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Triple Spatial Effects of the Administrative Hierarchy on Urban Built-Up Areas in Fujian Province, China: Heterogeneity, Radiation, and Segmentation

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Abstract: The expansion of urban built-up areas is one of the most prominent characteristics of land use change in China. A growing body of literature has emphasized the triple spatial effects of the administrative hierarchy on urban built-up areas expansion, including heterogeneity, radiation, and segmentation. However, the existing studies have mainly focused on the administrative hierarchy at the prefectural level and above and have primarily concentrated on one single effect; few have integrated the triple effects as a whole. Based on high-resolution land use data and taking Fujian province as a study case, this study proposes an integrated theoretical framework and modeling approach and investigates the triple spatial effects of administrative hierarchy on built-up areas at the prefectural level and below. Descriptive statistics show the following: (1) Built-up areas of municipal districts are significantly larger than those of county-level units, showing the heterogeneity characteristics of urban land distribution across different levels of administrative hierarchy; (2) The county-level units adjacent to municipal districts exploit more built-up areas than other county-level units, indicating the radiation effects of municipal districts; (3) The radiation effects tend to be reduced if a municipal district and its adjacent county-level units are not located in the same prefectural city, revealing the segmentation effects among the different prefectural cities. Using the spatial econometric model with regimes, we further find the following: (1) The strengths of driving forces of built-up areas are heterogeneous between municipal districts and county-level units, and there are significant spatial interactions among administrative units; (2) The spatial interactions between municipal districts and county-level units are stronger than those between two county-level units, but the strength is restricted by the prefectural boundary, reflecting the radiation effects of municipal districts and the segmentation effects of the prefectural boundary, respectively. By investigating the triple spatial effects of the administrative hierarchy on urban built-up areas, we conclude that comprehensively considering these triple effects as a whole will result in a fuller understanding of the rapid built-up areas expansion in China, especially at the prefectural level and below.

Keywords: administrative hierarchy; built-up areas; spatial effects; heterogeneity; radiation; segmentation; Fujian province; China

1. Introduction

Rapid urbanization worldwide is changing land cover significantly [1]. The world's urban population accounted for about 33% in 1950 and increased to 54% in 2014 [2]. At the global scale, the percentage of urban land to the total land increased from 0.23% in 1992 to 0.53% in 2013 [1]. The implementation of China's economic reform and open policy in 1978 stimulated dramatic urbanization and land expansion. In 1978, the urbanization rate of China was only 17.92%, exceeded 60% at the end of 2019, and is expected to increase to 70% by 2030 [3]. From 1985 to 2018, the mean growth rate of built-up areas in China was 4663 km^2 per year, which was much faster than that in other countries. In 2015, China became the country with the most built-up areas in the world [4]. This unprecedented urban growth in China has significant impacts on ecological security [5], environmental quality [6], and agricultural production [7], all of which finally influence human health and well-being [4].

To inform sustainable development and land use planning, a rich body of literature has already investigated the driving factors of urban land expansion in China. Scholars have found that urban land expansion has been driven by urbanization [8], marketization [9], industrialization [10], and transport networks [11]. Furthermore, political and institutional factors are also extensively mentioned in the literature, suggesting that urban expansion is not merely a result of market forces but also shaped by government behavior [8]. Under the current land use system in China, local governments are the sole legitimate providers of newly increased urban construction land [12]. Especially after the reform of tax-sharing and the land market in China, land conveyance fees have rapidly increased and become the most important resource for local revenue, which enable local governments to attract investments, develop infrastructures, and stimulate urban economic growth [9,13]. Thus, the ability and incentive of local government to expand urban land have inevitably triggered unprecedented land urbanization in China.

By emphasizing government behavior and the inflexible administrative system in China, recent studies have paid more attention to the triple spatial effects (i.e., heterogeneity, radiation, and segmentation) of the administrative hierarchy on urban land development, which can be attributed to the vertical and horizontal structure of the urban administrative system.

From the vertical perspective, the urban administrative units are structured into three primary levels of local government, namely the province level, the prefecture level, and the county level [14]. In the transition process of decentralization, important administrative powers have devolved from the central state, level by level [9]. Higher administrative levels correspond to stronger land administration power (e.g., the autonomy of land use planning) [9,15] and higher political capability to make locally privileged policies to attract the impetuses of urban growth (e.g., development zones and foreign investment) [9]. Thus, urban land expansion tends to coincide with the administrative level, presenting heterogeneity across different administrative levels. For example, Liu et al. found that cities with higher administrative levels tended to expand at a higher speed [3].

From the horizontal perspective, the urban administrative units at the same level engage in intense cooperation and competition, leading to radiation and segmentation effects on built-up areas [16,17]. On one side, to realize industrial upgrading and the scale economy, close cooperation has been formed among local governments [18,19]. Especially in the emergence process of urban agglomeration, communication enhancement and integration development have emerged through the high-dense connection between central and adjacent administrative units [20]. In this case, the spatial spillover between central and adjacent administrative units is stronger than between two peripheral units. For example, Cen et al. stated that administrative central cities demonstrated a radiation effect on the surrounding cities in terms of urban land development [17]. On the other side, local governments are controlled by the central government via gross domestic product (GDP) centric promotion competition [21]. To gain an advantage in the competition, local government often establishes market barriers and administrative interventions to maximize local economics based on administrative division [22]. As urban land is the most important resource for local government to acquire revenue and promote economics [15], it also demonstrates the segmentation characteristics across an administrative boundary. For instance, Wang et al. revealed that provincial boundaries significantly restrict the spatial spillover effect between county-level units that are not located in the same province [16].

To summarize, due to the vertically tiered structure and horizontal cooperation and competition, the administrative hierarchy has shown multiple spatial effects on urban land development, including heterogeneity, radiation, and segmentation. A rich body of literature has paid attention to these effects, but the existing research has mainly focused on a single effect. The parallel and distinct research have provided limited understanding and resulted in partial and potentially misleading conclusions about land urbanization in China. Thus, a more comprehensive theoretical and modeling framework is urgently needed to fully reveal the land urbanization mechanisms under the Chinese administrative hierarchy.

Drawing upon high-resolution land use data extracted from remote sensing images, this study aims to fill this research gap and contribute a comprehensive and integrated framework to investigate the link between Chinese administrative hierarchy and urban built-up areas, taking Fujian province as a study case. Based on descriptive statistics, this study will demonstrate that the administrative hierarchy has triple spatial effects on built-up areas (i.e., heterogeneity, radiation, and segmentation), stemming from the vertical and horizontal interaction among the administrative units. By applying a spatially explicit model named the spatial lag model with regimes, this study will further deal simultaneously with the triple effects of the administrative hierarchy in a single spatial econometric model, showing that the administrative hierarchy not only plays a proactive role in built-up area development but also has a profound impact on other driving forces of built-up area expansion.

2. Recent Urban Development in China

Urban development in China is by no means disconnected from the legitimate power and hierarchical structures in the national administrative system [9]. Under the inflexible administrative hierarchy, Chinese cities are endowed with tiered administrative authorities and are affected by collaboration and competition with surrounding cities. Thus, the administrative hierarchy has triple evident effects on urban built-up areas' development: heterogeneity, radiation, and segmentation.

2.1. The Heterogeneity Effects of Administrative Levels on Built-Up Areas

Urban administrative levels are closely connected with social mobility between regions, which further affects regional land use. First, administrative status is a crucial impact factor of population development. A study of East Germany showed that losing county capital status has a significant negative effect on annual changes in population after the administrative reforms have been implemented, and this effect continues to increase over time [23]. Second, scholars in the USA and the Netherlands found that interregional migration flows are disaggregated by age and show radically different patterns of net population redistribution in the sense of upward and downward movements within the urban hierarchy [24,25]. For example, elderly Americans tend to congregate in micropolitan and rural counties, while younger adults like to flock to large metropolitan areas [24]. Third, in the urbanization process in China, millions of poor and low-income rural migrant workers migrate to urban areas at high administrative levels, and the expansion of urban areas has potential impacts on the social mobility of their children. For example, a study of Beijing (i.e., the capital city of China) showed that the process of eliminating villages in the city (chengzhongcun) to urban areas hampers the social mobility of migrant youth in the context of the rigid class structure in late-socialist China [26]. Furthermore, the rural migrant workers in cities at high administrative levels can neither apply for the urban residence certificate (hukou) of these cities nor have the motivation to permanently stay in cities at the cost of abandoning their agricultural land and rural houses. Therefore, the rural migrant workers work and live in cities, but few sell out their rural houses, resulting in ubiquitous "hollow villages." More importantly, most migrant workers have remitted a large proportion of the money earned in cities to build new houses in their hometowns, leading to the abnormal expansion of rural residential land [27].

As the administrative powers of urban land are endowed diversely, and the driving forces of built-up areas are distributed unevenly across Chinese cities at different administrative levels, urban built-up areas show notable spatial heterogeneity, reflecting the tiered administrative hierarchy. First, Chinese cities are institutionalized under rank-based land administrative authorities. For instance, only four province-level municipalities directly under the Central Government have limited legislative power of land administration [9], and cities at higher administrative levels tend to receive a higher construction land quota [28]. Second, the urban administrative system reinforces the uneven distribution of impetuses underlying urban growth. For example, as higher-level cities have advantages in resource allocation and institutional arrangement, they can attract more immigration and foreign investment and establish higher-level development zones, which are the main driving forces of built-up areas expansion [9,29]. Consequently, urban built-up areas highly coincide with the administrative hierarchy; cities with higher administrative levels tend to develop more built-up areas.

