodiversity loss (Cui and Shi, 2012; Peng et al., 2017). The expansion of built-up areas and construction land reflects a broader trend in China's urbanization strategy, but without careful regulation, such practices could undermine long-term sustainability goals (Musse et al., 2018).

Given the significant weight assigned to land-related indicators, such as the amount of urban construction land (0.36) and size of built-up areas (0.35), it is crucial to reconsider the current emphasis on land consumption. The data suggest that land urbanization has primarily been driven by the expansion of existing cities rather than the establishment of new urban areas, reflecting a focus on intensive urban land use (Chen et al., 2016). These findings highlight the importance of developing more sustainable urban land use strategies that not only support economic growth but also protect environmental resources and promote long-term sustainability.

To summarize, the analysis of land urbanization patterns underscores the need for more balanced urbanization approaches that integrate environmental sustainability with economic and social development. As China continues its urbanization trajectory, prioritizing sustainable land use practices will be essential for mitigating the negative impacts of rapid urban expansion.

4.2 Population and economic urbanization: the hukou dilemma and structural challenges

China's household registration system, or *hukou*, is a central feature of its social structure, dividing the population into agricultural and non-agricultural (urban) categories. Those with urban hukou enjoy access to a more comprehensive range of social services, such as healthcare, housing subsidies, and education, while rural *hukou* holders, including those who migrate to cities, often remain excluded from these benefits (Chan and Buckingham, 2008). This divide has significant implications for understanding urbanization in China. While current population urbanization metrics focus on the number of residents in urban areas, they do not fully account for the disparities between *de jure* urban residents (those with urban *hukou*) and *de facto* urban residents (migrant workers who lack *hukou* registration) (Chan, 2010).

This gap creates challenges in assessing the true extent of urban integration. For example, urban population proportion and urban core population density indicators reflect the overall concentration of people in urban areas, but they obscure the social inequalities faced by rural migrants. Despite living and working in urban environments, these migrants often experience limited access to public services, housing, and social security (Bosker et al., 2018). The persistence of the *hukou* system has, therefore, slowed the "citizenization" process—the formal integration of rural migrants into urban social structures (Wang, 2010). As a result, population urbanization has advanced without corresponding improvements in social inclusion for all urban residents. This disconnect undermines the broader goal of urbanization to enhance quality of life and could exacerbate social inequalities in the long term.

Moreover, economic urbanization is similarly impacted by this structural divide. The lack of comprehensive social security for rural migrants not only limits their personal economic security but also creates challenges for urban labor markets (Ann et al., 2014). Migrants, often engaged in low-skilled or temporary work, face job instability and limited upward mobility. This has broader implications for employment ratios in secondary and tertiary industries, as urban economies struggle to absorb the influx of rural labor without comprehensive structural reforms (Meng, 2012). Without policies that promote economic diversification and the growth of high-value industries, urban labor markets could face saturation, leading to employment challenges and stagnation in job quality (Zhao Z. et al., 2022).

At the same time, certain regions in China have focused heavily on land urbanization as an economic growth strategy, often neglecting necessary economic structural reforms (Liang et al., 2022). This approach has created a lag between land urbanization and economic urbanization, with the pace of economic development trailing behind land utilization. Many regions continue to rely on traditional resource-intensive industries, which limits their ability to transition to more innovative, high-value sectors. This imbalance hampers the sustainable growth of urban economies and diminishes their capacity to support the growing urban population (Tan et al., 2016).

In summation, the hukou system plays a critical role in shaping both population and economic urbanization in China. The disconnect between *de facto* and *de jure* urban residents complicates efforts to achieve socially inclusive urbanization, while the uneven pace of economic urbanization presents challenges for labor market integration and urban competitiveness. Addressing these structural challenges will require reforms that not only focus on land and economic development but also prioritize social inclusion for all urban residents.

4.3 Balancing excess and deficiency: towards sustainable urbanization

Urbanization in China represents a profound shift in the human-land relationship, transitioning individuals from an agrarian society to urban-centric economic activities. Historically, China's urbanization strategies have been primarily land-centric, emphasizing the physical expansion of cities through the conversion of agricultural land for urban use (Liu Y. et al., 2014). However, this focus on land urbanization has often led to structural imbalances between land, population, and economic development, resulting in challenges such as overstocked real estate, ghost towns, and underutilized infrastructure.

