urban science

MDPI

Article

Spatio–Temporal Dynamic Characteristics and Driving Mechanisms of Urban Compactness in Central China

Wenqin Ren [1], Linggui Wei [2,3,*], Xinhai Lu [1], Jinlong Xu [1] and Yun Qin [1]

[1] School of Public Administration, Central China Normal University, Wuhan 430079, China
[2] Institution for Finance and Economics, Guangxi University of Finance and Economics, Nanning 530003, China
[3] School of Politics and Public Administration, Guangxi Min zu University, Nanning 530006, China
* Correspondence: ag237368734@outlook.com

Abstract: As a result of rapid urbanization in China, the spatial restructuring of towns and cities has significantly impacted urban compactness. The study of the spatio–temporal characteristics and driving mechanisms of urban compactness in central China is a strategic imperative and conducive to promoting regional sustainable development that is based on easing the contradiction between land resource supply and demand and reducing energy consumption. Therefore, this study focused on 80 prefecture-level cities in central China, utilizing barycenter model and GTWR model, among others, to analyze the spatio–temporal evolution pattern of urban compactness from 2006 to 2020 and its driving factors, with the aim of uncovering the intrinsic mechanisms behind enhancing urban compactness in the area. The results show the follows: (1) The urban compactness in central China has generally shown an upward trend, with a pronounced spatial clustering around provincial capital cities and the spatial changes in compactness predominantly concentrated in the north–south direction. (2) Various factors have influenced urban compactness, where government intervention and population aggregation present as bi-directional driving factors, while the effective use of land resources and high-quality industrial development, among others, present as positive driving factors. The spatio–temporal heterogeneity and agglomeration features of each driving factor are significant. (3) Further analysis indicates that the effective use of land resources is the primary factor in enhancing urban compactness, followed by technology. Therefore, we should adhere to the concept of compact cities and gradually promote the compactness of cities in central China based on the impact of the driving factors.

Keywords: compact cities; spatio–temporal dynamic characteristics; central China; urban compactness; driving mechanism

Citation: Ren, W.; Wei, L.; Lu, X.; Xu, J.; Qin, Y. Spatio–Temporal Dynamic Characteristics and Driving Mechanisms of Urban Compactness in Central China. *Urban Sci.* **2024**, *8*, 40. https://doi.org/10.3390/urbansci8020040

Academic Editors: Elahi Ehsan and Guo Wei

Received: 22 February 2024
Revised: 8 April 2024
Accepted: 9 April 2024
Published: 24 April 2024

1. Introduction

Cities, as iconic products of human civilization, embody the essence of our developmental achievements, making sustainable urban development a critical pathway for perpetuating these successes. With land resources serving as the foundation of urban expansion, there currently exists a notable mismatch between the demand for and supply of urban development and land utilization. Since the economic reforms and the process of opening up, China has witnessed a rapid phase of urbanization, primarily characterized by the migration of populations and industries from rural to urban areas. This shift has not only led to an accelerated expansion of urban construction land, encroaching upon agricultural and arable lands, but has also gradually evolved urban development towards a model of boundless expansion. Moreover, this migration process represents an integration of urban and rural areas, where the rapid pace of urbanization has led to inefficient and highly polluted land use, alongside the ensuing ecological and environmental degradation. The urbanization of land is a crucial component of China's urbanization process, where issues such as low land-use efficiency and wastage are increasingly pressing concerns.

Thus, within the context of China's urbanization efforts, the concept of compact cities has found a conducive environment for adaptive growth. Embracing the compact cities model is seen as a pivotal strategy for addressing the challenges of "urban disease" and achieving sustainable urban development in China.

The concept of compact cities was initially introduced as a solution to the issues of urban sprawl, lengthy commuting, and social isolation that arose during the growth of Western cities [1]. The objective was to encourage city residents to return to the core of cities, thereby addressing the problem of attractiveness [2]. Subsequently, this concept has been continuously expanded, having been practically tested in numerous countries and regions. While the precise definition of compact cities remains uncertain, the fundamental elements of compact cities are rapidly being recognized. Western studies primarily associate compact cities with their spatial configuration, believing that a condensed urban layout can conserve land and promote urban liveliness [3]. Hofstad (2012) posited that compact cities should be sustainable, characterized by high residential density and mixed land-use functions [4]. Hamidi et al. (2014) argued that compactness is the antithesis of sprawl, and that a high-density urban spatial layout helps to facilitate efficient land use and stimulate urban development [5].

The theory of compact cities advocates the adoption of high-density urban land-use development patterns to discourage urban sprawl. This implies accommodating more urban activities through high-density urban development and reducing investment in urban infrastructure development while increasing the utilization of public services [6]. However, high-density does not equate to compactness. The core of the compact cities lies in the compact nature of functions, i.e., the construction of diversified and abundant urban functions based on the mixed application of land. Such a model can implement the benefits of urban economic agglomeration as well as the effective development of urban resources [7]. Thus, compact cities represent an evolutionary process that extends from the study of a unitary form of the city to the comprehensive aspects of the city's development [8]. Appropriate population densities, rather than overcrowded population numbers, are essential for achieving economies of scale in infrastructure and reducing the energy consumption and polluting emissions from transportation. This is because population density is a key factor in the efficient operation of cities [9]. Essentially, compact cities are a type of land development that combines transit and infrastructure [10]. The Comparative Review of Compact Cities Policies recognizes compact cities as having a role in fostering economic, environmental, and social development [11]. Scholars have generally perceived compact cities as the objective and model of planning aimed at promoting urban efficiency through the realization of urban functions [12].

The concept of compact cities refers to the concentrated and efficient organization of urban activities and structures, achieved through various dimensions such as economic, spatial, demographic, infrastructural, social, and ecological compactness. It entails a high concentration of urban space and adheres to the principle of sustainable urban development. This approach represents a novel method for modernizing the management of urban space and a fresh model for adjusting and optimizing land-use structure.

It holds significant theoretical and practical importance in terms of altering land-use patterns and enhancing land-use intensity to control urban expansion and enhance urban efficiency [13]. The concept of compact cities has gradually gained recognition and promotion in China based on its efficacious response to the multifaceted problems that China has confronted in the rapid process of urbanization and development.

Currently, there is limited research on compact cities in central China. The existing studies have primarily focused on the economic, industrial, and ecological aspects of central China. For instance, scholars have explored topics such as achieving the high-quality development of the regional economy [14], the influence of the rise of central China's strategy relating to the regional industrial structure [15], the relationship between economic development and ecology [16], and the impact of urbanization on economic efficiency [17]. Within the realm of urban development in central China, several academics have concen-

trated on the growth of small towns [18] or the establishment of urban agglomerations [19]. However, only a limited number of scholars have performed analyses of compactness as a concept or associated assessments relating to any specific province in central China [20,21].

Regarding the study of compact cities, the study of influential relationships is an important aspect. For instance, scholars have explored the influence of traffic on the urban compactness index, based on the case of South Tangerang City [22]. The findings of the threshold of the relationship between the compact urban form and carbon emission reductions indicate that a compact urban form is positively correlated with the reduction in energy consumption. However, when the compactness surpasses a specific threshold level, the urban heat island effect (UHI) occurs [23]. There are also scholars who have expanded on previous studies to examine the correlation between urban street networks, urban compactness, and social equity measures [24]. Additionally, scholars have explored the impact of urban compactness on ecosystem services, including those of food production, carbon storage, habitat quality, and recreational services [25], and the relationship between compact cities and economic efficiency [26]. The methodologies have included entropy weighting and expert scoring methods, questionnaire surveys, and dynamic panel modelling (GMM) [25–27]. We can discover from previous studies that the urban form is a significant factor in the development of cities and even regions. Therefore, the implementation of the strategy in central China's rise is well established, and an accurate assessment of its urban compactness is of practical significance for solving the contradiction between urban development and the utilization of land resources in central China.