Besides exploring divergence, previous studies have employed several modeling approaches to reveal that the driving mechanisms of built-up areas also show significant differences across cities at different administrative levels. Ma et al. found that the key influencing factors of urban land varied substantially across the county, prefectural, and provincial levels through three independent ordinary least squares models at each level [14]. Li et al. demonstrated that socioeconomic and policy factors of urban expansion differed between the county and provincial levels with a single regression model using the multilevel modeling technique [30]. Li et al. further revealed that the strengths of economic and demographic drivers of urban growth were also sensitive to a city's administrative rank based on the spatial regimes modeling approach, which can produce comparable regression coefficients dedicated to each city level [9].

In short, the heterogeneity characteristics of urban land across different administrative levels have been extensively studied. However, previous studies have mainly focused on the prefectural level and above, and the divergence pattern of built-up areas at the prefectural level and below is still lacking. Under China's system of "city administering counties (shi guan xian)," county-level units are under the administrative control of the prefectural government, which has greater administrative power (e.g., urban planning and land use management) than county-level governments [13,21,31]. In the Chinese administrative system, the administrative territory of prefecture-level cities is divided into two categories: municipal districts and county-level units (i.e., counties and county-level cities). Municipal districts are directly controlled by the prefecture-level government. As a result, administrative conflicts between prefecture-level cities and county-level units are mainly manifested as conflicts between municipal districts and county-level units [13,21]. For example, many prefecture-level cities have annexed county-level units and transformed these units into municipal districts. In this process, the prefectural government expropriated the land resources of county-level units and significantly increased their land conveyance fees [13]. Surprisingly, although administrative differences between municipal districts and county-level units have been thoroughly discussed from an institutional perspective [13,21,31], studies investigating the heterogeneity characteristics of built-up areas between them are still limited.

2.2. The Radiation Effects of Administrative Centers on Built-Up Areas

Besides the heterogeneity effect on built-up areas, previous studies have shown that central cities of the urban agglomeration can have a radiating effect on the surrounding city areas [16,17], which can be attributed to industrial upgrading and the scale economy.

First, to promote economic development, urban governments tend to adopt an industrial upgrading strategy and relocate the secondary industry from central cities to nearby cities to make room for tertiary industry [18]. In addition, increased land prices in central cities also force low-value-added sectors to move to surrounding cities [32]. Consequently, the land eliminated from central cities spills into nearby cities where land rent is affordable, and there is convenient access to the adjacent central city [33].

Second, in industrialization, various production factors are driven by agglomeration and scale economies. They gradually concentrate on urban areas and drive the expansion of urban land [32]. However, if the urban land in central cities continues to expand and surpasses the turning point, the scale economies of urban land can fade out or even shift to scale diseconomies [19]. With new urbanization in China, urban agglomeration has emerged as a new city form consisting of a high-density connection between central cities and adjacent small cities. Through inter-city connection, urban agglomeration can effectively extend scale economies beyond administrative boundaries and continue to improve urban economic efficiency [19,20]. Consequently, the urban land driving effects of the scale economy can spread to adjacent cities that are closely connected to central cities.

To summarize, due to industrial upgrading and the scale economy, central cities have a radiating effect on adjacent lower-level cities, which expand much more rapidly than cities far from the administrative central cities.

In terms of methodology, spatial visualization is employed as a qualitative tool to demonstrate the radiation pattern of provincial central cities [17]. Furthermore, Zeng et al. proposed a quantitative framework of spatial econometric models using different spatial weight matrices to represent various scenarios. In their empirical study, 15 scenarios were established by considering five different administrative statuses (i.e., urban district, suburban district, county, county-level city, and district). They found that administrative status has evident effects on the spatial spillover of land-use intensity in the Wuhan urban agglomeration. Especially the provincial central city shows a significant radiation effect on land-use intensity [34]. Although the radiation effects of the provincial centers have been noticed in previous studies, the radiation effects of administrative centers of prefectural cities (i.e., municipal districts) have been neglected by most studies.

2.3. The Segmentation Effects of Administrative Boundaries on Built-Up Areas

Besides the spatial radiation effects, the spatial segmentation effects across the boundary of administrative units are also significant, which are the institutional consequences of economic decentralization and promotion tournaments [8,22,35,36]. On one side, decentralization of economic governance grants local governments autonomy to make economic decisions and distribute resources within their own regions. Therefore, local governments have the incentive and responsibility to develop their local economies [22]. On the other side, the higher level government still maintains vertical control via promotion tournaments and has the authority to appoint and promote the leaders of local governments according to the performance of local economic development, which leads to fierce competition between local governments. To win the GDP-centric promotion tournament, local governments generally distort the price of the land market and use the low price of industrial land as a bargaining chip to attract investment [36]. Thus, intergovernmental competition significantly affects urban land development, demonstrating the segmentation effect across administrative boundaries [35].

Recently, Wang et al. proposed a new modeling strategy to explore how the spatial spillover effect of urban land intensity is restricted by competition among administrative units. They found that the strength of the spatial spillover effect between county-level units can be cut to half by the provincial boundary (i.e., county-level units do not belong to the same province) [16]. However, even though some studies have pointed out that the competition among prefectural-level cities has a significant effect on urban land development [35,36], few studies pay attention to the segmentation effect of prefectural boundary on the spillover effect of urban land (e.g., the radiation effect of municipal districts).

To summarize, the triple spatial effects of the administrative hierarchy on urban land have attracted extensive research attention, but these effects are investigated separately by most studies. Thus, an integrated framework is urgently needed to fully understand the multiple effects of administrative hierarchy on urban land. Moreover, the heterogeneity characteristics between municipal districts and county-level units, the radiation effect of municipal districts on adjacent county-level units, and the segmentation effects of the prefectural boundary on the radiation effects of municipal districts are still understudied, calling for further studies to address these research gaps.

3. An Analytical Framework

To comprehensively investigate the effects of the Chinese administrative hierarchy on built-up areas, we propose an analytical framework to better summarize the mechanism of built-up areas' development (Figure 1).

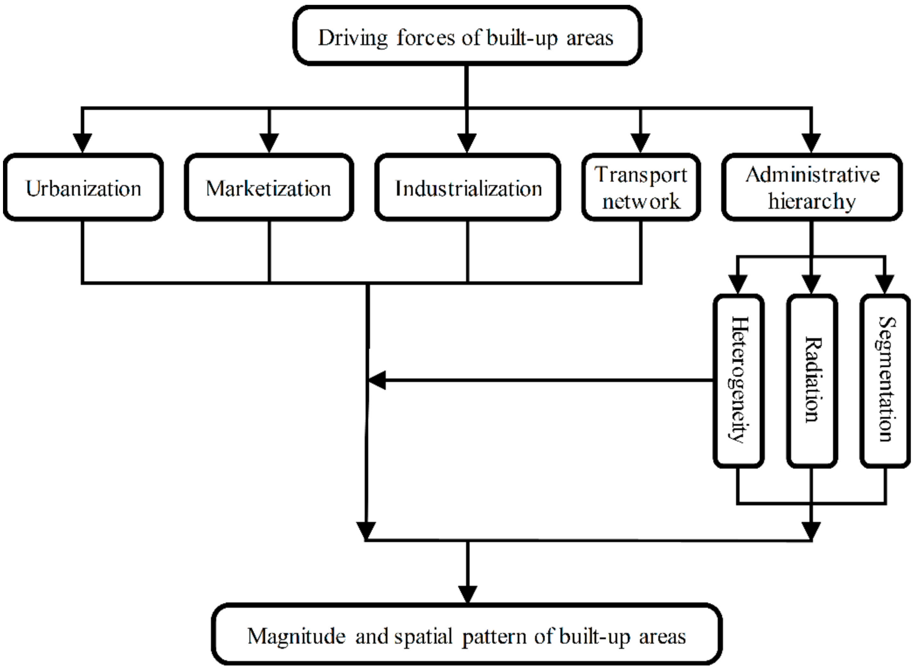


Figure 1. Analytical framework to examine the administrative hierarchy and built-up areas in China.

First, in the context of the Chinese socio-economic transition, urbanization, marketization, and industrialization are broadly recognized as the primary processes that affect urban land expansion [8–10]. Specifically, factors considered as significant driving forces of urban land include demographic urbanization, GDP, and enterprise development [8,10]. Moreover, many studies have stated that the transportation network also plays a key role in urban land expansion [11].

Second, the administrative hierarchy in China has triple spatial effects on built-up areas, including heterogeneity, radiation, and segmentation. From the vertical perspective, as the administrative powers and economic resources are distributed unevenly across different hierarchy levels, the magnitudes and driving forces of built-up areas tend to be sensitive to the tiered structure of the administrative hierarchy. From the horizontal perspective, local governments at the same administrative level engage in intensive cooperation and competition. The cooperation relationship leads to a spatial spillover effect between adjacent administrative units [35], and the administrative central cities demonstrate a radiation effect on nearby administrative units. At the same time, the competitive relationship induces a spatial segmentation effect between adjacent administrative units, which can restrict the radiation effect of administrative central cities across the administrative boundary.

