

Article

Spatial Effects and Impact Mechanisms of New-Type Urbanization on Land Use Efficiency at the County Level in Zhejiang Province, China

Peng Zheng *, Yijing Weng, Luxuan Wu and Wenke Zhang

School of Economics, Zhejiang University of Science and Technology, Hangzhou 310023, China

* Correspondence: zhengpeng@zust.edu.cn

Abstract

The purpose of this study is to investigate the impact of new-type urbanization on land use efficiency and its spatial spillover effects, aiming to provide theoretical support and practical references for improving land resource allocation and optimizing regional development strategies. Using panel data from 61 counties in Zhejiang Province between 2010 and 2022, this research applies a two-way fixed effects model, supplemented by mediation effect analysis and spatial econometric models, to empirically examine these relationships. The results indicate that: (1) both the level of new-type urbanization and land use efficiency show an overall upward trend, exhibiting a spatial pattern characterized by “coastal regions outperforming inland areas, and northern Zhejiang surpassing the south”; (2) new-type urbanization exerts a significantly positive impact on land use efficiency, with industrial structure upgrading serving as a partial mediator in this relationship; (3) significant spatial spillover effects are observed—new-type urbanization not only enhances local land use efficiency but also generates positive spillovers to neighboring regions through spatial diffusion mechanisms; (4) the influence of new-type urbanization on land use efficiency displays regional heterogeneity, with stronger promoting effects observed in coastal and low-efficiency areas, whereas marginal effects diminish in non-coastal and high-efficiency regions. In conclusion, strategic priorities should be established to enhance the quality of new-type urbanization, foster green and intensive development, optimize the industrial structure, and strengthen land conservation practices. Furthermore, region-specific policies are essential to improve land use efficiency across diverse areas, which will ultimately contribute to coordinated regional development.

Keywords: new-type urbanization; land use efficiency; industrial structure upgrading; spatial spillover effect; county level



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1. Introduction

New-type urbanization serves as a core driving force for population agglomeration, economic growth, and social transformation, profoundly reshaping the utilization patterns and efficiency of land resources [1–3]. Against the strategic backdrop of China’s establishment of a “dual-circulation” development framework, new-type urbanization has been positioned as a key pivot for stimulating domestic demand potential and optimizing resource allocation [4,5]. Top-level policy documents such as the “14th Five-Year Plan for New-type Urbanization Implementation” and the “National New-type Urbanization Plan

(2021–2035)” explicitly prioritize enhancing urban carrying capacity and promoting intensive and economical land use, underscoring the central importance of land use efficiency in high-quality urbanization.

However, the current urbanization process still faces prominent challenges. There is a lack of coordination between land urbanization on the one hand and industrial and population urbanization on the other [6]. Meanwhile, urban expansion in some cities has been accompanied by urban shrinkage and ecosystem degradation, exacerbating land resource waste [7,8]. The traditional development model, reliant on “land finance” while driving economic growth, has simultaneously intensified the contradictions of urban-rural spatial imbalance and inefficient land use [9]. In response, the Opinions on Promoting Urbanization with Counties as Important Carriers issued by the General Office of the Central Committee of the Communist Party of China and the General Office of the State Council explicitly proposes advancing urban-rural integrated development with counties as the basic units and enhancing the efficiency of land resource utilization. Land use efficiency refers to the relative ratio of input to output per unit area of land, and improving land use efficiency essentially means achieving the greatest socioeconomic benefits with minimal resource input [7]. Academia has conducted extensive research on the driving factors of land use efficiency. Studies indicate that economic development level, industrial structure, and regional integration promote urban land use efficiency, while fiscal pressure and real estate investment have significant inhibitory effects [10,11]. Regarding regional disparities in land use efficiency, scholars have not yet reached a consistent conclusion [12]. Although a substantial body of literature has examined the influencing factors of land use efficiency, most studies have been conducted from a macro perspective, with relatively insufficient research exploring the underlying mechanisms from a micro viewpoint. Against this backdrop, this study delves into how new urbanization influences land use efficiency at the county level, exploring its intrinsic mechanisms and spatial effects, which hold urgent theoretical value and practical significance for optimizing territorial space governance and promoting urban-rural integration.