Therefore, this study uses panel data from 80 prefecture-level cities in central China from 2006 to 2020 as the samples. Through the creation of a measurement index system for urban compactness, the mechanisms and factors that contribute to the enhancement of urban compactness are investigated. This analysis is based on an examination of the spatial–temporal evolution of urban compactness in central China. The aim is to encourage the compact growth of cities in central China and offer fresh perspectives and strategies for optimizing the national regional development pattern. This study seeks to facilitate the concentrated growth of cities in central China, offering spatial governance perspectives to address the conflict between urban development and land use in the implementation of the strategy for the advancement of central China. Additionally, it aims to provide fresh directions and ideas for enhancing the national regional development pattern.

2. Materials and Methods

2.1. Indicator System Construction and Measurement Methods

2.1.1. Urban Compactness

Compactness is an indicator of the level of development in cities that are designed to be compact [28]. In relation to the methods for measuring compactness, Western scholars, such as Tsai (2005), Frenkel and Ashkenazi (2008), and Debbage et al. (2017), have primarily concentrated on utilizing spatial measurements, landscape pattern indices, and other methods to assess compactness. In contrast, Chinese scholars have emphasized the comprehensive evaluation of multiple dimensions in urban development [12]. Based on the summary findings, Chinese scholars have argued that the development of compact cities should prioritize the optimization of the urban population–land–economy structure and the enhancement of urban efficiency [20]. Therefore, the primary dimensions for measuring compact cities are land, population, society, and economy. Additionally, the ecological dimension and infrastructure dimension should also be considered, given the emphasis on constructing eco-cities and promoting green development. The measurement approach primarily relies on the objective empowerment method. A comprehensive index system is created to measure urban compactness based on previous research [2,29]. The details of this index system are provided in Table 1.

Table 1. Comprehensive measure index system of urban compactness.

Dimension	Indicator	Definition
Economy	Secondary and Tertiary Industries' Share of GDP	The combined GDP of the secondary and tertiary sectors as a percentage of total GDP (%)
	GDP Density Index	City GDP per unit area (CNY/km^2)
Land	Per Capita Construction Land	Construction land area per capita of the urban population (km^2)
Population	Urban Development and Utilization Intensity	Built-up area as a percentage of total urban area (%)
	Urban Population Density	Urban population per unit area (persons/km^2)
	Built-up Area Population Proportion	Population in the built-up area as a percentage of total urban population (%)
Infrastructure	Per Capita Road Area	Urban road area as a percentage of built-up area (%)
	Road Area Proportion	City road area as a percentage of built-up area (%)
Social	Medical Services	Number of hospital beds per 10,000 inhabitants in the urban area (beds/10,000 people)
	Social Security Completeness	Number of social welfare workers as a percentage of the population in municipal districts (%)
Ecology	Per Capita Public Green Space	Per capita public green space (km^2)
	Green Coverage Rate in Built-up Areas	Green Coverage Rate in built-up areas (%)

2.1.2. Urban Compactness Measurement—Entropy Approach

To mitigate the influence of subjective bias, researchers commonly employ objective assignment methods in their studies. The entropy value method can assess the extent to which an indicator contributes to the measurement variable through evaluation of the magnitude of the entropy value. In other words, the indicator's impact on the variable is stronger when the information entropy is higher. To mitigate the potential impact of scale differences on entropy value outcomes, the original data can be standardized using the extreme difference method. Subsequently, the entropy value can be computed, and finally, the composite index Y can be calculated using the linear weighting method based on the weights j. To obtain a comprehensive understanding of the entropy method's calculating process, please consult the referenced literature [30].

$$Y_j = \sum_{j=1}^{m} w_j \bullet X_{ij} \quad (1)$$

where X_{ij} denotes the value after standardization of the jth (j = 1, 2, …, m) indicator in the ith (i = 1, 2, …, n) year; Y_j is the comprehensive evaluation score; and W_j is the calculated weight.

2.2. Spatio–Temporal Geographically Weighted Regression Model (GTWR)

The spatio–temporal geographically weighted regression model (GTWR) is an extension of the GWR model developed by Huang et al. (2010) [31] which incorporates a temporal dimension to examine perspectives over time, aiming to simultaneously analyze spatial and temporal heterogeneity. Hence, the GTWR model is capable of efficiently addressing spatio–temporal non-stationarity and enhancing the precision of estimation outcomes [32]. The computation formula is as follows [33]:

$$Y_i = \beta_0(\beta_i, \mu_i, t_i) + \sum_{k=1}^{p} \beta_k(\mu_i, v_i, t_i) X_{ik} + \varepsilon_i \quad (2)$$

where Y_i denotes the explanatory variable for the ith sample point; X_{ik} denotes the kth explanatory variable for the ith sample point; u and v are the latitude and longitude of the sample city, respectively; t is time; $\beta_0, \mu_i, v_i, t_i)$ is the intercept; $\beta_k(\mu_i, v_i, t_i)$ is the estimated coefficient of the kth explanatory variable; p represents the total number of explanatory variables; and ε_i is the random perturbation term.

2.3. The Barycenter Model

The purpose of performing a barycenter study is to determine the spatial balance of a particular factor inside a given location. By observing variations in the coordinates of the barycenter, one can infer the geographical movement and temporal changes of the factor [34]. The barycenter model is currently a significant approach for analyzing the patterns of concentration and dispersion of development within urban agglomerations [35]. Thus, this study utilizes the barycenter model to examine the spatial evolution characteristics of urban compactness in central China through the analysis of the migration of the barycenter of compactness in terms of direction and distance. The barycenter model is based on the assumption that the research region is made up of n units. Each unit is represented by its latitude and longitude coordinates. The barycenter coordinates are given as follows [34]:

$$\overline{x} = \frac{\sum_{i=1}^{n} x_i \times m_i}{\sum_{i=1}^{n} m_i}, \overline{y} = \frac{\sum_{i=1}^{n} y_i \times m_i}{\sum_{i=1}^{n} m_i} \quad (3)$$

where $\overline{x}$ and $\overline{y}$ are the latitude and longitude where the barycenter is located (barycenter coordinates), and m_i is the mass or weight of region i. The spatial change and evolutionary tendency of the element can be indicated via analysis of the distance and direction of the offset between the coordinates of its barycenter and the coordinates of the geometric center of the unit [36].

2.4. Driver Selection and Measurement

The upsurge in urban compactness is a complex outcome influenced by various factors. Therefore, when choosing the drivers, it is important to consider the environmental and developmental context of compact cities and align them with the strategic attributes and development positioning of central China. Therefore, based on previous research and the features of the sample [20,30], the following variables were chosen as the key determinants of urban compactness in central China and examined for their underlying driving processes.

The government plays a crucial role in promoting the transition of cities into compact cities through policy creation and implementation. Therefore, the government serves as the external factor that enhances urban compactness. When analyzing industrial development, input factors such as population, industry, and land resources are typically considered. The advanced industrial structure index, calculated using Fu's spatial vector angle calculation method, is used to characterize industrial development [37]. Additionally, since central China is a significant energy and chemical hub, the energy driver is also included as a driving factor. Furthermore, the establishment of smart cities has led to an increasingly prevalent use of scientific and technological advances in urban development. Therefore, the level of innovation in science and technology should also be considered a contributing component of the whole system. The distinctive construction and significance of different drivers are illustrated in Table 2.

Table 2. Measurement of drivers of urban compactness.