Third, under the Chinese administrative system, the administrative territory of prefecture-level cities is divided into two categories: municipal districts and county-level units, which are the most significant levels that local government rushed to take land from the farmers and expand urban land [37,38]. However, previous studies concerned with the effects of administrative hierarchy on urban land have mainly focused on cities at the prefectural level, and above, the effects at municipal districts and county-level units are still unexamined [9,10]. This study tries to fill this gap and investigate the triple spatial effects at relatively lower administrative levels, including the heterogeneity characteristics between municipal districts and county-level units, the radiation effects of municipal districts on nearby county-level units, and the segmentation effects of prefectural boundaries on the radiation effects of municipal districts.

To summarize, in this study, we hypothesize that the administrative hierarchy has tripe effects on built-up areas' development, including heterogeneity, radiation, and segmentation. Furthermore, we also argue that the triple effects should be investigated as a whole to fully understand the development mechanism of built-up areas, especially at the prefectural level and below, which are neglected by most previous studies.

4. Data and Study Area

Fujian province is situated on the southeast coast of China. It is adjacent to Zhejiang province in the northeast, bordering Jiangxi province in the northwest, and neighboring Guangdong province in the southwest. As the connection channel of the two largest and most important urban agglomerations in China (i.e., the Yangtze River Delta and the Pearl River Delta), Fujian province is a vital part of China's coastal economic belt and plays a prominent role in the national economic development layout.

Fujian province has a long history of city building. For example, Fuzhou, the capital of Fujian Province, is a famous historical and cultural city. However, until the reform and opening up, the cities in Fujian Province were relatively small. Specifically, the built-up areas of Fujian province were only 259 km^2 in 1990 and dramatically increased to 1335 km^2 in 2020 [39], with an annual growth rate of 13.4%. In terms of the spatial distribution characteristics, the built-up areas present evident heterogeneity. First, the built-up areas are mainly concentrated in two central cities, Fuzhou and Xiamen, which are the provincial capital and economic center of Fujian province, respectively. For example, the two cities accounted for 52% of Fujian province in 2015 regarding the built-up areas in municipal districts [39]. Second, the built-up areas in the west are much lower than that in the east of Fujian province, where the economy is more prosperous. For example, in terms of the built-up areas in municipal districts in 2015, the mean built-up area of three prefectural cities in the west is 45.3 km^2, while that of six prefectural cities in the east is 162.8 km^2 [39]. The significant uneven distribution indicates that administrative hierarchy and economic development profoundly affect the built-up areas.

The territory of Fujian province mainly consists of mountains and hills, accounting for more than 80% of the total area. Thus, the scarcity of available land resources has gradually limited urban expansion. Governing built-up areas' development to align economic demands with limited land resources is a challenging task for the local government. Consequently, holistically and comprehensively understanding the development mechanism of built-up areas to support sustainable land use in Fujian province is urgently needed.

In terms of administrative hierarchy, Fujian province has jurisdiction over nine prefecture-level cities. The administrative territory of prefecture-level cities is divided into two categories: municipal districts and county-level units. The municipal districts are under the direct control of prefectural governments, and county-level units include counties and county-level cities. By the end of 2015, Fujian province had a total of 44 counties and 13 county-level cities. Most of the prefectural cities have at least five county-level units, but Putian only has one county. In addition, since Tong'an county was upgraded to a municipal district in 1997, Xiamen has no county-level units. It should be pointed out that Yongding county and Jianyang city were upgraded to municipal districts in 2014 and 2015, respectively. Considering this happened at the end of the study period (i.e., 2005–2015), these two units are regarded as county-level units in this study. Finally, as Jinmen county only consists of some small islands and no evident urban built-up areas can be found there, it was removed from the study area (Figure 2).

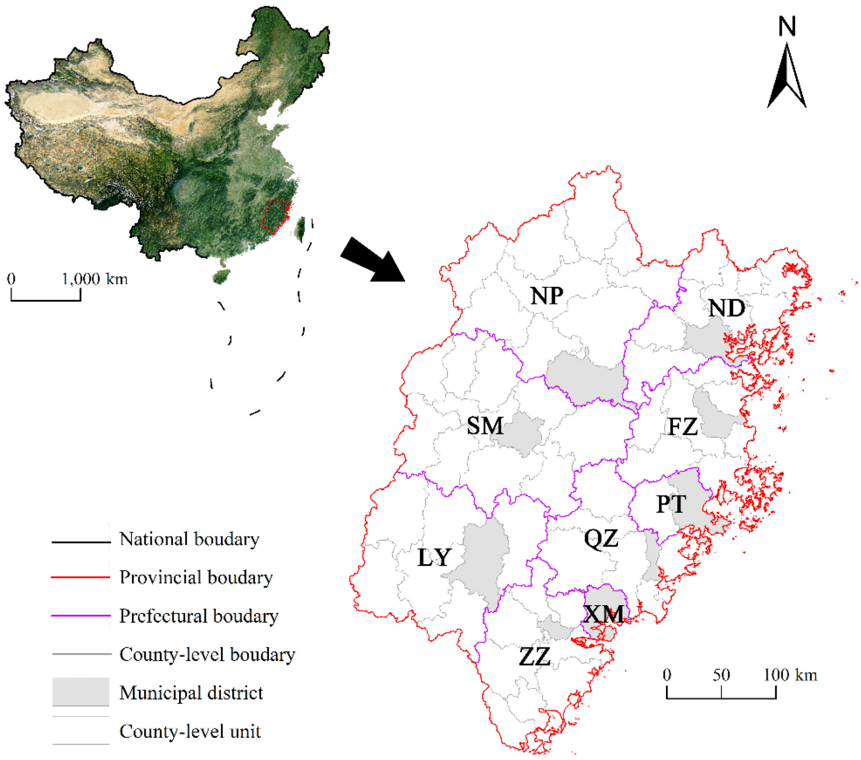


Figure 2. Study area. Note: Fujian province has nine prefectural cities, including Nanping (NP), Ningde (ND), Sanming (SM), Fuzhou (FZ), Putian (PT), Longyan (LY), Xiamen (XM), and Zhangzhou (ZZ).

Data used include the land use dataset with a resolution of 30 m, obtained from the Data Center of Resources and Environmental Sciences, the Chinese Academy of Sciences (http://www.resdc.cn/, accessed on 14 December 2018). This dataset is considered one of the most accurate Chinese land use datasets (e.g., the accuracy of urban land is higher than 93%) and is widely used in the empirical research of urban land in China [40]. From this dataset, we extracted the urban built-up areas of Fujian province in 2005 and 2015. The statistical data for regression analysis (e.g., population and GDP) were collected from the Fujian Statistical Yearbook (2006 and 2016).

5. Method

5.1. Descriptive Statistics

Several descriptive statistics (i.e., minimum, median, mean, and maximum) were applied to reveal the triple spatial effects of the administrative hierarchy on built-up areas, including heterogeneity, radiation, and segmentation effects. First, the magnitudes of built-up areas of municipal districts and county-level units were compared. If the former was higher than the latter, this revealed the heterogeneity characteristics of the built-up areas, and the built-up areas coincided with the administrative hierarchy. Second, 58 county-level units of Fujian province were divided into two groups. The first group was the neighbors of municipal districts, while the second group was not. If the former was higher than the latter, this indicated the radiation effects of municipal districts on nearby county-level units. Third, 58 county-level units of Fujian province were further divided into three groups. The first group was the neighbors of municipal districts, and these county-level units and their adjacent municipal districts were in the same prefectural city. The second group was also the neighbors of municipal districts, but these county-level units and their adjacent municipal districts were in different prefectural cities. The third group was the county-level units not adjacent to municipal districts. If the built-up areas in the second group were smaller than the first group, or even comparable to the third group, this indicated that the radiation effects of municipal districts were restricted by prefectural boundaries, representing the spatial segmentation effect of administrative hierarchy.

5.2. Spatial Econometric Model

Some scholars have posited that built-up areas are driven by urbanization, marketization, industrialization, and transport network [8–11]. Considering the evident impacts of the administrative hierarchy on built-up areas, two approaches were proposed to add the administrative hierarchy into the regression model to adapt to the unique institutional background of China.

In the first approach, Wei et al. examined the heterogeneity characteristics of urban land development mechanisms using the spatial regime model:

$$\begin{bmatrix} y_1 \\ y_2 \end{bmatrix} = \begin{bmatrix} X_1 & 0 \\ 0 & X_2 \end{bmatrix} \begin{bmatrix} \beta_1 \\ \beta_2 \end{bmatrix} + \begin{bmatrix} \varepsilon_1 \\ \varepsilon_2 \end{bmatrix} \quad (1)$$

where the subscripts 1 and 2 indicate different regimes (i.e., different administrative levels); y_1 and y_2 are vectors of observations on the dependent variable (urban land) for spatial regimes 1 and 2, respectively; X_1 and X_2 are matrices of observations on the explanatory variables; β_1 and β_2 are vectors of the regression coefficients in each regime; and ε_1 and ε_2 are vectors of error terms.