Zhejiang Province, as a pioneering region in China’s high-quality urbanization development, exhibits typical characteristics such as strong economic vitality, tight resource constraints, and pronounced regional disparities, which provide an ideal sample for micro-level mechanism research. Based on this, utilizing panel data from 61 counties in Zhejiang Province from 2010 to 2022, this study comprehensively employs a two-way fixed effects model, a mediation effect model, and a spatial econometric model, while applying methods such as the instrumental variable approach to address potential endogeneity issues, with the aim of systematically and empirically investigating: (1) the direct impact of new urbanization on county-level land use efficiency; (2) the mediating role of industrial structure advancement within this relationship; (3) the spatial spillover effects of new urbanization on land use efficiency; and (4) the regional heterogeneity of these impacts. Through this research, the study seeks to provide a scientific basis for optimizing county-level territorial spatial planning and promoting the synergistic development of urbanization and land use.

2. Literature Review

The enhancement of land use efficiency is pivotal for optimizing territorial space governance within the context of new-type urbanization [13]. With the advancement of the new-type urbanization strategy, academic discourse on the relationship between urbanization and land use efficiency has evolved from an initial focus on macro-level correlations to a deeper examination of intrinsic transmission mechanisms and complex spatiotemporal effects. A systematic review of the existing literature reveals a growing concentration of research on a key intermediary process—the advancement of industrial

structure. This process is regarded as the core economic link that transforms the driving force of urbanization into the optimized efficiency of land resource allocation.

On the one hand, the research perspective has shifted its focus from identifying macro-level direct relationships to analyzing micro-level mechanisms. Early studies aimed to confirm the macro-level associations between the two. Some studies have found that cities with higher levels of urbanization and economic development typically exhibit higher land use efficiency [14,15]. However, the conclusions regarding this direct relationship are complex, and subsequent research has revealed its nonlinear characteristics. For example, Yue et al. [16] found that the relationship between the two exhibits a U-shaped curve, while Li et al. [17] cautioned that, under conditions such as excessive agglomeration, population urbanization may have a negative impact on efficiency. Behind these nonlinear findings lies a substantive inquiry into the internal “black box” mechanism. Research has gradually moved beyond singular focuses on population agglomeration or infrastructure investment, turning toward a deeper analysis of economic structural transformation. The consensus is that urbanization is not merely the spatial transfer of factors but also a process that drives the evolution of the industrial structure from lower to higher levels. The advancement of industrial structure can optimize factor allocation, facilitating the flow of land resources from inefficient sectors to efficient ones, thereby serving as a fundamental pathway for enhancing land use efficiency [18].

On the other hand, the understanding of how the advancement of industrial structure specifically affects land use efficiency has deepened across multiple dimensions, forming the focal point of current theoretical discourse. Firstly, research focuses on the differentiated roles of industrial agglomeration patterns. Studies indicate that diversified industrial agglomeration generally promotes land allocation efficiency [19]. However, this effect exhibits significant context-dependence. For example, research in the Yellow River Basin found that the moderating effect of industrial diversification highly depends on the local existing industrial structure: specialization in the tertiary sector enhances its positive effect, whereas specialization in the secondary sector weakens it [20]. This suggests that the impact of industrial agglomeration patterns on land use efficiency is not fixed but is embedded within the region-specific industrial foundation. Secondly, from the perspective of coordinated development, the coordination degree between the level of industrial structure advancement and land use efficiency shows a patterned spatial differentiation (such as the “lower reaches > middle reaches > upper reaches” pattern in the Yangtze River Economic Belt) and exhibits significant spatial correlation [21]. This implies that the impact of industrial structure upgrading on land use efficiency deeply depends on the local existing structural foundation and the regional spatial context; in other words, the relationship between industrial structure advancement and land use efficiency has a spatial dimension. Blind industrial upgrading that disregards regional coordination may fail to achieve the expected land benefits. Thirdly, spatial heterogeneity has gained extensive empirical support. Whether it is the differences in resource endowments and development stages pointed out by Luo et al. [22], the “east high, west low” pattern of coupling coordination degree revealed by Zhao et al. [23], or the “southeast high, northwest low” spatial differentiation discovered by Xiao et al. [24] on the Loess Plateau, all jointly confirm that the impact of industrial structure transformation on land use efficiency strongly depends on specific regional contexts, and there is no universal, single model.

In summary, while existing literature offers a solid foundation for understanding the urbanization-land use efficiency nexus, several gaps remain. First, research has predominantly focused on cities and large regions, often overlooking micro-level variations at the county scale. As key spatial units bridging urban and rural areas, counties play a crucial role in achieving coordinated regional development through enhanced land use efficiency.