Type	Factor	Definition
Government Drivers—Government Intervention	Government investment in fixed assets	Investment in fixed assets/total GDP (CNY 10^4)
Demographic Drivers—Human Resource Concentration	Employment density index of the population	Number of persons employed per unit/area of urban area (10^4 persons/km^2)
Industry Drivers—High Quality Development of Industry	Advanced industrial structure	Index of advanced industrial structure
Land Drivers—Land Resource Utilization	Land-use efficiency	Built-up land area/urban area (%)
Energy Drivers—Energy Utilization	Energy efficiency	Energy consumption per unit of GDP (tons of standard coal/CNY 10^4)
Science and Technology Drivers—Level of Science, Technology and Innovation	Percentage of expenditure on science and technology	Science and technology expenditure/government expenditure (%)

2.5. Overview of the Study Area and Data Sources

Central China includes six provinces: Shanxi, Henan, Hubei, Hunan, Jiangxi, and Anhui, totaling 80 prefecture-level cities. It is home to urban clusters such as the Wuhan metropolitan area, the Chang–Zhu–Tan urban agglomeration, and the Poyang Lake urban agglomeration area. As of 2020, the administrative region of Central China covered an area of around 1,028,400 square meters. It had a population of over 364,690,000 individuals and a total GDP of CNY 22.18 trillion, or approximately 21.9% of the national GDP. Given China's crucial position in terms of east–west and north–south connectivity, the ascent of central China has taken on a strategic role in coordinating and expanding the new framework of regional development. Specifically, central China serves as China's primary source of food production, energy, and other raw materials, as well as a comprehensive transportation hub. These factors ultimately shape the long-term development of cities in central China and are the source of challenges related to land. Therefore, the strategy for the emergence of central China is based on a fundamental strategic decision to adapt to new international and domestic development situations and to give full play to the location advantages of central China. Enhancing urban functions is a crucial stage in the ascending plan to bolster the region's overall strength and competitiveness. Therefore, examining the progress of condensed urban areas in central China holds immense practical importance in advancing local regional integration and bolstering the region as a vital link between the east and west, as well as a pivotal hub connecting the north and south. In Figure 1, the location schematic diagram of central China is shown.

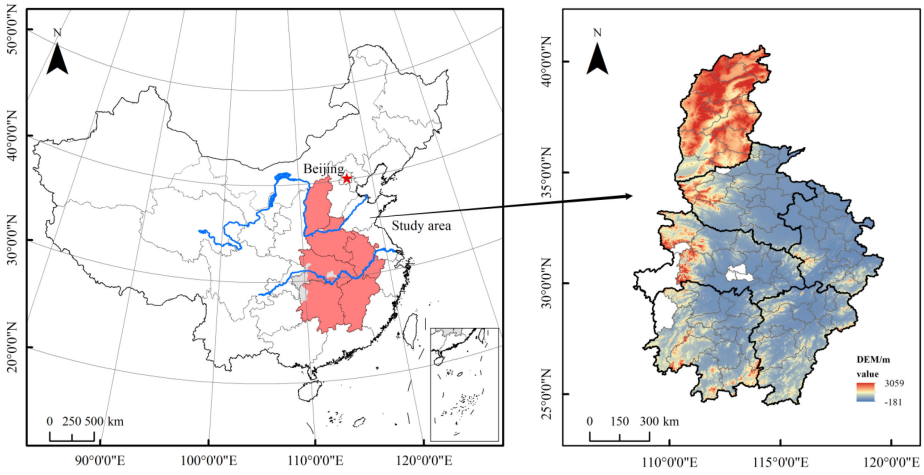

Figure 1. Location schematic diagram of central China.

This study utilized data from the China Urban Statistical Yearbook and the China Urban Construction Statistical Yearbook spanning from 2006 to 2020. The main focus of observation was on the municipal districts, given the substantial number of cities in the area and their varying degrees of size. For a small portion of missing data, we used provincial and local statistical yearbooks, national economic and social development statistical bulletins, and other relevant sources. If necessary, we used linear interpolation to estimate the missing values.

3. Empirical Findings

3.1. Analysis of the Development of Geographical and Temporal Patterns of Urban Compactness

As depicted in Figure 2, using the natural breaks method to categorize urban compactness into five levels (low, lower-middle, middle, upper-middle, high) at the temporal markers of 2006, 2010, 2015, and 2020, the diagram illustrates the spatial agglomeration and evolutionary characteristics of urban compactness in central China. The variation in the dark shaded areas within the diagram indicates that throughout the current study period, the overall comprehensive index of urban compactness in central China has demonstrated

an upward trend. The spatial distribution of various compactness intervals has remained relatively stable, with the areas of high compactness predominantly concentrated around provincial capitals and in their vicinity.

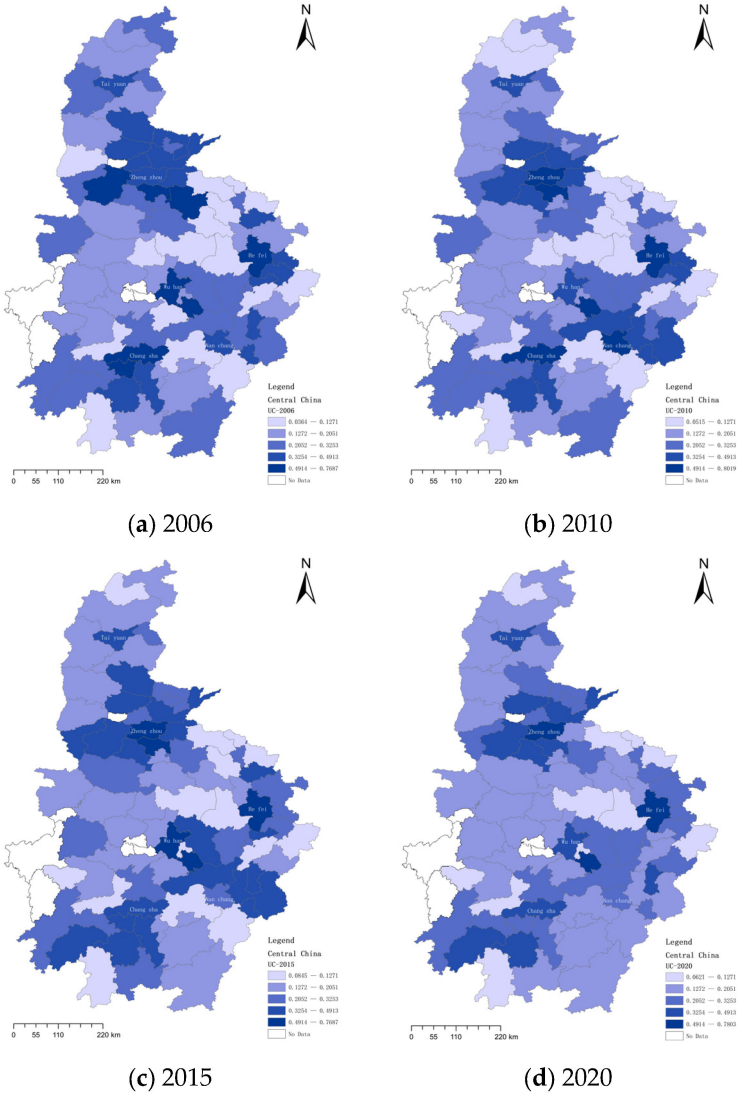

Figure 2. Spatio–temporal dynamic evolution of urban compactness in central China (2006–2020).