The spatial regime regression can produce two sets of comparable coefficients dedicated to each administrative level, revealing the different mechanisms of urban land expansion across cities at different administrative levels.

In the second approach, some scholars have investigated the spatial spillover and segmentation effects of the administrative hierarchy on urban land development by embedding the administrative status into the spatial weight matrix of the spatial econometric model [16,34,41].

To integrate the triple effects of the administrative hierarchy into one regression model, we combined the two approaches by employing the spatial econometric model with regimes. The spatial econometric model has two forms: the spatial lag model and the spatial error model.

In terms of the spatial lag model, spatial regime regression is extended with a spatially lagged dependent variable:

$$\begin{bmatrix} y_1 \\ y_2 \end{bmatrix} = \rho W \begin{bmatrix} y_1 \\ y_2 \end{bmatrix} + \begin{bmatrix} X_1 & 0 \\ 0 & X_2 \end{bmatrix} \begin{bmatrix} \beta_1 \\ \beta_2 \end{bmatrix} + \begin{bmatrix} \varepsilon_1 \\ \varepsilon_2 \end{bmatrix} \quad (2)$$

the spatially lagged dependent variable is constructed with the spatial weight matrix W and spatial autoregressive coefficient ρ. The independent variables in each regime (i.e., y_1 and y_2) are the built-up areas extracted from the land use map. Other parameters in Equation (2) are the same as in Equation (1).

In terms of the spatial error model, spatial regime regression (Equation (1)) is extended with a spatial autoregressive process in the error terms:

$$\begin{bmatrix} \varepsilon_1 \\ \varepsilon_2 \end{bmatrix} = \lambda W \begin{bmatrix} \varepsilon_1 \\ \varepsilon_2 \end{bmatrix} + \begin{bmatrix} u_1 \\ u_2 \end{bmatrix} \quad (3)$$

where W is the spatial weight matrix, λ is the spatial autoregressive parameter, u_1 and u_2 are the idiosyncratic error vectors belonging to each regime, and ε_1 and ε_2 are the same as Equation (1).

Using the spatial econometric model with regimes, spatial heterogeneity and spillover effects can be dealt with simultaneously. Specifically, regression coefficients specific to municipal districts and county-level units can be derived from the model, representing the heterogeneity effects of the administrative hierarchy. Moreover, the impact of the administrative hierarchy on the spillover effects between administrative units (including radiation and segmentation effects) can also be examined by embedding the administrative structure into a spatial weight matrix, which is explained in Section 5.3. The regression analysis of this study uses the python software package spreg(1.2.4), the spatial econometrics module of PySAL library [42].

Moreover, several statistics were employed for regression diagnosis: (1) The Lagrange multiplier test statistics were applied as the detector for spatial dependence and the criterion to use either the spatial lag model or spatial error model. In this study, the Lagrange multiplier tests suggested that the hypothesis of no spatial spillover effects should be rejected and the spatial lag model should be adopted rather than the spatial error model. (2) Two versions (i.e., global and individual) of Chow tests were employed to see whether there was a significant difference between the coefficients across different levels of the administrative hierarchy. (3) The Anselin–Kelejian test was used to assess whether the residuals of the spatial econometric model with regimes exhibited a spatial pattern.

5.3. Spatial Weight Matrix Construction

As mentioned in Section 5.2, the spatial econometric model with regimes can be applied to explore the heterogeneity characteristics of built-up development mechanisms between municipal and county-level units. The model can further reveal the impacts of administrative hierarchy on the spillover effects of built-up areas (including radiation and segmentation effects) by embedding the administrative structure into a spatial weight matrix.

Initially, the built-up areas in one administrative unit are assumed to be affected by the adjacent units, and this effect has a close connection with the administrative status. Then, based on the spatial adjacent relations across the administrative hierarchy, 3 scenarios were devised, and these spatial adjacent relations were embedded into the spatial weight matrices in spatial econometric models. Finally, the results of the spatial econometric models were used to verify this spatial effect of the administrative hierarchy on built-up areas.

As shown in the schematic diagram of administrative hierarchy (Figure 3), the administrative territory of prefecture-level cities consists of municipal districts and county-level units, and there are three types of spatial adjacent relations between municipal districts and county-level units. Adjacent type I is two county-level units that are adjacent to each other (e.g., C and D). Adjacent type II is a county-level unit adjacent to a municipal district, and they are located in the same prefectural city (e.g., C and B), indicating the interaction between different administrative levels. Adjacent type III is also a county-level unit adjacent to a municipal district, but they are located in different prefectural cities (e.g., A and B), implying the composition effect of the interaction between different administrative levels and the potential segmentation caused by prefectural boundaries.

As shown in Equation (4), these spatial adjacent types are embedded into the spatial weight matrices through parameters α and β: (1) The spatial weight is 0, if the administrative units i and j are not adjacent. (2) The spatial weight is 1, if the adjacent relationship of i and j is type I. (3) The spatial weight is 1 + α, if the adjacent relationship of i and j is type II, where α is the indicator reflecting the radiation effect of a higher administrative level. (4) The spatial weight is 1 + $\alpha \times \beta$, if the adjacent relationship of i and j is type III, where β is the indicator representing the segmentation effect of the prefectural boundary.

$$Wij = \begin{cases} 0 & i\ and\ j\ are\ not\ adjacent \\ 1 & adjacent\ type\ \mathrm{I} \\ 1+\alpha & adjacent\ type\mathrm{II} \\ 1+\alpha\times\beta & adjacent\ type\mathrm{III} \end{cases} \tag{4}$$

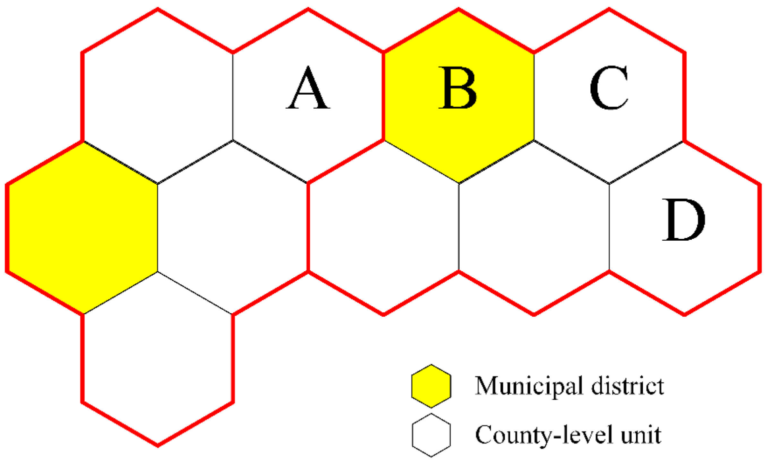


Figure 3. The schematic diagram of administrative hierarchy.

As a simplified example, the spatial weight matrix of A, B, C, and D can be expressed as:

$$W_{ABCD} = \begin{array}{c} \\ A \\ B \\ C \\ D \end{array} \begin{array}{c} \begin{array}{cccc} A & B & C & D \end{array} \\ \begin{bmatrix} 0 & 1+\alpha\times\beta & 0 & 0 \\ 1+\alpha\times\beta & 0 & 1+\alpha & 0 \\ 0 & 1+\alpha & 0 & 1 \\ 0 & 0 & 1 & 0 \end{bmatrix} \end{array} \quad (5)$$

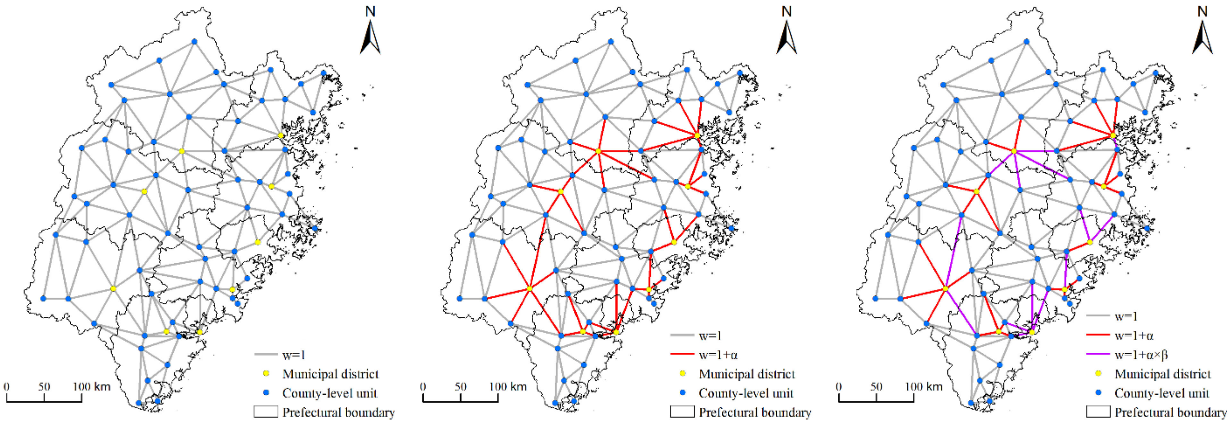
By controlling the values of α and β, three scenarios with different spatial weight matrices were constructed for further spatial econometric modeling (Figure 4). In scenario 1, both α and β were set to 0. This means that the spatial weight matrix is constructed with general queen contiguity regardless of administrative status/level. In scenario 2, α was set to be larger than 0, while β was set to 0, indicating that we only consider the radiation effect of municipal districts. In scenario 3, both α and β were set to be larger than 0, and β was further restricted to a value smaller than 1. Compared with scenario 2, scenario 3 further considered the reduction in the radiation effect, which was caused by the segmentation effect of the prefectural boundary. We evaluated multiple combinations of the candidate values of α and β, looking for regression models that best explain the dependent variable within the context of regression diagnosis criteria, such as the Anselin–Kelejian test and the spatial pseudo R-squared. In this study, α was assigned a value of 1.5 and 1 in 2005 and 2015, respectively; β was assigned a value of 0.1 and 0.8 in 2005 and 2015, respectively.