The introduction of the New Urbanization Plan (2014-2020) marked a pivotal shift in China's urbanization trajectory (State Council of China, 2014). Moving away from the land-centric approach that characterized earlier phases, this plan focuses on sustainable development, prioritizing the citizenization of rural migrants, improving urban living standards, and fostering a more integrated urban-rural relationship (Chen et al., 2016). This strategic shift reflects the recognition that earlier urbanization strategies, while successful in accelerating economic growth through land development and industrial expansion, created challenges such as over-expansion, environmental degradation, and growing social inequality.

Our study's findings reflect this shift in emphasis. In the early stages of China's urbanization (1980s-1990s), land urbanization outpaced both population and economic urbanization, as seen in the rapid increase in built-up areas and urban construction land. This period was marked by significant infrastructure investment but also inefficiencies in land use and environmental degradation. By contrast, the post-2005 period saw population urbanization gain greater importance, a trend further reinforced by the introduction of the New Urbanization Plan in 2014. The urban core population density indicator, which holds the highest weight in our population urbanization analysis (0.52), underscores the increasing focus on managing population concentration in cities, improving housing, and enhancing access to public services.

Moreover, the plan's emphasis on sustainable urban development is reflected in the reduced pace of land expansion after 2014, as evidenced by the stabilization of built-up areas and the decline in the growth rate of urban construction land. This suggests that urbanization strategies have increasingly focused on optimizing land use rather than simply expanding urban spaces. A key component of the New Urbanization Plan is the promotion of urban-rural integration and the improvement of living conditions for migrant workers. This strategy contrasts with earlier approaches, which largely sidelined the social dimensions of urbanization (Chu, 2020).

The proportion of the urban population is a widely used indicator by the National Bureau of Statistics (NBS) to assess the level of urbanization in China. While this metric effectively captures the concentration of urban residents, it does not adequately reflect the broader, more nuanced dimensions of urbanization, such as economic restructuring, land use patterns, and social integration (Chu, 2020). Although valuable for monitoring demographic shifts, this metric overlooks essential factors, including the transformation of industrial structures, the provision of adequate public services, and the development of infrastructure necessary to support growing urban populations. Thus, an exclusive reliance on this single indicator risks providing an incomplete portrayal of urbanization, particularly in the context of China's evolving strategies. To address these limitations, our comprehensive urbanization index integrates multiple dimensions—including land use efficiency, economic performance, and demographic transitions—offering a more holistic and robust assessment of urbanization. This approach is aligned with the goals outlined in China's New Urbanization Plan (2014–2020), which emphasizes sustainable growth, the citizenization of rural migrants, and the balanced development of population, land, and economic dimensions.

Our findings suggest that urban growth is not solely driven by population migration; it is deeply intertwined with economic restructuring and the optimization of land use. As China continues to urbanize, future urbanization strategies must prioritize the integration of rural migrants, efficient land use, and sustainable economic development to ensure alignment with the principles of sustainable urbanization. The urbanization process should therefore be viewed as a dynamic and multi-dimensional phenomenon, requiring comprehensive policies that address these interdependent factors. China's urbanization trajectory has evolved notably, with the New Urbanization Plan marking a strategic shift towards sustainability. Our research underscores the critical importance of balancing the urbanization of land, population, and the economy to foster holistic and sustainable urban development.

4.4 Limitations and future research

While this study provides a comprehensive analysis of China's urbanization from 1981 to 2016, several limitations warrant consideration and suggest avenues for future research. First, the reliance on national-level data may obscure regional variations and local nuances in urbanization patterns. China's vast geographical expanse and socio-economic diversity result in significant disparities in urbanization processes among provinces and cities. Future research should conduct localized analyses by disaggregating data at regional, provincial, or district levels to uncover diverse urbanization patterns, regional disparities, unique challenges, and effective strategies that national-level data might overlook.

Second, the study focuses on three core dimensions of urbanization—population, land, and economic aspects—using selected indicators for each subsystem. While these indicators are instrumental in reflecting the multifaceted nature of urbanization, they may not encompass all relevant factors. Environmental sustainability, social equity, quality of life, and governance aspects are critical components not directly addressed in the current indicator system (Zhao et al., 2010). Expanding the indicator system to incorporate environmental, social, and governance factors would align urbanization studies with global sustainable development goals and provide a more holistic understanding of urbanization's impacts.