Between 2006 and 2010, there was a noticeable increase in the number of upper-middle and high compactness cities, particularly concentrated in the Wuhan urban agglomeration, the Chang–Zhu–Tan city cluster, and the Poyang Lake city cluster. From 2010 to 2015, not only was there an improvement in the urban compactness across the entire central China, but the disparity in compactness between cities also began to narrow. The north formed a major agglomeration of high compactness centered around Taiyuan and Zhengzhou, while the south saw the formation of a high compactness urban distribution belt along the Hefei–Nanchang–Wuhan–Changsha line, with the compactness index gradually decreasing from these centers. During the 2015 to 2020 period, the spatial distribution of the compactness index remained relatively stable. However, influenced by the sudden major public health event of COVID-2019, the socio-economic statistical data for central China in 2020 were generally lower, leading to a lower measurement of urban compactness for that year. Nonetheless, based on the development trend of existing measurements, it can be inferred that the urban compactness index for central China continued to hold a steady and rising state from 2015 to 2020.

Through an examination of the spatial clustering patterns of urban compactness and the dynamics of compactness change in central China, it becomes clear that the most significantly compact cities in this region are predominantly provincial capitals or sub-provincial capitals. In addition, these cities demonstrate a progressive decline in the compactness index moving away from their center. The spatial concentration and distribution of urban compactness in central China are indicative of the deliberate planning and execution of national city clusters. The promotion of regional cohesion is the result of various elements, encompassing institutional, economic, social, humanistic, and natural effects. The compactness of cities in central China can be linked to the creation of the Taiyuan urban agglomeration, Hefei metropolitan area, Wuhan metropolitan area, Changsha–Zhuzhou–Xiangtan urban agglomeration, and the urban agglomeration around Poyang Lake.

3.2. Evolutionary Trajectory of the Barycenter of Urban Compactness

To further understand the spatial trajectory of urban compactness, we used the barycenter model to trace the movement of the center point of urban compactness in central China from 2006 to 2020. Correlation investigations were performed by studying the connection between the migration distance and the geometric change direction of the compactness barycenter, as depicted in Figure 3. The barycenter of urban compactness is situated at the geographic coordinates of 114.16~114.20° E and 31.58~31.46° N. It operates within the geographical limits of Xinyang City in Henan Province and Xiaogan City in Hubei Province.

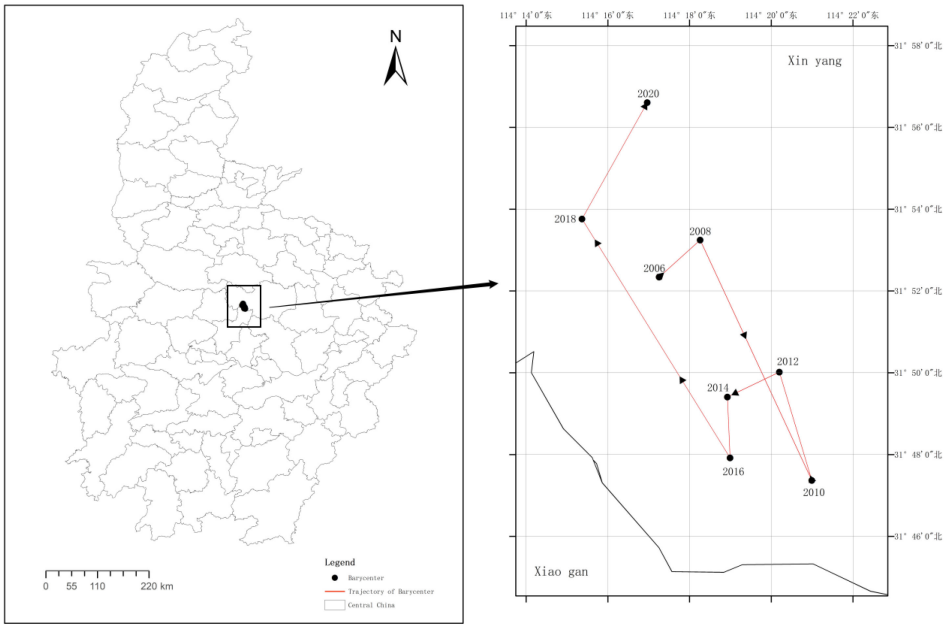

Figure 3. Center of gravity migration trajectory of urban compactness in central China.

The migration direction can be broadly classified into two phases: "southward" and "northward". The phrase "southward" refers to the shift of the central point of compactness in a southern direction, which took place between 2006 and about 2016. The movement towards the southern region may have been accelerated with the establishment and implementation of the Wuhan metropolitan area and the Changsha–Zhuzhou–Xiangtan urban agglomeration. The term "moving northward" refers to the reorientation of the compactness centroid towards the north, concentrated in the period from 2016 to 2020. This trajectory shift may be associated with the construction of the Zhengzhou metropolitan area, as well as the approval of the "Central Plains Urban Agglomeration Development Plan", which had a significant impact on the centroid's northward relocation.

The rate of migration exhibits acceleration during the time intervals of 2008–2010 and 2016–2020. During this period, there was a significant increase in the disparity in compact growth between north–south cities in central China. In contrast, the period from 2010 to 2016 exhibits a notable level of stability. These findings indicate that the differences in development across compact cities in central China are not substantial, leading to a relatively minor change in the barycenter. In general, migration patterns predominantly exhibit a north–south orientation, indicating that the differences in compactness in central China are mainly reflected between the cities in the south and the north. The movement speed presents a fluctuating characteristic of fast and slow changes, which indicates that the development differences of compact cities in central China also have an unstable evolutionary trend of expansion and contraction. This may be related to the formulation and implementation of national urban agglomeration development planning.

3.3. Analysis of Urban Compactness Driving Mechanism and Spatio–Temporal Heterogeneity of Drivers

The examination of the spatial and temporal attributes of urban compactness in central China reveals that the trajectory of high-compactness cities in the region between 2006 and 2020 aligns with the following urban agglomerations: Hefei metropolitan area, Wuhan metropolitan area, and the Changsha–Zhuzhou–Xiangtan urban agglomeration. The GTWR model was then utilized to evaluate and graphically represent the regression findings of each driving factor (average force coefficient) through ArcGIS. This analysis aimed to investigate the driving mechanism behind compactness and the spatial and temporal heterogeneity of the influence of each factor.

To effectively avoid the bias caused by spurious regression, a multicollinearity diagnostic was performed on the variables. The results showed that the variance inflation factor (VIF) values for all variables were less than 5, with the highest value being 4.141. This indicates that there is no multicollinearity among the variables, suggesting that the selection of drivers is reasonably appropriate. Furthermore, when comparing the fitting outcomes of the GTWR model and the OLS model, it is evident that the adjusted R^2 value in the OLS model is merely 0.657, whereas the adjusted R^2 value in the GTWR model can reach 0.868 (see Table 3). This observation suggests that the GTWR model, which incorporates both spatial and temporal dimensions, provides a more comprehensive explanation for the present study.

Table 3. GTWR model fitting results.

Implicit Variable	Res.2	Sigma	AICc	R^2	Adi.^{2}	STDR	Trace of Matrix
UC	1.492	0.048	−1795.99	0.868	0.869	0.373	108.971

3.3.1. Government-Driven Intervention Factors

As depicted in Figure 4a, the spatio–temporal differentiation map illustrates the impact of government intervention factors on the urban compactness in central China. The effect of government intervention on urban compactness across the region exhibits a bifurcation into positive and negative influences. Positive drivers are predominantly concentrated in Shanxi and Hunan provinces, whereas negative drivers are mainly located within Anhui and Jiangxi provinces. When examining the absolute values of the driving force indices, both the positive and negative drivers are approximately equal, around 0.2, indicating that the driving effect of government intervention on urban compactness is diminishing. Indeed, the early construction and development of major urban agglomerations, like the Greater Taiyuan and the Changsha–Zhuzhou–Xiangtan urban agglomeration, have been the result of government policy initiatives. In summary, government policies and practices regarding urban development have played a certain role in promoting the compact development of cities.