To summarize, under these scenarios, the radiation and segmentation effects of the administrative hierarchy are integrated into the spatial weight matrix by controlling parameters α and β. By analyzing the spatial econometric modeling under these scenarios, we can investigate the radiation effect of municipal districts and the segmentation effect of prefectural boundaries.

5.4. Control Variables of Regression

In Sections 5.2 and 5.3, the dependent variable (i.e., built-up areas) and how the administrative hierarchy is embedded in the regression model are described and explained. According to our analytical framework (Figure 1), the variables that represent urbanization, marketization, industrialization, and the transport network are also included in the regression as control variables:

Urbanization: as China has undergone urbanization, millions of rural migrants have flooded into cities, which is a prominent driving force of urban expansion [8]. We selected the urbanization rate, urban population, and rural population to represent the demographic urbanization process. In addition, the literature mentioned that, along with the rural population transitioning to urban citizens, the rise in their income and consumption was found to increase land used to meet the rising demand for housing, production, and leisure spaces [8,10]. Thus, wages and social consumption were incorporated to reflect the socioeconomic aspects of urbanization.



(**a**) (**b**) (**c**)

Figure 4. The maps of spatial weight matrices under different scenarios. (**a**) The map of spatial weight matrix under scenario 1. (**b**) The map of spatial weight matrix under scenario 2. (**c**) The map of spatial weight matrix under scenario 3.

Marketization: in the context of the marketization transition, labor and production factors have been allowed to flow freely and concentrate in cities, which has greatly promoted the urban economy. The expansion of the urban economy logically will have an impact on the growth of the urban areas [8]. We used the GDP of the secondary industry and the GDP of the tertiary industry to represent the development status of the urban economy.

Industrialization: industrialization is the main process used to boost the local economy. Local governments generally invest heavily in the industrial sector to raise GDP, leading to the expansion of industrial land. The literature contended that industrial enterprise development was closely connected with urban expansion [10]. We used the number of employees and enterprises' profits and taxes to measure the development of industrial enterprises.

Transport network: transportation land is inherently an important type of built-up land use, and transportation construction requires land. Thus, transportation development is a crucial factor in promoting urban expansion. On the other hand, the development of transport networks facilitates inter-city and intra-city interaction, which can further affect urban growth [11]. We used highway mileage to represent the development status of transport networks.

6. Result

6.1. Descriptive Statistics and Spatial Visualization Analysis

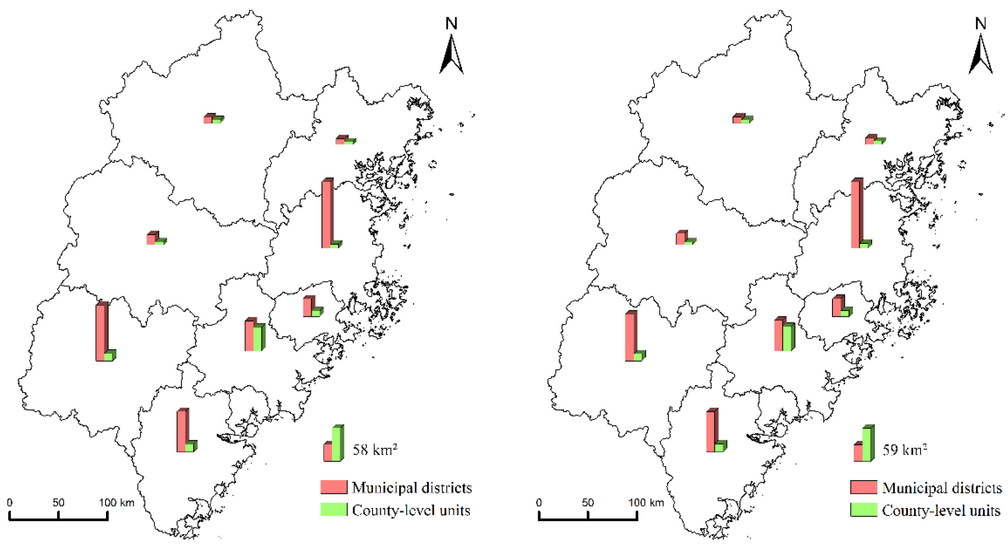
6.1.1. The Heterogeneity Characteristics of Built-Up Areas, Comparing Municipal Districts and County-Level Units

Table 1 represents the divergence of built-up areas in Fujian province by comparing municipal districts and county-level units. It shows that built-up areas of municipal districts were much larger than that of county-level units, reflected by the descriptive statistics. Specifically, the minimum built-up areas at the county level were less than 1 km^2 in 2005 and 2015, while the minimum values at the municipal district level were higher than 10 km^2 in both years. In terms of the mean of built-up areas, the values of municipal districts were nearly four times higher than that of counties in 2005 and 2015. Moreover, the medians of built-up areas at the municipal district level were 9.57 and 7.99 times as large as that at the county level in 2005 and 2015, respectively. It should be pointed out that the maximum values of the built-up areas of county-level units were slightly higher than those of municipal districts. In both 2005 and 2015, the administrative unit with the maximum built-up areas at the county level was Jinjiang. According to its government website, Jinjiang's county-level economy has been the strongest in Fujian province for 28 consecutive years, and its competitiveness of county-level economy ranks fourth in China. Urban land expansion in China is closely related to economic growth [15]. Jinjiang is the only county-level administrative unit with more built-up areas than all the municipal districts in Fujian. To summarize, although this is a unique exception, it is evident that municipal districts occupy more built-up areas than county-level units.

Table 1. The descriptive statistics of built-up areas in municipal districts and county-level units.

Year	Administrative Level	Min	Median	Mean	Max
2005	Municipal districts	10.26	52.64	59.17	125.24
	County-level units	0.15	5.50	11.92	128.06
2015	Municipal districts	11.04	54.68	59.19	129.68
	County-level units	0.06	6.84	12.67	132.02

Figure 5 shows the spatial distribution of the disparity of built-up areas between municipal districts and county-level units across the prefectural cities in Fujian province. In all the prefectural cities, built-up areas of municipal districts were larger than the mean built-up areas of county-level units. This further confirmed that municipal districts had more built-up areas than county-level units. Notably, the disparity of built-up areas was more conspicuous in Fuzhou, the capital city of Fujian province. The built-up areas of the Fuzhou municipal district were 16.3 and 13.8 times as large as the mean areas of its eight county-level units in 2005 and 2015, respectively. This can be attributed to the fact that the Fuzhou municipal district is the resident of the provincial government. Thus, in terms of administrative hierarchy, the gap between municipal district and county-level units in Fuzhou is greater than that in other prefectural cities [34], which leads to a more conspicuous disparity in built-up areas.



(**a**) (**b**)

Figure 5. The disparity of built-up areas when comparing municipal districts and county-level units across prefectural cities. (**a**) The disparity of built-up areas when comparing municipal districts and county-level units in 2005. (**b**) The disparity of built-up areas when comparing municipal districts and county-level units in 2015.

6.1.2. The Radiation Effects of Municipal Districts on Built-Up Areas

To explore the radiation effect of municipal districts, we divided 58 county-level units of Fujian province into two groups. The counties of group A are the neighbor of municipal districts; in contrast, the counties of group B are not adjacent to municipal districts. Table 2 demonstrates the disparity of built-up areas when comparing the counties of group A and group B. It can be found that the built-up areas of group A were larger than that of group B when using descriptive statistics. Specifically, the median value of built-up areas of group A was 5.56 km^2, which was 0.27 km^2 higher than that of group B in 2005. In 2015, the difference was further expanded to 1.53 km^2. Notably, in both years, the means and maximums of built-up areas of group A were more than twice and five times as large as those of group B, respectively. These results demonstrate that municipal districts have strong radiation effects and greatly promote the expansion of built-up areas of their adjacent county-level units.

Table 2. The descriptive statistics of built-up areas in groups A and B.