Furthermore, the scarcity of county-level studies makes it difficult to reveal the underlying characteristics and mechanisms of intra-regional development disparities. Therefore, to address this research gap, this study employs panel data from 61 counties in Zhejiang Province to provide a fine-grained analysis of the spatial variation in land use efficiency, thereby offering insights specific to the county level. Second, while most studies focus on the direct impact of new-type urbanization on land use efficiency, research into the underlying mechanisms remains limited. This is particularly true regarding the mediating role of industrial structure upgrading, which optimizes resource allocation to enhance efficiency. Against the backdrop of an imbalance between “population urbanization” and “land urbanization”, industrial upgrading is crucial for high-quality development. Therefore, this study introduces a mediation effect model to systematically examine how new-type urbanization improves land use efficiency by fostering industrial structure evolution, thereby enriching the understanding of this transmission mechanism. Third, prevailing methods for measuring land use efficiency predominantly focus on economic output, often overlooking the balance between social and ecological benefits. In reality, urban land use constitutes a complex system involving interactions among human, economic, social, and ecological elements. A singular economic perspective is thus inadequate for fully capturing its performance. To address this gap, this study employs a super-efficiency SBM-Undesirable model that incorporates three categories of expected and undesired outputs—economic, social, and ecological—thereby enhancing the comprehensiveness and scientific rigor of the assessment.

3. Theory and Mechanism Analysis

3.1. *The Direct Effect of New-Type Urbanization on Land Use Efficiency*

New-type urbanization serves as a vital driving force for economic and social development, and its role in enhancing land use efficiency manifests across multiple dimensions. Unlike the simplistic linear promotion often perceived in traditional views, this influence is complex, multidimensional, and conditional. Its direct mechanisms of action are primarily reflected in three aspects: economic agglomeration, spatial restructuring, and functional enhancement. These mechanisms are intertwined and collectively shape the ultimate efficiency of land use.

Regarding Economic Agglomeration: A core feature of new urbanization is the efficient spatial agglomeration of production factors (population, capital, technology) [25]. This agglomeration, facilitated by knowledge spillovers, specialized division of labor, and shared infrastructure, can generate significant economies of scale, thereby enhancing the output efficiency per unit of land within an appropriate range [26]. However, this scale effect is not infinitely increasing. An optimal distribution pattern of city sizes exists within an urban system [27]. When urban expansion becomes excessive or the spatial structure becomes imbalanced, it can trigger issues such as traffic congestion, soaring commuting costs, redundant construction of public infrastructure, and low utilization rates. These problems may, in turn, weaken the positive effects of agglomeration economies, leading to diminishing or even negative marginal returns on land use.

Regarding Spatial Restructuring and Structural Optimization: Unlike the traditional urbanization model dominated by land area expansion, new urbanization emphasizes a fundamental shift from “incremental expansion” to “stock quality enhancement”. Its key pathway lies in promoting the optimization and restructuring of the internal spatial structure of cities [28]. This includes: the redevelopment and functional replacement of inefficiently used industrial land and idle land; promoting the renewal and renovation of old residential communities and urban villages to enhance residential density and living environment quality; and encouraging the functional mixing of urban land uses to reduce

the demand for long-distance commuting. This process essentially involves enhancing the utilization intensity and composite functions of existing built-up areas. By unlocking the value potential of stock space without adding or with minimal addition of new construction land, it achieves an intensive improvement in land use efficiency.

Regarding Functional Enhancement and Carrying Capacity: New urbanization adheres to a people-centered philosophy. Its improvement of land use efficiency is reflected not only in economic output but also in the enhancement of comprehensive social and environmental carrying capacity. The modernization, digitalization, and networking of infrastructure significantly increase the connectivity and operational efficiency of per-unit land space [29]. This functional enhancement, on one hand, indirectly supports the growth of economic density by attracting and retaining high-quality labor and innovative resources. On the other hand, it directly elevates the “development quality” and resident well-being that the land supports, embodying the comprehensive efficiency of land use under the multidimensional objectives of society, economy, and ecology. Therefore, the improvement of infrastructure and public services constitutes an indispensable supporting condition for the efficient and sustainable utilization of land.

Based on this, this paper proposes Hypothesis 1:

Hypothesis 1. *The advancement of the new urbanization process can enhance land use efficiency at the county level.*