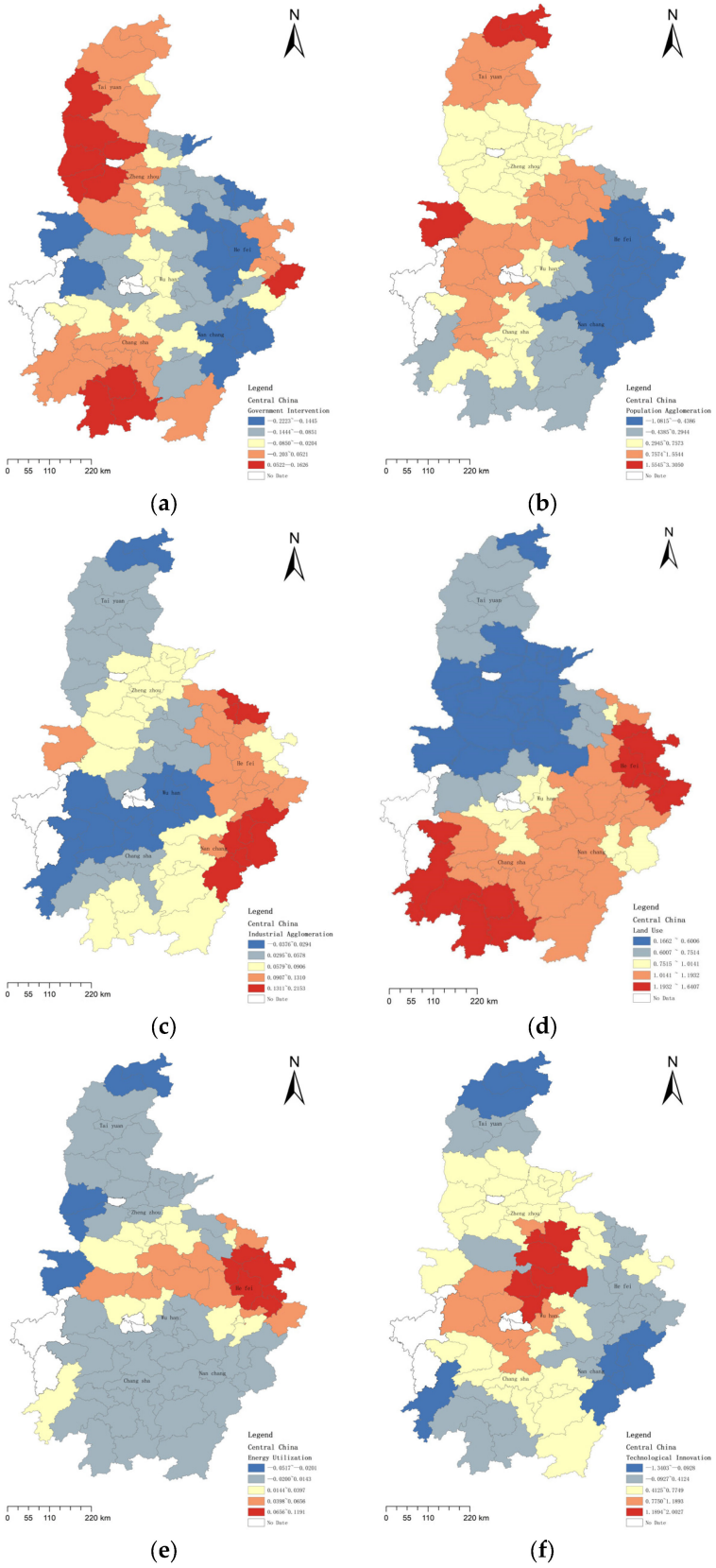

Figure 4. Spatial and temporal divergence of urban compactness driving factors in central China, 2006–2020. (**a**) government intervention level, (**b**) population agglomeration level, (**c**) industrial development level, (**d**) land use level, (**e**) energy utilization level, (**f**) technological innovation level.

The government serves as an external proponent for the creation of compact cities and seeks to promote a shift from expansive growth to concentrated construction through policy-driven regulation. This entails employing administrative tools to forcefully intervene in the development trajectory and transport choices of cities. With the implementation of the socialist market economic system, the government has decreased its involvement in extensive societal intervention. Nevertheless, it retains the capacity to shape urban growth through the implementation of strategies including financial investment, industrial strategizing, and infrastructure development [30]. However, the differences in the fundamental and economic attributes of cities might lead to government policies that do not consistently promote urban growth. Both excessive and insufficient government action can impact the degree of urban compactness. However, through the adjustments to policy instruments and overseeing the extent of government involvement, the main factor driving urban compactness will remain dominant.

3.3.2. Population-Driven Intervention Factors

The spatio–temporal divergence characteristic map of human resource aggregation's drive to urban compactness in central China is shown in Figure 4b. From the viewpoint of human resource aggregation on the whole area of central China, the negative driving force is mainly concentrated in the territory of Anhui Province and some cities in Jiangxi Province. The area is generally positively driven, with the highest negative driving force index of 1.0815 and the positive driving force index of up to 3.3050. Anhui Province is a populous province in China, while Jiangxi Province is the largest province in East China but has a relatively small population. It shows that population compactness should be moderately compact, and that either insufficient talent or overloaded talent aggregation may inhibit urban compactness.

Although population compactness is one of the motives and purposes of enhancing urban compactness, population compactness should be relative. As the driving force for the development of compact cities, the concentration of various types of talents provides technical support and manpower reserves for the completion of urban functions. This is manifested in the process of population transfer to the city, which may lead to the adjustment and optimization of the industrial structure and the compact development of transportation brought about by population concentration. The purpose of urbanization and urban compactness is to serve the people, which determines that population concentration will lead the city's economic, social, cultural, and even spatial structure to develop in a compact manner. However, when the population concentration is insufficient or the population carrying capacity is excessive, it may inhibit the increase in urban compactness. Underpopulation can slow down urban development by not providing sufficient labor, while overpopulation can lead to development barriers due to rapid resource consumption or resource shortages. Therefore, an appropriate population is a necessary condition for the sustainable development of compact cities.

3.3.3. Industry-Driven Intervention Factors

The map in Figure 4c illustrates the spatial differentiation characteristics of the impact of high-quality industrial development on urban compactness in central China. From the image, it is evident that industrial development has a predominantly favorable impact on urban compactness, with only a few cities showing exceptions. The high driving force index is mainly concentrated in Anhui and Jiangxi, indicating a central distribution. However, there is still room for improvement in terms of driving intensity. As Anhui aligns its development with the Yangtze River Delta region, the impact of industrial growth on urban compactness in Anhui is clearly evident. Similarly, the urban agglomeration around Poyang Lake in Jiangxi is influenced by the economic progress of the eastern region, and the effect of industrial development on its urban compactness is also quite noticeable. Nevertheless, the urban regions located inland, specifically focused on Changsha and Wuhan, exhibit a very limited dependence on industrial growth.

Industry is crucial for economic growth and plays a pivotal role in stimulating urban development. The industrial structure is intricately linked to the process of economic development. An optimal industrial structure and a well-functioning industrial system can facilitate the efficient allocation and utilization of resources. However, excessive economic growth can result in the depletion of the ecological environment due to the overconsumption of energy [34]. Clark's theorem states that the differentiation of industrial employment elasticity results in an elongated "S" curve relationship between urbanization and the economy [38]. Thus, prosperous industries in an urban area can additionally enhance the improvement of urban compactness. Simultaneously, the modernization of the industrial framework facilitates market expansion, promotes the market-oriented flow of elements, and rejuvenates the market economy, establishing a strong basis for achieving economic efficiency. A complete industrial system signifies the potential for scalable matching across the entire value chain of both material and human capital, thereby leveraging the pull effect brought about by industrial agglomeration. Therefore, achieving economic compactness, which is a key aspect of urban compactness, is a necessary strategy for achieving high-quality industrial growth. Furthermore, it serves as the fundamental basis for fostering compact urban development.