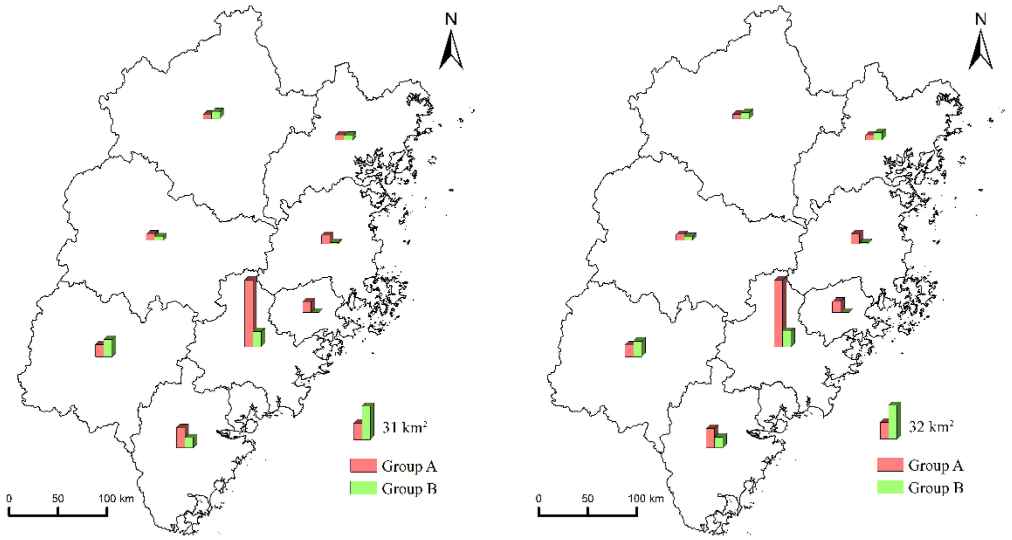
Year	Group	Min	Median	Mean	Max
2005	A	0.15	5.56	15.82	128.06
	B	1.02	5.29	7.45	24.68
2015	A	0.06	9.73	16.62	132.02
	B	1.36	6.34	8.12	22.76

Figure 6 shows the disparity in the means of built-up areas when comparing the two groups at the prefectural level. First, in most prefectural cities, the means of built-up areas of group A were higher than that of group B. For example, in Fuzhou, the means of built-up areas of group A were 6.6 and 7.1 times as large as those of group B in 2005 and 2015, respectively. This further confirms the radiation effects of municipal districts on their adjacent counties. Second, in a few prefectural cities, the means of built-up areas of group A were lower than those of group B, including Ningde in 2015, Nanping, and Longyan in 2005 and 2015. This can be attributed to the fact that some counties not adjacent to municipal districts (e.g., Fuding in Ningde, Shaowu in Nanping, and Changting in Longyan) have abnormally large built-up areas, making the means of group B larger than group A in corresponding prefectural cities. According to official statistics, these county-level units have a greater population than surrounding units [43], which is an important impetus for urban expansion [8]. This indicates that, besides administrative hierarchy, other factors can also affect the growth of built-up areas. To summarize, although there are other factors, the radiation effect of municipal districts has a significant impact on built-up areas' development.

6.1.3. The Segmentation Effects of Prefectural Boundaries on Built-Up Areas

To identify the spatial segmentation effect across the boundaries of prefectural cities, we divided 58 county-level units of Fujian province into three groups. Groups A and B include the counties that are adjacent to municipal districts. Counties in group A and their adjacent municipal districts belong to the same prefectural city; in contrast, counties in group B and their adjacent municipal districts locate in different prefectural cities. Finally, counties in group C are not adjacent to any municipal district.

Table 3 represents the differences in built-up areas among these three groups through several descriptive statistics. First, the built-up areas of group A were much higher than groups B and C in both 2005 and 2015. Strikingly, in both years, the maximum area of group A was five times higher than the maximum of groups B and C. This indicates that a municipal district can greatly promote the land expansion of its adjacent counties within the same prefectural city. Second, although the counties of group B are adjacent to municipal districts, the built-up areas of group B are smaller than group A and even smaller than group C (e.g., the median and maximum areas in 2005 and 2015). This shows that the municipal district does not promote the land expansion of its adjacent counties that are located in other prefectural cities. In other words, the radiation effect of municipal districts is restricted to within the prefectural city boundary, and there are evident spatial segmentation effects across the boundaries of prefectural cities.



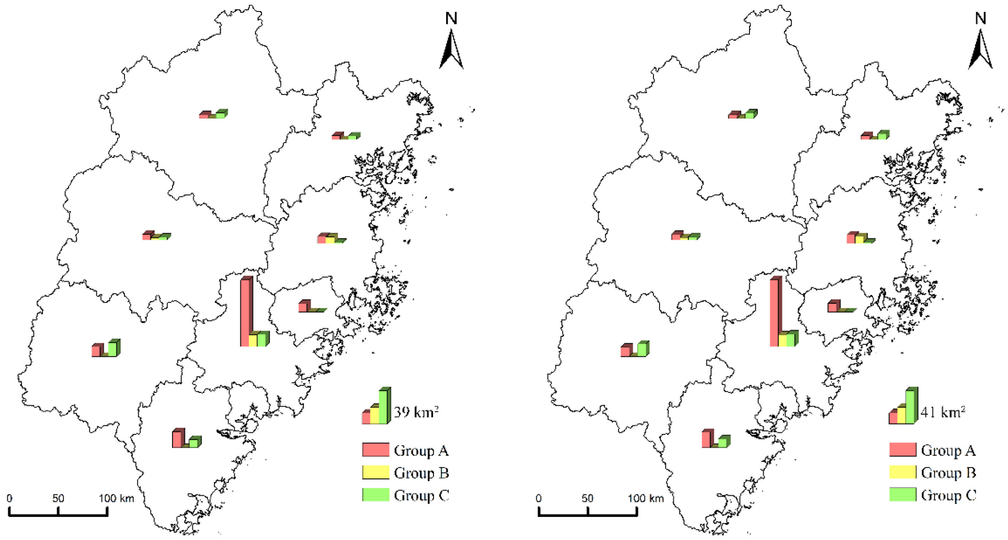
(**a**) (**b**)

Figure 6. The disparity of built-up areas when comparing group A and group B across prefectural cities. (**a**) The disparity of built-up areas when comparing group A and group B in 2005. (**b**) The disparity of built-up areas when comparing group A and group B in 2015.

Table 3. The descriptive statistics of built-up areas in groups A, B, and C.

Year	Group	Min	Median	Mean	Max
2005	A	0.15	6.60	17.35	128.06
	B	0.95	3.12	7.85	18.71
	C	1.02	5.29	7.45	24.68
2015	A	0.06	9.90	18.19	132.02
	B	0.95	4.48	8.45	19.97
	C	1.36	6.34	8.12	22.76

Figure 7 displays the means of built-up areas among the three groups across the prefectural cities in Fujian province. First, the means of built-up areas of group A were higher than those of group B in all three prefectural cities wherein the counties of group B are located. The means of built-up areas of group A were also higher than those of group C in most prefectural cities. As discussed in Section 6.1.2, due to other driving forces of built-up areas, the means of built-up areas of group A were lower than those of group C in a few prefectural cities (e.g., Naping and Longyan). Second, even though counties of group B are adjacent to municipal districts, the built-up areas of group B are smaller than group A and even smaller than group C in some prefectural cities (e.g., Quanzhou and Sanming in both 2005 and 2015). To summarize, these results indicate that the radiation effect of municipal districts only promotes the expansion of urban land of counties that are located within the same prefectural city, further confirming the spatial segmentation effects across the boundaries of prefectural cities.



(**a**) (**b**)

Figure 7. The disparity of built-up areas among groups A, B, and C across prefectural cities. (**a**) The disparity of built-up areas among groups A, B, and C in 2005. (**b**) The disparity of built-up areas among groups A, B, and C in 2015.

6.2. Spatial Econometric Modeling

The previous section analyzes the triple spatial effects of administrative hierarchy on urban built-up areas based on descriptive statistics and spatial visualization. To explore these effects in a more rigorous multi-variant environment, we employed the spatial lag model with regimes, a technique that explicitly recognizes the heterogeneity of driving mechanisms and spillover strength across the different statuses of the administrative hierarchy.

First, the spatial lag model with regimes can produce two sets of comparable coefficients that are dedicated to each level of administrative hierarchy, reflecting the differences in driving mechanisms between municipal districts and county-level units. The result (Table 4) shows that rural population, GDP of tertiary industry, enterprises' taxes, and highway mileage were significant determinants of built-up areas in 2005 and 2015, echoing the previous findings that urbanization, marketization, industrialization, and transport networks are the key driving forces of built-up areas [8–11]. It is important to note that the coefficients of these driving forces varied across different administrative levels, and the global Chow tests provided strong evidence of the overall significant differences between coefficients in municipal districts and those in county-level units in both 2005 and 2015.

Moreover, individual Chow tests show that several individual coefficients differed significantly between the two administrative levels in 2005 and 2015, such as highway mileage, the GDP of tertiary industry, and the rural population. Specifically, in 2005, the coefficients of highway mileage were statistically significant at both administrative levels, but the coefficient in municipal districts was significantly higher than in county-level units. In contrast, in 2015, the coefficients of tertiary industry GDP were statistically significant at both administrative levels, but the coefficient in municipal districts was significantly lower than in county-level units. Interestingly, the coefficients of the rural population were statistically significant only in municipal districts and exhibited significant differences between municipal districts and county-level units in 2005; however, the coefficients of the rural population were statistically significant in both administrative levels and showed no significant difference. This is consistent with Chinese urbanization; the floating population is first concentrated in higher-level cities and spreads to lower-level cities in later years [29].