3.2. The Mediating Effect of New-Type Urbanization on Land Use Efficiency

In the process of new-type urbanization, industrial structure advancement acts as a key mediating variable, profoundly connecting and transmitting the impact of new urbanization on land use efficiency. The functioning of this mediating role originates from the core driving force of new urbanization: the spatial agglomeration of population and economic activities not only promotes the continuous transfer and upgrading of labor from the primary industry to the secondary and tertiary industries, particularly to high-end manufacturing and modern services [30], but also, through knowledge spillovers, innovation environment creation, and consumption structure upgrading, comprehensively enhances the value-added, complexity, and technology intensity of the economic system, thereby substantively driving the evolution of the industrial structure toward advancement [31]. Subsequently, the advanced industrial structure exerts multidimensional and powerful effects on enhancing land use efficiency. By attracting and matching high-quality labor and capital, it directly promotes the optimization of urban functions and profound adjustments in land resource allocation patterns, such as encouraging functional mixing, compact development, and efficient reuse of stock space. Simultaneously, advanced industries oriented toward smart manufacturing, the digital economy, and green and low-carbon development inherently demand intensification, intelligence, and ecological sustainability in spatial use. Their development directly drives the widespread application of digital infrastructure and green building technologies, leading to a technological leap in land output efficiency [32,33]. Therefore, industrial structure advancement plays the central roles of a “transformer” and “amplifier” between new urbanization and land use efficiency. It is not only a key outcome of improved urbanization quality but also the core transmission pathway that effectively converts the momentum of urbanization development into intensive, green, and efficient land use patterns.

Based on this, this paper proposes Hypothesis 2:

Hypothesis 2. *The new urbanization process enhances land use efficiency at the county level by promoting the advancement of the industrial structure.*

3.3. The Spatial Effect of New-Type Urbanization on Land Use Efficiency

New-type urbanization influences land use efficiency not only locally but also in surrounding regions through spatial spillover effects. On the one hand, central cities facilitate the optimal allocation of land resources in neighboring areas via infrastructure connectivity, industrial chain extension, information dissemination, and institutional innovation [34]. On the other hand, interregional economic linkages and factor mobility enable developed urban areas to enhance intensive and sustainable land use in adjacent regions through demonstration effects, resource reallocation, and technology diffusion. Moreover, the expansion of regional transportation networks, industrial relocation, and urban–rural integration has further strengthened spatial interconnections, thereby extending the geographic reach of land use efficiency improvements driven by new-type urbanization [24]. Thus, from a spatial perspective, new-type urbanization exerts both local and cross-regional impacts on land use efficiency through various spillover mechanisms (Figure 1).

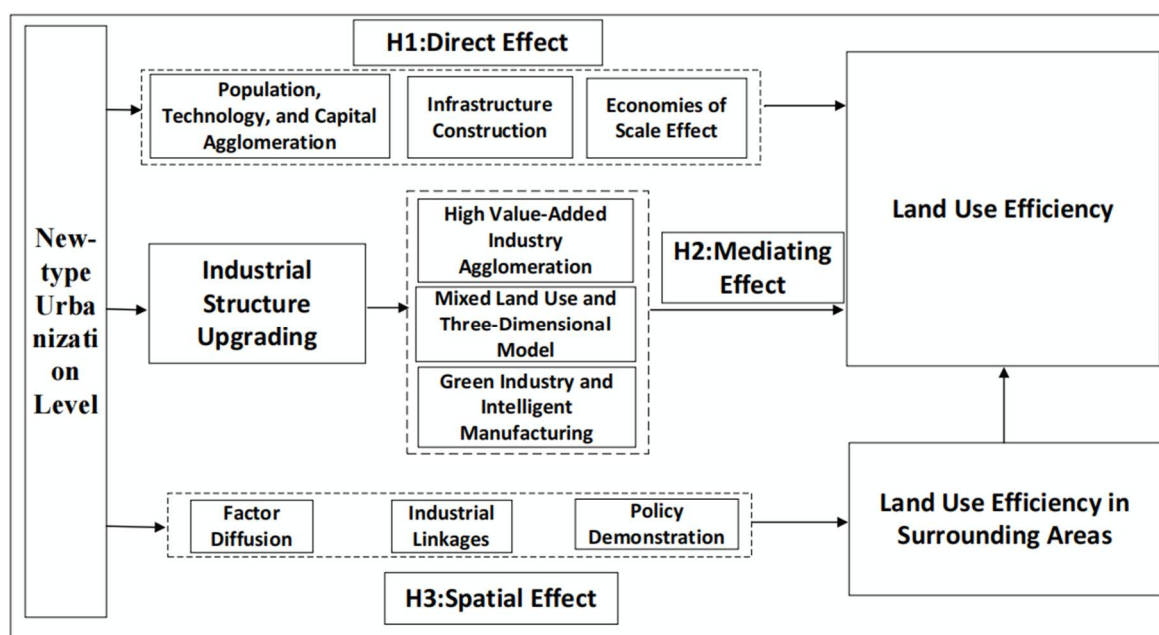


Figure 1. Mechanism Analysis of New-Type Urbanization on Land Use Efficiency.