3.3.4. Land-Driven Intervention Factors

Figure 4d illustrates the spatial differentiation characteristics of land resource utilization efficiency in relation to urban compactness in central China. The figure illustrates that land use significantly influences urban compactness in central China, with the highest values observed in the Wuhan metropolitan area, the Changsha–Zhuzhou–Xiangtan urban agglomeration, Hefei metropolitan area, and the urban agglomeration around Poyang Lake centered around Nanchang. These areas are primarily located in the southern region of central China. The building of and growth in urban agglomerations have resulted in the effective use of land resources, with a progressively evident impact on urban compactness.

Land serves as the foundation and basis for urban development, and urban development must be established on land, which is the tangible manifestation of land utilization. Currently, urban growth is confronted with a significant scarcity of land resources, and so it is crucial to achieve the efficient utilization of urban land and its multifunctionality. The compact cities, which are the most recent form of sustainable urban development, encompass land-use concepts, principles, and implementation methods that offer guidance and significance in properly managing the connection between urbanization and land use [8]. Hence, cities must opt for intensive land use as a prerequisite for implementing compact development. Enhancing land-use efficiency is a crucial aspect of intensive land utilization. It can effectively address the issue of urban land scarcity and facilitate the development of high-density and multifunctional land layouts during urban construction. This approach aligns with the development concept of compact cities.

3.3.5. Energy-Driven Intervention Factors

The graph in Figure 4e illustrates the spatial differentiation characteristics of the energy use drive on urban compactness in central China. The figure demonstrates that energy consumption has a favorable influence on urban compactness in central China. Specifically, enhancing energy use efficiency can effectively stimulate urban compactness. Notably, the impact of energy consumption rises from west to east, with significant levels centered in Anhui Province and predominantly moderate to high levels found in Henan Province. Central China serves as the primary supplier of raw materials for China's energy sector, with its six provinces boasting diverse and abundant energy resources. For instance, Nanyang, Hebi, Puyang, Sanmenxia, Luoyang, Chuzhou, Suzhou, Maanshan, and Wuhu are cities that rely heavily on natural resources. Resource-based cities have a strong dependency on energy; thus, the utilization of energy drives the compact development of these cities.

An analysis of the previous research indicates a strong connection between urbanization and energy consumption in China. The correlation coefficient between urbanization and the demand for coal, oil, and natural gas exceeds 0.7 [39]. Simultaneously, the evidence indicates that urban energy consumption is primarily derived from industry, transportation, and construction [40]. Energy utilization significantly influences urban compactness through alterations to the industrial composition, transportation infrastructure, and spatial dynamics of cities [28]. Energy efficiency is a fundamental measure of energy consumption that impacts both the efficient use of urban land and the arrangement of land based on the urban spatial development model. Therefore, enhancing energy efficiency will effectively foster the expansion of urban compactness.

3.3.6. Science- and Technology-Driven Intervention Factors

Figure 4f displays a graph illustrating the relationship between the level of science and technology innovation (STI) and the compactness of cities in central China. The chart demonstrates that STI has a favorable impact on enhancing regional compactness, particularly in the provinces of Hubei and Henan. Nevertheless, the driving force indexes of certain prefecture-level cities in Shanxi and Jiangxi exhibit low and negative values, suggesting insufficient investment in science and technology innovation within the province or a lack of effective utilization of existing scientific research outcomes in promoting urban compactness. The driving force index now has a maximum value of 2.0027, indicating the need for further enhancement of the impact of science and technology innovation on urban compactness.

Urban development is a process of clustering and changing factors, where activities related to science, technology, and innovation serve as a connection and enabler. Through the process of engagement in a range of STI activities, cities can effectively gather and utilize factors of production, including talents, capital, energy, and raw materials, to enhance social production activities. This enables cities to achieve varying levels of coordinated development across demographic, economic, social, and ecological dimensions. Compact urban development emphasizes the integration of various aspects, such as science, technology, infrastructure, talent, and ecological balance. In utilizing technological innovation, cities can then optimize their industrial structure, upgrade their infrastructure, attract and retain talent, and maintain an ecological balance. This interconnected approach enhances the compactness of cities and promotes their overall development. Hence, actively enhancing the capability of scientific and technological innovations and extensively implementing the outcomes of these innovations are of significant benefit in enhancing urban compactness.

3.4. Identification and Regionalization of Drivers

The regression coefficients of urban compactness drivers in central China from 2006 to 2020 were clustered using the K-means clustering method in order to group the drivers into clusters for analysis. The clustering outcomes were visually represented to illustrate the spatial distribution and clustering attributes of the drivers. When clustering according to the number of drivers, the results show that the ratio of the total sum of squares to the total sum of squares between clusters is 0.748, which shows that the clustering results are improved. The specific findings are shown in Figure 5 and Table 4.

The clustering of communities impacted by a single driver is evident on the spatial scale, as illustrated in the figure. Sub-region 1 comprises cities primarily propelled by the utilization of land resources. These cities are predominantly located in Hunan, Hubei, and Jiangxi provinces, totaling 23 prefecture-level cities. They play a crucial role in promoting urban compactness in central China, indicating that the enhancement of urban compactness in this region is primarily influenced by the utilization of land resources. Sub-region 2 comprises technology-driven urban centers, primarily located in select cities within Henan and Hubei provinces. It serves as the second primary catalyst for urban compactness in central China. Sub-region 3 encompasses cities mostly influenced by government policies, particularly in Shanxi and Henan provinces. This suggests that the ad-

vancement of compact cities in this area is dependent on the implementation of government policy instruments. Sub-region 4 symbolizes the cities driven by industrial development, predominantly concentrated in Jiangxi and Anhui, which emphasizes the need to boost industrial restructuring to achieve high-quality industrial development. Subregions 5 and 6 correspond to cities that are primarily influenced by energy and population, respectively. These cities are relatively dispersed within the overall region.

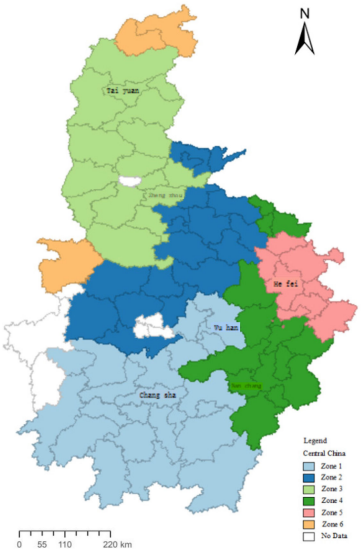

Figure 5. Regional breakdown of urban compactness drivers in central China, 2006–2020.

Table 4. The driving factor K-means clustering results of urban compactness in central China.

Driving Force	Partition 1	Partition 2	Partition 3	Partition 4	Partition 5	Partition 6
Government Drivers	0.2702	−0.6471	1.0653	−1.2941	0.0829	0.0116
Energy Drivers	−0.3944	0.3273	−0.4264	0.0883	2.3450	−1.9639
Demographic Drivers	0.0112	0.7280	0.4048	−1.1406	−1.5106	3.0997
Land Drivers	0.8650	−0.5066	−0.5831	0.6878	1.0769	−0.9628
Technology Drivers	0.0947	1.2416	0.0473	−0.9376	−0.2437	−1.9506
Industry Drivers	−0.4166	−0.1730	−0.0792	1.5991	0.9438	−1.0041
Number of Cities	23	18	16	12	8	3

4. Conclusions and Recommendations

4.1. Discussion

The construction of compact cities represents a tangible application of the sustainable development philosophy, with this investigation centered on central China. It leverages urban compactness as a metric to scrutinize the evolution of compact urban areas within this locale. Such an approach bears significant implications for fostering compact growth and mitigating the dilemmas associated with resource utilization in central China. Nonetheless, given the array of factors influencing urban compactness, this study, informed by the extant literature, has endeavored to incorporate a broad spectrum of pivotal determinants within its analytical purview. However, it acknowledges the existence of certain observational variables outside its current research framework, which necessitate further inquiry in future endeavors.