Table 4. The regression result of the spatial lag model with regimes under scenario 3.

Variables	2005			2015		
	Municipal Districts	**County-Level Units**	**Chow Test**	**Municipal Districts**	**County-Level Units**	**Chow Test**
Intercept	−331.51	2.58	0.3	421.7 **	40.87 **	8.62 **
Rural population	−60.63 *	−3.07	3.86 *	−21.64 *	−3.75 *	2.6
Wages	−36.36	−2.91 **	1.86	−5.41 **	−0.67 *	5.23 *
Social consumption	0.34 **	0.25	0.18			
GDP of tertiary industry				1.01 **	2.07 **	6.14 *
Number of employees				−0.77 **	0.04	20.14 **
Enterprises' taxes	1.12	1.35 **	0.03			
Highway mileage	122.15 *	4.87 **	5.53 *	0.24	0.03	0.02
Spatial lag (ρ)	0.04 *			0.03 *		
Global Chow test	69.34 **			86.70 **		
Anselin-Kelejian Test	0.19			0.24		
Spatial pseudo R-squared	0.59			0.86		

Note: ** p value < 0.01; * p value < 0.05.

Second, the spatial autoregressive coefficients of the spatial lag model with regimes were highly significant, and the Anselin–Kelejian test was not significant in both 2005 and 2015 (Table 4). This suggests that there is little evidence of any remaining spatial error autocorrelation, and the specification of the spatial weight matrix is sufficient to address the spatial dependence in the regression model. In other words, the results further confirm that: (1) the spatial interactions between municipal districts and their adjacent county-level units are stronger than those between two county-level units, indicating the radiation effect of municipal districts; (2) the radiation effect of municipal districts are restricted to within the boundaries of prefectural cities, reflecting the segmentation effects of the administrative hierarchy.

Third, the spatial weight matrixes under scenarios 1 and 2 (Tables 5 and 6) were employed in spatial lag models with regimes to further explore the institutional influence on built-up areas. In these models, the coefficient of determination (i.e., spatial pseudo R-squared) and spatial lag coefficient (ρ) varied significantly under different scenarios, reflecting the radiation and segmentation effects of the administrative hierarchy. As specified in Section 5.3, scenario 1 embraces the spatial weight matrix with general queen contiguity regardless of the administrative status/level, and scenario 2 enhances the spillover strengths between the municipal district and county-level units. Compared with scenario 2, scenario 3 further restricts the enhancement of spillover strengths within the boundaries of prefecture cities. In Tables 4–6, it can be found that, except for the only exception (scenario 2 in 2005), the spatial pseudo R-squared of scenario 3 (Table 4) was much higher than other scenarios in both 2005 and 2015. In addition, except for scenario 3, all of the spatial lag coefficients were not significant, indicating that scenarios 1 and 2 cannot catch the spatial interaction among the administrative units. These results indicate that the spatial weight matrixes of scenario 3 are better than others to fit and capture the spatial structure of built-up areas, further confirming the radiation effect of municipal districts on nearby county-level units and that the radiation effect is restricted to within the boundaries of prefecture cities since the spatial segmentation effect among prefecture cities.

Table 5. The regression result of the spatial lag model with regimes under scenario 1.

Variables	2005			2015		
	Municipal Districts	**County-Level Units**	**Chow Test**	**Municipal Districts**	**County-Level Units**	**Chow Test**
Intercept	−612.05	−10.04	0.09	−3068.57	34.75 *	0.22
Rural population	52.33	−1.06	0.08	120.96	−3.46	0.27
Wages	69.05	−2.43 **	0.1	45.01	−0.57 *	0.23
Social consumption	−0.15	0.2	0.12			
GDP of tertiary industry				−2.55	2.14 **	0.53
Number of employees				4.09	0.04	0.22
Enterprises' taxes	−1.55	1.49 **	0.22			
Highway mileage	−70.86	5.14 *	0.09	−1.53	0.14	0.05
Spatial lag (ρ)	−0.01			0.02		
Global Chow test	37.20 **			13.95 *		
Anselin-Kelejian Test	0.05			0.03		
Spatial pseudo R-squared	0.44			0.31		

Note: ** p value < 0.01; * p value < 0.05.

Table 6. The regression result of the spatial lag model with regimes under scenario 2.

Variables	2005			2015		
	Municipal Districts	**County-Level Units**	**Chow Test**	**Municipal Districts**	**County-Level Units**	**Chow Test**
Intercept	6.93	−5.33	0	−3064.03	35.38 *	0.22
Rural population	−72	−1.69	1.62	120.67	−3.49 *	0.27
Wages	−45	−2.55 **	1.18	44.95	−0.58 *	0.23
Social consumption	0.29	0.21	0.09			
GDP of tertiary industry				−2.55	2.16 **	0.53
Number of employees				4.08	0.04	0.22
Enterprises' taxes	1.69	1.46 **	0.03			
Highway mileage	107	4.94 **	1.41	−1.52	0.16	0.05
Spatial lag (ρ)	0.01			0.01		
Global Chow test	271.12 **			15.27 *		
Anselin-Kelejian Test	0.81			0.04		
Spatial pseudo R-squared	0.66			0.31		

Note: ** p value < 0.01; * p value < 0.05.

7. Discussion

The administrative hierarchy is one of the most salient influencing factors of urbanization; its triple spatial effects (heterogeneity, radiation, and segmentation) have been broadly used to explain the spatial pattern and expansion mechanism of urban built-up areas [9,16,34]. Using descriptive statistics, spatial visualization, and spatial econometric model, we comprehensively explored and quantified the triple spatial effects of administrative hierarchy on built-up areas in Fujian province, China. In terms of theory, this study advances the understanding of the triple spatial effects of the administrative hierarchy on built-up areas at the prefectural level and below. In terms of methodology, this study provides a comprehensive modeling framework to integrate the triple spatial effects into a single spatial econometric model.

7.1. The Further Understanding of the Triple Spatial Effects of the Administrative Hierarchy on Built-Up Areas at the Prefectural Level and below

First, in terms of the heterogeneity effect, we found that built-up areas of municipal districts were much larger than those of county-level units, and the driving forces of built-up areas were also sensitive to the two different levels of the administrative hierarchy. Previous studies found that, with a higher administrative level, municipalities directly under the

Central Government and provincial capitals had a higher speed of urban expansion than prefectural cities [3]. Li et al. further presented that the driving forces of built-up areas have different influences on cities at the prefectural level and above [9]. In short, previous studies have focused on the divergences between prefectural cities and cities above prefectural level. However, few studies have paid attention to the divergence of built-up areas between municipal districts and county-level units, even though many studies have conducted in-depth historical and institutional analyses of the tense relations and obvious differences between the two levels of the administrative hierarchy [13,21,31]. This study fills this gap and points out that, not only in terms of the spatial areas but also in terms of the driving mechanisms of built-up areas, the heterogeneity of built-up areas is evident across the municipal districts and county-level units in Fujian province.

Second, in terms of the radiation effect, we found that the built-up areas of county-level units were larger if these units were adjacent to municipal districts, reflecting the radiation effect of municipal districts, which is the administrative center of prefectural cities. Previous studies have shown that administrative centers play a vitally important role in urban land expansion and have qualitatively depicted the downward trend of built-up areas intensity from provincial administrative centers to peripheral areas through spatial visualization [17], indicating the radiation effect of provincial administrative centers on nearby administrative units. In recent years, Zeng et al. argued that the adjacency status of administrative units (e.g., whether or not the two adjacent units are at the same level of administrative hierarchy) has an evident spatial effect on urban land development and proposed a quantitative framework to verify that a provincial center has a significant radiation effect on nearby administrative units [34]. To summarize, using qualitative and quantitative methods, previous studies have shown the radiation effects of administrative centers at the provincial level. However, the radiation effect of administrative centers below the provincial level has not received enough attention. We filled this research gap and further revealed that municipal districts also have radiation effects on nearby county-level units, showing the radiation effects of administrative centers on built-up areas below the provincial level.

Third, besides the radiation effect of municipal districts on county-level units, we further found that the radiation effect was restricted to within the boundary of prefectural cities, reflecting the spatial segmentation effect at the prefectural level. Although a rich body of literature has discussed the spatial segmentation between administrative units in China [35,36], very few studies have investigated the spatial segmentation effects of administrative boundaries on the spillover effects of urban land. Until recently, Wang et al. employed spatial econometric modeling and found that the strengths of the spillover effect were reduced by 50% when two adjacent administrative units belonged to different provinces, indicating the spatial segmentation effect caused by mutual competition between provinces [16]. Surprisingly, although many studies have discussed the severe competition between prefecture cities and pointed out that this competition has a salient impact on urban land development [35,36], studies investigating the spatial segmentation effects between prefecture cities have been rare. This study fills this gap and demonstrates that the radiation effect of municipal districts on nearby county-level units will be reduced if they do not belong to the same prefectural city, reflecting the spatial segmentation effects of the prefectural boundary.