Based on this, this paper proposes Hypothesis 3:

Hypothesis 3. *The new urbanization process exerts a positive impact on the land use efficiency of neighboring counties through spatial spillover effects.*

4. Study Area and Data

4.1. Description of Study Area

Zhejiang Province, as one of China's most economically dynamic and urban-rural balanced regions along the southeastern coast, provides a highly representative case for this study. Its economic development is characterized by a "private sector-driven, cluster-based industrial structure" with a high degree of marketization. The province's urbanization process started early and has achieved rapid qualitative improvements, pioneering institutional reforms and the equalization of public services. Meanwhile, Zhejiang faces a rigid resource constraint due to its "large population but limited land availability", making the enhancement of land use efficiency both an inherent requirement and an ongoing practice for achieving high-quality development. The long-standing gradient disparities within the

province—between “coastal and inland” areas as well as between “northern and southern Zhejiang”—provide a natural setting for examining regional heterogeneity. Thus, Zhejiang serves as a typical microcosm that has completed its initial accumulation and is now at a critical stage of development model transformation. The dual challenges it faces—improving the quality of urbanization and optimizing land allocation—hold forward-looking reference value for the entire nation and even many developing economies.

4.2. Data Source and Processing

This study focuses on counties within Zhejiang Province. Due to systematic gaps in key indicators across certain county statistical yearbooks—particularly in coastal counties of Hangzhou and Taizhou where multiple required metrics are published only at the municipal level without district-specific breakdowns—and the absence of independent data for two districts in Jinhua City, the analysis faces limitations. Additionally, historical data inconsistencies arise in Longgang City due to administrative restructuring. To ensure data integrity and comparability, this study excludes 29 counties and cities: 13 from Hangzhou, 9 from Taizhou, 4 from Zhoushan, Wucheng District and Jindong District in Jinhua, and Longgang City in Wenzhou. The final dataset comprises panel data from 61 counties and cities in Zhejiang Province spanning 2010–2022. Table 1 presents descriptive statistics for the variables used in this study. All data were sourced from the statistical yearbooks and bulletins of Zhejiang’s prefecture-level cities. Minor data gaps in certain years were filled using interpolation methods.

Table 1. Descriptive Statistics of Variables.

Variable Type	Variable Name	Symbol	Mean	Std. Dev.	Min	Max
Explained variable	Land Use Efficiency (based on Super-efficiency SBM model)	LUE	0.592	0.273	0.086	1.515
Core explanatory variable	New-type Urbanization Level	NUC	0.200	0.096	0.037	0.584
Mediating variable	Industrial Structure Upgrading	ISU	1.616	1.606	0.194	17.100
Alternative variable	Land Use Efficiency (based on SBM model)	SBM-LUE	0.584	0.257	0.086	1
Control variable	Per Capita GDP	PGDP	74,676	40,765	10,803	304,319
	Population Density	PD	692.7	606	86.23	4067
	General Fiscal Expenditure	GE	600,378	445,074	21,493	3,718,022

4.3. Variable Definitions and Measurement

4.3.1. Dependent Variable: Land Use Efficiency (LUE)

This study refers to the method of existing research [35–38] and employs the SBM-Undesirable model to measure land use efficiency. The Super-Efficiency SBM model that incorporates undesirable outputs combines the advantages of both the super-efficiency model and the SBM model. It integrates undesirable outputs into the model while further decomposing efficient decision-making units (DMUs) with an efficiency value of 1, thereby avoiding the loss of information from these DMUs. The specific calculation process of the model is as follows. In the formulas, n represents the number of DMUs; m , r_1 and r_2 represent inputs, desirable outputs, and undesirable outputs, respectively; x , y^d and y^u are the elements in the corresponding input matrix, desirable output matrix, and undesirable

output matrix; λ_j is the weight coefficient; s, q, k, u are the decision-making units; and ρ represents the land use efficiency value.

$$\min \rho = \frac{\frac{1}{m} \sum_{i=1}^m (\bar{x} / x_{ik})}{\frac{1}{r_1 + r_2} \left(\sum_{s=1}^{r_1} \bar{y}^d / y_{sk}^d + \sum_{q=1}^{r_2} \bar{y}^u / y_{qk}^u \right)} \quad (1)$$

$$\begin{cases} \bar{x} \geq \sum_{j=1, j \neq k}^n x_{ij} \lambda_j; \bar{y}^d \leq \sum_{j=1, j \neq k}^n y_{sj}^d \lambda_j; \bar{y}^u \geq \sum_{j=1, j \neq k}^n y_{qj}^u \lambda_j \\ \bar{x} \geq x_k; \bar{y}^d \leq y_k^d; \bar{y}^u \geq y_k^u \\ \lambda_j \geq 0; i = 1, 2, \dots, m; j = 1, 2, \dots, n \\ s = 1, 2, \dots, r_1; q = 1, 2, \dots, r_2 \\ k = 1, 2, \dots, m; d = 1, 2, \dots, r_1; u = 1, 2, \dots, r_2 \end{cases}$$