Moreover, pertaining to the constraints associated with the methodologies employed for gauging influencing factors, the precision of the measurement techniques for specific determinants requires enhancement to ensure a more accurate representation. Additionally, the accessibility of the research data has shaped this study's time-frame to span from 2006 to 2020. However, as the compactness of urban areas in central China continues to undergo

transformation, there is a compelling need for the acquisition of updated data to facilitate more comprehensive analyses in subsequent phases of this research.

4.2. Conclusions

From 2006 to 2020, the following conclusions were reached through an analysis of the motivating factors and mechanisms, as well as the characteristics of spatial and temporal evolution, of urban compactness in central China:

1. The urban areas in central China exhibit a growing trend in compactness, characterized by clear spatial clustering and minimal variation within compactness intervals. However, there is still room for improvement in achieving higher levels of compactness. The migration trajectory of the center of gravity of urban compactness reveals that the difference in urban compactness in central China mostly manifests in the north–south direction. This difference follows a pattern of expansion, followed by contraction, and then expansion again.

2. Through the identification of the inherent driving mechanisms and examination of the spatial distribution characteristics of the driving factors on urban compactness, it is shown that all the driving variables exhibit clustering and diversity within the spatial extent. Government policies and population agglomeration have both positive and negative effects on the development of urban compactness. On the other hand, land resource utilization, high-quality industrial development, energy utilization, and scientific and technological innovation have overall positive effects. However, the indices for industry-driven and energy-driven driving forces need further improvement.

3. Cluster analysis, focusing on the driving factors, reveals that land resource utilization is the primary factor contributing to the rise in compactness in the majority of cities in central China. Conversely, the number of cities where energy consumption and population concentration serve as the primary driving forces is relatively limited. Regarding the spatial distribution of driver clusters, Shanxi Province is mostly shaped by government policies, whilst Hunan Province is predominantly influenced by land resource utilization. In contrast, cities in other provinces are impacted by a diverse range of drivers.

4.3. Recommendations

The administrative region of Central China holds significant strategic importance for China's growth, and the implementation of compact cities plays a crucial role in the region's urbanization and the promotion of environmentally friendly and sustainable city development. Hence, increasing the compactness of urban areas in central China aligns with the principles of urban development and is a necessary decision to meet the strategic requirements of the region. According to the findings of this study, the following recommendations for development are put forward:

1. The promotion of compact city development underscores the importance of limited government intervention and the establishment of adaptable population control measures. The development of compact cities is influenced by government intervention, which serves as both an institutional constraint and an external impetus. Consequently, during the process of compact city development, it is crucial to carefully consider the selection of government policy tools and the level of government intervention. By implementing reasonable and appropriate policy regulations, we can effectively guide the development of compact cities and facilitate their realization through the integration of the city's inherent resource endowment. Promoting the compact development of urban population is crucial, since it is one of the key factors in constructing compact cities. Nevertheless, it is important for a population to possess a moderate level of compactness, since either an excessive concentration or a sparse dispersion of population is insufficient to sustain the effective functioning of urban areas. To achieve the development of a compact city, it is necessary to adopt a population policy that effectively organizes the employment and urban life of the people. This will ensure that there are enough human resources available for the growth of the compact city.

2. The promotion of compact city development also requires the enhancement of the urban government structure and the aggressive fostering of industrial development and scientific and technological innovation. The modernization of urban governance is driven by the objective of achieving a compact city. It is crucial to actively promote the modernization of the urban governance system and its capabilities in order to facilitate the implementation of spatial governance in compact cities. Simultaneously, it is imperative to facilitate the advancement of industrial transformation and upgrading, enhance the progress of industrial interconnection, and furnish economic impetus for the condensed growth of the city while striving to fulfil the ecological dimension of the compact city through adherence to green and low-carbon prerequisites to the greatest extent feasible. Furthermore, scientific and technological innovation can offer technical assistance for the implementation of compact cities, and thereby foster concurrent economic and social progress. Specifically, cities in central China that have a limited level of scientific and technological innovation can conduct focused scientific and technological research and development. This will enable them to achieve efficient city governance through the use of scientific and technological capabilities.

3. The scope of compact urban strategies must be extended to enhance energy and land utilization efficiency. The concept of compactness in relation to cities is a dynamic definition that adapts to the overall environment. Therefore, the practical dimensions of compact cities should also be broadened to align with evolving development needs. Specifically, the research indicates that energy utilization has a significant impact on the development of compact cities. Therefore, it is essential to consider energy compactness not only in the research measurement of compact cities but also in the practical aspect of urban energy compactness. This will help enhance the efficiency of energy utilization. Land resources are essential for achieving land-use compactness, as they serve as the foundation for urban development. It is therefore imperative to closely align with the notion of a small city and enhance land utilization to curb unrestricted urban expansion.

Author Contributions: Conceptualization, W.R. and L.W.; methodology, W.R.; software, J.X.; validation, W.R. and J.X.; formal analysis, X.L.; investigation, W.R. and L.W.; resources, X.L.; data curation, X.L. and Y.Q.; writing—original draft preparation, W.R.; writing—review and editing, W.R. and X.L.; visualization, Y.Q.; supervision, X.L.; project administration, Y.Q.; funding acquisition, X.L. All authors have read and agreed to the published version of the manuscript.

Funding: This study was funded by the Outstanding Graduate Education Innovation Funding Program of the Central China Normal University (2023CXZZ042).

Data Availability Statement: Publicly available datasets were analyzed in this study. The data can be found here: (https://www.cnki.net (accessed on 27 September 2023)).

Acknowledgments: The authors extend much gratitude to the anonymous reviewers and editors for their helpful reviews and critical comments.

Conflicts of Interest: The authors declare no conflicts of interest.

References

1. Neuman, M. The Compact City Fallacy. *J. Plan. Educ. Res.* **2005**, *25*, 11–26. [CrossRef]
2. Huang, Y.; Dong, S.; Bai, Y. The Spatial and Temporal Characteristics of the Relationship Between Urban Compactness and Urban Efficiency in China. *Popul. Resour. Environ.* **2015**, *25*, 64–73.
3. Ewing, R.H. Characteristics, Causes, and Effects of Sprawl: A Literature Review. *Environ. Urban Stud.* **1994**, *21*, 1–15.
4. Hege, H. Compact City Development: High Ideals and Emerging Practices. *Eur. J. Spat. Dev.* **2012**, *10*, 1–23.
5. Hamidi, S.; Ewing, R. A Longitudinal Study of Changes in Urban Sprawl Between 2000 and 2010 in the United States. *Landsc. Urban Plan.* **2014**, *128*, 72–82. [CrossRef]
6. Lv, B.; Qi, L. The Inspiration of Compact City Theory for Urbanization in China. *Urban Plan. J.* **2008**, 61–63.
7. Li, H.; Cao, X. The Connotation of "Compact City" and Its Adaptability to the Development of Chinese Cities. *J. Lanzhou* **2014**, *6*, 110–116.
8. Li, H.; Cao, X. Analysis of Land Use Characteristics in Compact Cities. *Study Pract.* **2015**, *379*, 28–34.