Third, the use of the entropy weight method, though objective in assigning weights based on data variability, may not fully capture the subjective importance of certain indicators from policy or societal perspectives. Indicators with lower variability but high practical significance might have been undervalued, potentially affecting the overall assessment of urbanization progress (Kumar et al., 2021). Combining subjective weighting methods, such as the Analytic Hierarchy Process (AHP), with objective methods like the entropy method could offer a more balanced approach to evaluating indicator importance.

Fourth, the temporal scope of the study ends in 2016, excluding recent developments in China's urbanization policies and practices. Significant initiatives, such as the continued implementation of the New Urbanization Plan, responses to emerging challenges like the COVID-19 pandemic, and technological advancements like digitalization and smart city initiatives, could have influenced urbanization trajectories post-2016 (Sharifi and Khavarian-Garmsir, 2020). Extending datasets beyond 2016 would enable a more current evaluation of urbanization trends and policy impacts.

Furthermore, assessing the effectiveness of major policies, such as the New-Type Urbanization Plan and hukou reforms, could provide critical insights into their long-term outcomes. Comparative studies between China and other rapidly urbanizing nations may reveal universal principles and country-specific solutions to urbanization challenges. Incorporating qualitative analyses and case studies could also enrich the understanding of urbanization processes and their socio-economic effects.

By addressing these limitations and pursuing the suggested research directions, future studies can offer a more comprehensive understanding of urbanization in China, supporting the development of sustainable, inclusive, and resilient urban policies.

5 Conclusion

This study evaluated China's urbanization trajectory to determine whether it represents an overextension or is still in progress. Our findings indicate that while China has made substantial progress in its urbanization journey, the rapid expansion of land urbanization compared to population and economic urbanization indicates a potential overextension, particularly in land development. This overemphasis on land urbanization risks unsustainable growth unless balanced with strategies that promote population integration and economic development. Recent policy shifts, such as the implementation of the New Urbanization Plan, indicate that China's urbanization is moving towards a more sustainable and integrated model.

This study developed a comprehensive evaluation framework integrating three core subsystems: population urbanization, land urbanization, and economic urbanization. By utilizing the entropy weighting method, relative weights were assigned to key indicators within each subsystem, enabling a balanced and objective assessment of their significance in the overall urbanization process. The integrated framework effectively represents the multidimensional nature of China's urbanization by encompassing the interplay between population, land, and economic dimensions. This approach provides a more comprehensive understanding of urbanization compared to single-dimensional analyses, which often overlook the complexity of urban growth dynamics. The analysis of the urbanization index revealed distinct patterns, with land urbanization significantly outpacing both population and economic growth. This imbalance underscores the need for synchronized development across all dimensions, as an overemphasis on land development could lead to unsustainable outcomes. The insights derived from this framework highlight the importance of balancing these three dimensions to shape sustainable urban development strategies for China. Policies should focus on integrating rural migrants into urban systems, enhancing economic opportunities, and optimizing land use to prevent overextension and support long-term sustainable growth.

These findings have notable implications for policymakers and urban planners. To address the identified imbalance, rebalancing strategies must equally prioritize population and economic development alongside land use optimization. Policies should aim to integrate rural migrants into urban systems, enhance access to public services, and ensure social equity, particularly through hukou reform. Additionally, sustainable urban growth will require careful land-use planning to minimize underutilized infrastructure and mitigate issues such as ghost towns. The multidimensional urbanization metrics developed in this study provide urban planners with a holistic tool for guiding urbanization strategies. Aligning future urbanization efforts with the principles of the National New Urbanization Plan—promoting urban-rural integration, enhancing environmental sustainability, and fostering economic innovation—is essential.

China's urbanization is at a critical juncture. While there are clear signs of potential overextension in land development, recent policy initiatives indicate progress towards a more balanced and sustainable urbanization model. By addressing the structural imbalances identified in this research and integrating population, land, and economic factors within a comprehensive framework, China can ensure that its urbanization process remains both inclusive and sustainable in the long term. Future research should continue to refine these models and consider additional dimensions—such as environmental sustainability and social equity—to further support the development of policies that promote economic resilience, social inclusiveness, and environmental sustainability.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Author contributions

YW: Conceptualization, Data curation, Formal Analysis, Funding acquisition, Investigation, Resources, Software, Validation, Writing–original draft, Writing–review and editing. FY: Formal Analysis, Methodology, Visualization, Writing–original draft, Writing–review and editing. ZY: Project administration, Supervision, Writing–original draft, Writing–review and editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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