This paper treats the same city in different periods as distinct Decision-Making Units, constructing an evaluation indicator system comprising three dimensions: “Multi-dimensional Inputs,” “Desirable Outputs,” and “Undesirable Outputs” (see Table 2). Specifically, based on the factors of production theory, land input, capital input, labor input, and technology input are categorized as primary indicators under “Multi-dimensional Inputs”. The “Desirable Outputs” consider the economic, social, and ecological benefits within land use efficiency. The “Undesirable Outputs” primarily account for the negative effects generated during the land use process, represented by industrial wastewater discharge, industrial SO₂ emissions, and general industrial solid waste generation in environmental pollution. Data for all input, desirable output, and undesirable output indicators in the evaluation system are sourced from the statistical yearbooks and bulletins of various prefecture-level cities in Zhejiang Province.

Table 2. Land Use Efficiency Index System Based on Input–Desired–Undesired Outputs.

Target Level	Criterion Level	Indicator Level	
Input Indicators	Land Input	Built-up area/km ²	
	Capital Input	Total fixed asset investment/10,000 yuan	
	Labor Input	Number of employees in the secondary and tertiary industries/10,000 persons	
	Technology Input	Government expenditure on science and technology/10,000 yuan	
Output Indicators	Desired Outputs (Land Use Efficiency)	Economic Benefit	Value added of the secondary and tertiary industries/10,000 yuan
		Social Benefit	Average wage of on-the-job employees/yuan
		Ecological Benefit	Green park area/hectare
	Undesired Outputs	Negative Benefit (Environmental Pollution)	Industrial wastewater discharge/ton
			Industrial SO ₂ emissions/ton General industrial solid waste generation/ton

4.3.2. Independent Variable: New-Type Urbanization (NUC)

Based on the actual conditions of counties in Zhejiang Province, this paper references the indicator framework proposed in the National New Urbanization Plan (2014–2020) and relevant scholarly research findings [39,40]. It constructs an evaluation indicator system for the level of new urbanization (NUC) across five dimensions: population, economy, spatial layout, society, and ecology (see Table 3). To ensure data comparability, the raw data was normalized using the range method, and the entropy method was applied to determine the objective weights of each indicator, thereby enhancing the scientific rigor and rationality of the indicator system.

Table 3. Evaluation System of New-type Urbanization Indicators.

Primary Indicator	Secondary Indicator	Indicator Attribute	Indicator Weight
Population Urbanization	Urbanization rate/%	Positive	0.073
Economic Urbanization	Per capita disposable income of urban residents/yuan	Positive	0.083
	Per capita consumption expenditure of urban residents/yuan	Positive	0.083
Spatial Urbanization	Urban road area per capita/m ²	Positive	0.052
Social Urbanization	Number of hospital beds per 10,000 people/units	Positive	0.183
	Number of public library books per capita/volumes	Positive	0.215
Ecological Urbanization	Green coverage rate of built-up areas/%	Positive	0.012
	Environmental management expenditure/10,000 yuan	Positive	0.298
	Harmless treatment rate of municipal solid waste/%	Positive	0.001

4.3.3. Mediating Variable: Industrial Structure Upgrading (ISU)

Industrial structure Upgrading refers to the sequential transition of industries from labor-intensive to capital-intensive, and then to knowledge-and-technology-intensive, as well as the process of shifting from a dominance of industries producing primary products to a dominance of those producing intermediate and final products [41]. From the perspective of technological level, industrial structure advancement can be described as the reallocation of original factors and resources from sectors with low productivity to those with high productivity. This leads to a continuous increase in the proportion of high-productivity industrial sectors, thereby raising the overall productivity across different sectors. This process encompasses both changes in proportional relationships and improvements in productivity [42]. Consequently, a constructed indicator for industrial structure advancement should include both a quantitative dimension (proportional relationships) and a qualitative dimension (productivity), aiming to reflect the increasing share of high-productivity industries within the industrial structure. Drawing on the methodologies of Huang et al. [42] and Wu et al. [43], the specific formula is as follows:

$$ISU_{it} = \sum_{j=1}^3 LP_{jit} \times R_{jit} \quad (2)$$

i and t denote cities and years, respectively; j denotes industry (classified into the three sectors of industry); ISU_{it} represents industrial structure upgrading; LP_{jit} denotes labor productivity in industry j for city i in year t ; R_{jit} denotes the proportion of output value in industry j for city i in t year relative to the total output value for that year. The greater the proportion of industries with high labor productivity within a county, the higher its Industrial Structure Upgrading index (ISU_{it}).