9. Han, G.; Yuan, J.; Wang, Z. The Research Process of Compactness of Foreign Cities and Its Enlightenment for China. *World Geogr. Res.* **2017**, *26*, 56–64.
10. Hao, W.; Zhang, M. Empirical Study on the Relationship Between Traffic Improvement, Urban Compactness and Urban Productivity: Based on the Econometric Analysis of Spatial Panel Data of Chinese Prefecture-level Cities. *Explor. Econ. Issues* **2016**, 66–75.
11. Li, J.; Xia, S. Measurement of Compactness of China's Extra-large Cities and Correlation Analysis of Multiple Effects. *Urban Dev. Res.* **2016**, *23*, 109–116.
12. Jia, M.; Liu, X.; Chen, T.; Fan, P. Measurement of Compactness of Cities at and Above the Prefecture Level in China. *Urban Probl.* **2019**, *292*, 4–12.
13. Hong, M.; Jin, F. Analysis and Enlightenment of Land Use Concept in Compact Cities. *China Land Sci.* **2010**, *24*, 10–13+29.
14. Zha, Y.; Pang, X. Study on the Impact of Target Constraints on High-quality Development of Regional Economy—Taking the Prefecture-Level Cities in Central China as an Example. pp. 1–9. Available online: http://kns.cnki.net/kcms/detail/34.1013.n.20211209.1809.002.html (accessed on 15 November 2023).
15. Chen, F.; Zhou, M. The Rise of Central China Strategy and the Transformation and Upgrading of Regional Industrial Structure: Empirical Evidence from Chinese Urban Panel Data. *China Soft Sci.* **2022**, *374*, 105–115.
16. Chen, M.; Li, Q.; Wang, Z.; Xie, L. Study on the Coupling of High-quality Development of Urban Economy and Ecological Sustainability in Central China. *Urban Probl.* **2022**, *321*, 77–86.
17. Zhou, H.; Zhou, J. Dynamic Spatial Effect Test and Convergence Analysis of Urbanization on Economic Efficiency in Central China. *Explor. Econ. Issues* **2020**, *455*, 77–87.
18. Wang, C.; Luo, X. The "Marginalization" of Urban Development in Central China: Thinking on Urbanization of Yueyang City, Hunan Province. *Mod. Urban Res.* **2022**, *37*, 99–105.
19. Zhang, S. The Real Value and Promotion Strategy of Urban Agglomeration Construction in Central China. *Reg. Econ. Rev.* **2022**, *56*, 81–87.
20. Zhou, W.; Zhu, H.; Liu, Q.; Lu, Y. Study on the Temporal and Spatial Characteristics and Influencing Factors of Urban Compactness in Hunan Province. *Hubei Agric. Sci.* **2018**, *57*, 25–28+35.
21. Rong, P.; Liu, H.; Lv, L.; Qin, Y. Comprehensive Evaluation of Urban Compactness in Henan Province Based on Evolutionary Tree Model. *Reg. Res. Dev.* **2019**, *38*, 48–53.
22. Aulia, P.L.; Taki, H.M.; Wartaman, A. Impact of transportation on urban compactness index in South Tangerang City, Indonesia. In Proceedings of the IOP Conference Series: Earth and Environmental Science, Surakarta, Indonesia, 24–25 August 2021; Volume 737, p. 012052.
23. Ding, G.; Guo, J.; Pueppke, S.G.; Yi, J.; Ou, M.; Ou, W.; Tao, Y. The influence of urban form compactness on CO_2 emissions and its threshold effect: Evidence from cities in China. *J. Environ. Manag.* **2022**, *322*, 116032. [CrossRef] [PubMed]
24. Rashid, M. On Spatial Mechanisms of Social Equity: Exploring the Associations between Street Networks, Urban Compactness, and Social Equity. *Urban Sci.* **2022**, *6*, 52. [CrossRef]
25. Kamble, T.; Bahadure, S. Investigating application of compact urban form in central Indian cities. *Land Use Policy* **2021**, *109*, 105694. [CrossRef]
26. Yao, Y.; Pan, H.; Cui, X.; Wang, Z. Do compact cities have higher efficiencies of agglomeration economies? A dynamic panel model with compactness indicators. *Land Use Policy* **2022**, *115*, 106005. [CrossRef]
27. Yu, P.; Zhang, S.; Yung, E.; Chan, E.H.W.; Luan, B.; Chen, Y. On the urban compactness to ecosystem services in a rapidly urbanising metropolitan area: Highlighting scale effects and spatial non–stationary. *Environ. Impact Assess. Rev.* **2023**, *98*, 106975. [CrossRef]
28. Han, G.; Yuan, J.; Zhang, X.; Feng, X. The Role Mechanism of Compact City Spatial Structure in Urban Energy Consumption: An Empirical Study Based on Jiangsu Province. *Sci. Geogr.* **2019**, *39*, 1147–1154.
29. He, D.; Zhou, J.; Cai, J.; Chen, Z. Measurement and Analysis of Changes in Urban Compactness in Beijing-Tianjin-Hebei Region. *Ecol. Sci.* **2022**, *41*, 178–186.
30. Mao, G.; Ding, J.; Cao, L. Comprehensive Measurement and Driving Force Analysis of Urban Compactness—Taking Jiangsu Province as an Example. *Sci. Geogr.* **2009**, *29*, 627–633.
31. Huang, B.; Wu, B.; Barry, M. Geographically and Temporally Weighted Regression for Modeling Spatio-Temporal Variation in House Prices. *Int. J. Geogr. Inf. Sci.* **2010**, *24*, 383–401. [CrossRef]
32. Wu, X.; Yang, S.; Yin, S.; Xu, H. Spatio-temporal Dynamic Characteristics of Urban Construction Land in the Yangtze River Delta Region and Its Driving Mechanism Based on GTWR Model. *Resour. Environ. Yangtze Basin* **2021**, *30*, 2594–2606.
33. Lu, X.; Li, J.; Liu, C.; Kuang, B.; Cai, D.; Hou, J. Driving Factors and Spatial Differentiation of Green Land Use Efficiency in Chinese Cities. *Sci. Geogr.* **2022**, *42*, 611–621.
34. Wu, K.; Gu, J.; He, H.; Dang, S. Study on the Spatial and Temporal Characteristics of Land Use Conversion in Hilly Mountainous Areas Based on Gravity Model. *J. Agric. Eng.* **2019**, *35*, 247–254.
35. Rong, X.; Zheng, H.; Wang, Y. Analysis of Temporal and Spatial Differences of Land Use Efficiency in Chinese Urban Agglomerations Based on Super-SBM and Gravity Model. *Hubei Soc. Sci.* **2019**, *396*, 70–77.
36. Liu, C.; Li, X.; Nie, Y. Analysis of Temporal and Spatial Coupling Between Grain Production and Water Resources Based on Gravity Model. *Mod. Agric.* **2021**, *42*, 1026–1036.

37. Fu, L. An Empirical Study on the Relationship between Industrial Structure Upgrading and Economic Growth in China. *Stat. Res.* **2010**, *27*, 79–81.
38. Sun, J.; Zhou, Y. Study on the Interaction Between China's Industrial Development and Urbanization—From the Perspective of Panel Threshold Regression Model. *Study Pract.* **2014**, *369*, 5–12.
39. Shen, L.; Cheng, S.; Gunson, A.J.; Wan, H. Urbanization, Sustainability and the Utilization of Energy and Mineral Resources in China. *Cities* **2005**, *22*, 287–302. [CrossRef]
40. Intergovernmental Panel on Climate Change. *Climate Change 2014—Mitigation of Climate Change: Summary for Policymakers*; IPCC: Geneva, Switzerland, 2015.