To summarize, this study furthers the understanding of the triple spatial effects of the administrative hierarchy on built-up areas (i.e., heterogeneity, radiation, and segmentation) at the prefectural level and below, which are relatively low administrative levels that have not received enough attention in previous research. Specifically, we revealed the heterogeneity characteristics of municipal districts and county-level units. In addition, we demonstrated the radiation effect of municipal districts on nearby county-level units, and the radiation effect is restricted to within the administrative boundary of prefectural cities, reflecting the segmentation effects of the administrative hierarchy.

7.2. The Comprehensive Approach to Integrating the Triple Spatial Effects into a Single Regression Model

We proposed a comprehensive modeling approach to integrate the triple spatial effects into a single spatial econometric model.

On the one hand, we integrated the heterogeneity and spillover effects of administrative hierarchy on built-up areas into the regression model. The regression results show both evident heterogeneity characteristics between municipal districts and county-level units and significant spillover effects between administrative units. In previous studies, the heterogeneity and spillover effects of administrative hierarchy on built-up areas have been widely discussed [3,14,17,33], but heterogeneity and spillover effects are handled separately. More specifically, Li et al. investigated the divergence between cities at prefectural level and above but did not consider the spillover effect [9]. Li and Xiong identified strong spillover effects in urban land expansion but neglected the heterogeneity characteristics of different administrative levels [12]. This study points out a new subject for further studies on urban land in China: heterogeneity and spillover effects of administrative hierarchy should be integrated. If one of the two is missing, the study may lead to biased results.

On the other hand, we integrated the radiation and segmentation effects of the administrative hierarchy on built-up areas into the spatial weight matrix of spatial econometric regression. The results showed that municipal districts had evident radiation effects on nearby county-level units, but the radiation effects were reduced by the boundary of prefectural cities, indicating the spatial segmentation effects between prefectural cities. In previous studies, the radiation effects of the higher-level administrative units and the spatial segmentation effects of administrative boundaries have been discussed [16,17,34], but spillover and segmentation effects have always been investigated separately. More specifically, Zeng et al. demonstrated the radiation effect of the provincial administrative center but did not consider the segmentation effect [34]. Wang et al. examined the segmentation effect of provincial boundaries on urban land development but neglected the radiation effect [16]. This study proposes a new approach to consider the radiation and segmentation effects simultaneously, which can support the better fitting of the regression model and better handling of the spatial autocorrelation problem.

To summarize, the triple impacts of the administrative hierarchy have effects on built-up areas simultaneously and should be integrated into a comprehensive modeling approach. Otherwise, biased conclusions may be drawn. The modeling approach we proposed integrates the triple effects into a single spatial lag model with regimes, which can delineate the heterogeneity effect by spatial regimes and embed the radiation and segmentation effects into the spatial weight matrix. This new modeling approach is transferable to other regions to shed further light on urban land expansion in China.

8. Conclusions

Due to rapid urbanization in the last four decades, Chinese cities have experienced dramatic land expansion. Under the land use system in China, local governments are the sole legitimate providers of newly increased urban land [12]. More importantly, in the process of tax-sharing reform and marketization transition, urban land has been regarded as a unique and very significant resource for local revenue, and it has become the most important instrument of local government to promote economic growth and urban construction [9]. Thus, urban land development has not been purely driven by market forces, and local governments have been playing a proactive role in this process. Since the organization of local governments is characterized by tiered political and economic power structures in a national hierarchy system, many studies have investigated the effects of administrative hierarchy on urban land expansion, such as heterogeneity, radiation, and segmentation. However, these studies mainly have focused on only one of these effects. As a result, these parallel and distinct studies have created a limited understanding that can result in partial and potentially misleading conclusions about urban land expansion in China. Contrary to previous literature, this study proposes a comprehensive theoretic and modeling framework to investigate the triple spatial effects of the administrative hierarchy as a whole. Furthermore, we focus on the relatively low levels of the administrative hierarchy (i.e., the prefectural level and below). These are the levels that have experienced much more intense land development [37,38] but have not received enough attention from previous studies.

This study advances the understanding of the triple spatial effects of administrative hierarchy (i.e., heterogeneity, radiation, and segmentation) on built-up areas by using a new comprehensive modeling approach to integrate the triple spatial effects as a whole.

From a theoretical perspective, we advance the understanding of the tripe effects of administrative hierarchy at the prefectural level and below. First, we revealed the heterogeneity characteristics of built-up areas by comparing municipal districts and county-level units, not only in terms of the magnitude but also in terms of the strengths of the driving forces. Moreover, we also discerned the radiation effect of municipal districts: a county-level unit would have more built-up areas if it is adjacent to a municipal district. Therefore, we further the understanding of the heterogeneity and radiation effect of the administrative hierarchy at the levels below prefectural cities, while previous studies have only focused on the prefectural level and above. Finally, we identified the segmentation effect of the prefectural boundary: the radiation effects of municipal districts on nearby county-level units are reduced if the county-level units are located in another prefectural city. Thus, we advance the understanding of the segmentation of administrative hierarchy at the prefectural level, while previous studies have only shown the administrative barriers to the spatial spillover of built-up areas at the provincial level. To summarize, compared with previous studies, we further verify that the triple effects of the administrative hierarchy are evident at the prefectural level and below, which have experienced more intensive land urbanization [37,38] but have not received enough attention from previous researchers.

From a modeling perspective, we propose a new approach to integrating the triple effects of administrative hierarchy on built-up areas into a single spatial lag model with regimes. Specifically, we handle the heterogeneity effect using spatial regimes and embed the radiation and segmentation effects into the spatial weight matrix through two parameters, α and β. Therefore, we improve the modeling method and can investigate the triple effects of administrative hierarchy simultaneously, while previous studies have merely focused on a single effect. As shown in Section 6.2, if one or more effects are neglected, biased or even misleading regression results would be obtained. Thus, leveraging the new transferable modeling approach proposed in this study, the multiple facets of the administrative hierarchy effects can be handled as a whole and deserve more attention from those who care about the urbanization process in China. Such attention will lead to a thorough understanding of the mechanism of urban land expansion and enlighten the policy debates on better land use under China's unique institutional environment.

From the perspective of international comparison regarding the connection between administrative hierarchy and urban development, Chinese and foreign scholars focused on different urban elements. Chinese scholars were mainly concerned with the built-up areas, while foreign scholars paid more attention to the population. For example, Heider et al. stated that administrative status significantly impacts urban growth [23]. Unlike many Chinese case studies, they chose population as the indicator of urban growth. Furthermore, some scholars from the USA and the Netherlands investigated the differences in the migration patterns of different ages across different levels of administrative hierarchy [24,25]. In the case study of the Netherlands, de Jong et al. found that the "75 and older" age cohort is oriented towards smaller towns and rural areas, while the "65–74" age cohort is increasingly oriented toward urban areas [25]. Considering the potential heterogeneity characteristics of built-up areas across the different levels of urban hierarchy, we argue that the effects of administrative hierarchy on urban land can be a new subject for foreign scholars.

The results of this study indicate that the effects of the administrative hierarchy result in divergence between different administrative levels and segregation across administrative boundaries. From the policy point of view, we argue for a reform and better design of the administrative arrangement to achieve balanced and integrated urban land development. Vertically speaking, the magnitudes and strengths of driving forces of built-up areas coincide with the administrative levels. The heterogeneity effect tends to reinforce the imbalances in land development and cause greater tensions between different levels of cities. We suggest reforming local land administrative rights and changing the constraint structures of local governments in the hierarchical system. Horizontally speaking, the radiation effect of municipal districts can promote the urban land expansion of nearby county-level units and helps alleviate the divergence of built-up areas between them. However, the segmentation effect of prefectural boundaries restricts the radiation effect and is a barrier to integrated urban land development. Therefore, breaking through the administrative barriers should be the next focus to optimize the structure of land use and improve the synergy of land development.

Foreign scholars also reported similar problems that stemmed from the inappropriate power arrangement of administrative hierarchy. For example, in a case study of Uyo (a midsized city in Nigeria), Etido found a lack of continuity in commitment to urban infrastructural development projects, which will hamper sustainable urbanization [44]. He attributed the problem to fiscal management across the administrative hierarchy. Specifically, Uyo follows a system of disbursing funds from the state to the local governments, which limits local governments' financial independence. Thus, regardless of Chinese and foreign countries, better design of the administrative arrangement is crucially important to achieve balanced and sustainable urban development.

China can learn from Germany and Japan, where a multi-tier government system has been widely used. In these countries, broader functions such as environmental protection and education can be managed by a higher level government, while decisions for the economy and people's livelihood can be made by local governments. As Gu et al. stated, this design can enhance the cooperation between governmental power and city management [45].

Finally, this study can be improved by considering more inter-city relationships that can affect urban land development. For instance, Zeng et al. argued that, besides the administrative hierarchy, spatial accessibility and social network should be integrated to provide a reference for urban policymakers [41]. Integrating more inter-city relationships into our proposed approach may have the potential to further improve our understanding. Furthermore, we have only focused on the prefecture and county levels because our study area is only one province. Considering the province is another primary administrative level in China, we will explore the differences and interactions between these levels and the provincial level in our future research.

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