4.3.4. Control Variables

Based on existing literature [39,40,43], this study selects per capita GDP (PGDP), population density (PD), and general fiscal expenditure (GE) as control variables to reduce omitted variable bias and enhance model robustness. Controlling for these variables helps ensure more accurate and reliable estimates of the relationship between urbanization, industrial structure upgrading, and land use efficiency.

4.4. Methods

To examine the direct mechanism through which the level of new-type urbanization influences land use efficiency, this study employs a two-way fixed effects regression model [44]. The model specification is as follows:

$$LUE_{it} = \alpha_0 + \alpha_1 NUC_{it} + controls + \mu_i + \delta_t + \varepsilon_{it} \quad (3)$$

LUE_{it} denotes the land use efficiency value for city i in year t ; NUC_{it} represents the new urbanization level for city i in year t ; *controls* is the set of control variables; μ_i is the regional fixed effect; δ_t is the year fixed effect; ε_{it} is the error term; β_0 and β_1 denote the regression coefficients for the constant term and urbanization level, respectively.

To test the indirect mechanism of new urbanization on land use efficiency, this paper constructs the following mediating effect model for verification:

$$LUE_{it} = \beta_0 + \beta_1 NUC_{it} + \beta_2 ISU_{it} + controls + \mu_i + \delta_t + \varepsilon_{it} \quad (4)$$

ISU_{it} represents the mediator variable, namely the level of industrial structure upgrading. β_0 , β_1 and β_2 denote the constant term, the regression coefficient for urbanization level, and the regression coefficient for industrial structure upgrading, respectively.

To validate the spatial spillover effects of new-type urbanization on land use efficiency, this paper further constructs a spatial econometric model, with the following model specification:

$$LUE_{it} = \rho \sum_j^N W_{ij} \cdot SE_TLE_{jt} + \lambda NUC_{it} + \theta \sum_j^N W_{ij} \cdot NUC_{jt} + \mu_i + \delta_t + \varepsilon_{it} \quad (5)$$

t denotes the year, i and j denote regions, W_{ij} denotes the spatial weight matrix, ρ denotes the vector of parameters to be estimated, λ denotes the spatial lag coefficient, and θ denotes the spatial regression coefficient for new-type urbanization.

5. Results and Analysis

5.1. Analysis of Spatio-Temporal Evolution Characteristics

5.1.1. Spatio-Temporal Evolution Characteristics of New Urbanization Levels

Based on the aforementioned calculation results of the New Urbanization Levels (NUC), as shown in Figure 2, the new-type urbanization level across all 61 counties and cities in Zhejiang Province exhibited a consistent upward trend from 2010 to 2022. Economically developed regions generally achieved higher urbanization levels, underscoring the significant role of economic growth in promoting new-type urbanization. Spatially, coastal cities outperformed their inland counterparts, with northern Zhejiang coastal areas displaying more advanced urbanization development than those in the south. This spatial pattern can be attributed to the comparative advantages of coastal regions, including superior geographical location, well-developed transportation infrastructure, and greater market openness. These factors collectively enhance economic performance and population agglomeration, thereby accelerating the progress of new-type urbanization.

An in-depth analysis of the distribution trends across different tiers of new-type urbanization reveals distinct patterns. The count of counties and cities in the lowest tier has declined steadily, falling from 41 in 2010 to zero by 2020. In contrast, those classified in the lower and medium tiers exhibited a fluctuating trend, increasing initially and then decreasing. Meanwhile, the number of jurisdictions in the higher and highest tiers demonstrated consistent growth. This dynamic shift indicates a steady overall rise in Zhejiang's urbanization level, marked by a gradual reduction in lower-tier areas and

a continuous expansion of higher-tier ones. These observations collectively suggest that Zhejiang's urbanization process is currently in a phase of accelerated advancement.

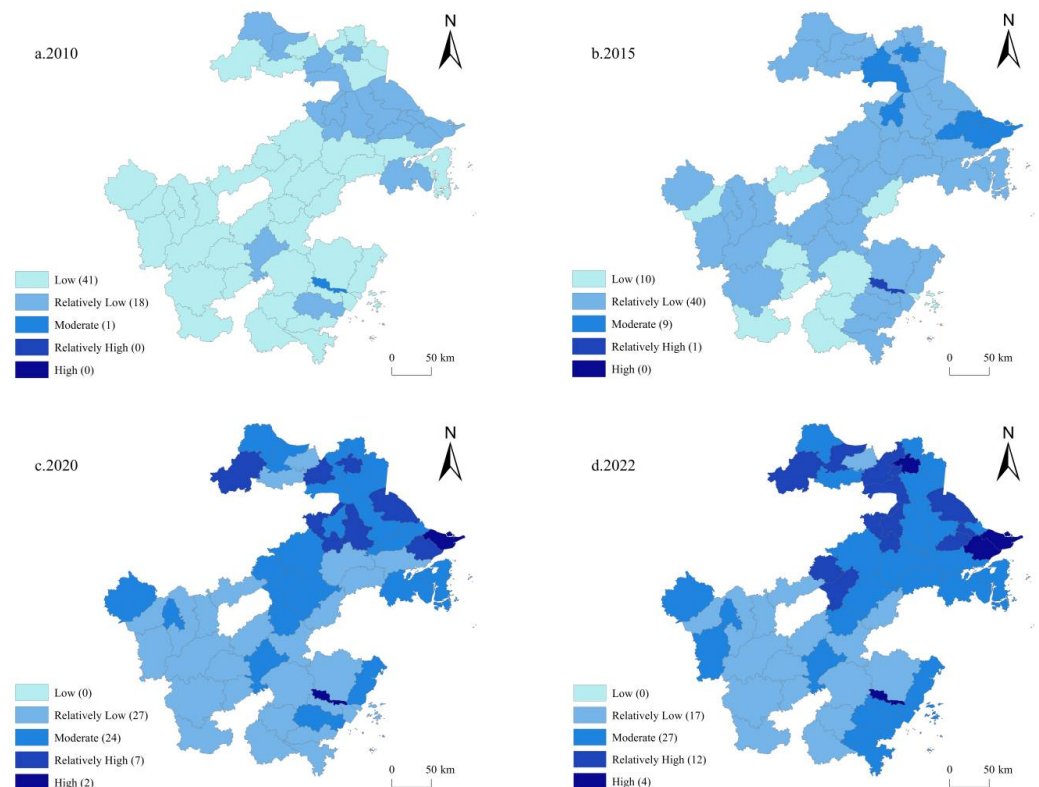


Figure 2. Spatio-temporal Evolution Maps of New-type Urbanization Levels in 61 Counties and Cities of Zhejiang Province in 2010, 2015, 2020, and 2022. Note: This figure is based on the standard map with approval number GS(2023)276 downloaded from the Ministry of Natural Resources' Standard Map Service website; the base map has not been modified. The same applies below.

5.1.2. Spatio-Temporal Evolution Characteristics of Land Use Efficiency

Based on the aforementioned calculation results of Land Use Efficiency (LUE), as shown in Figure 3, the temporal trend of land use efficiency across 61 counties in Zhejiang Province follows a “decline-then-rise” pattern. In 2010, higher land use efficiency was mainly observed in economically less developed regions such as Lishui, Jinhua, and Huzhou. By 2015, however, the number of high-efficiency counties and cities had decreased significantly, with most values clustering in the medium-efficiency range. This phase reflects certain bottlenecks or fluctuations in the improvement of land use efficiency, though the declining trend did not persist in subsequent years. By 2020, no counties or cities remained in the lowest efficiency category, with the majority attaining medium or higher levels—a clear indication that land use efficiency had begun to rebound. This upward trend continued, as evidenced by the number of high-efficiency units reaching 29 by 2022, surpassing the 20 recorded in 2010. Spatially, high-efficiency counties and cities were primarily located in southern Zhejiang in 2010. After 2020, however, northern Zhejiang overtook the south in overall land use efficiency, with high-performing units becoming concentrated in the north. By 2022, areas with high land use efficiency were predominantly found in more economically developed regions, presenting a spatial pattern markedly different from that of 2010.

Overall, land use efficiency in Zhejiang Province experienced a brief decline between 2010 and 2015, followed by a sustained upward trajectory. This pattern suggests that in the early stage, some counties and cities—particularly those initially operating at high

efficiency levels—may have overlooked further improvements or effective maintenance of land use efficiency due to various constraints. However, as development philosophies evolved and policy priorities shifted, these regions began to place greater emphasis on the rational utilization of land resources and implemented a series of proactive measures aimed at optimization. These efforts collectively contributed to the overall enhancement of land use efficiency across the province.

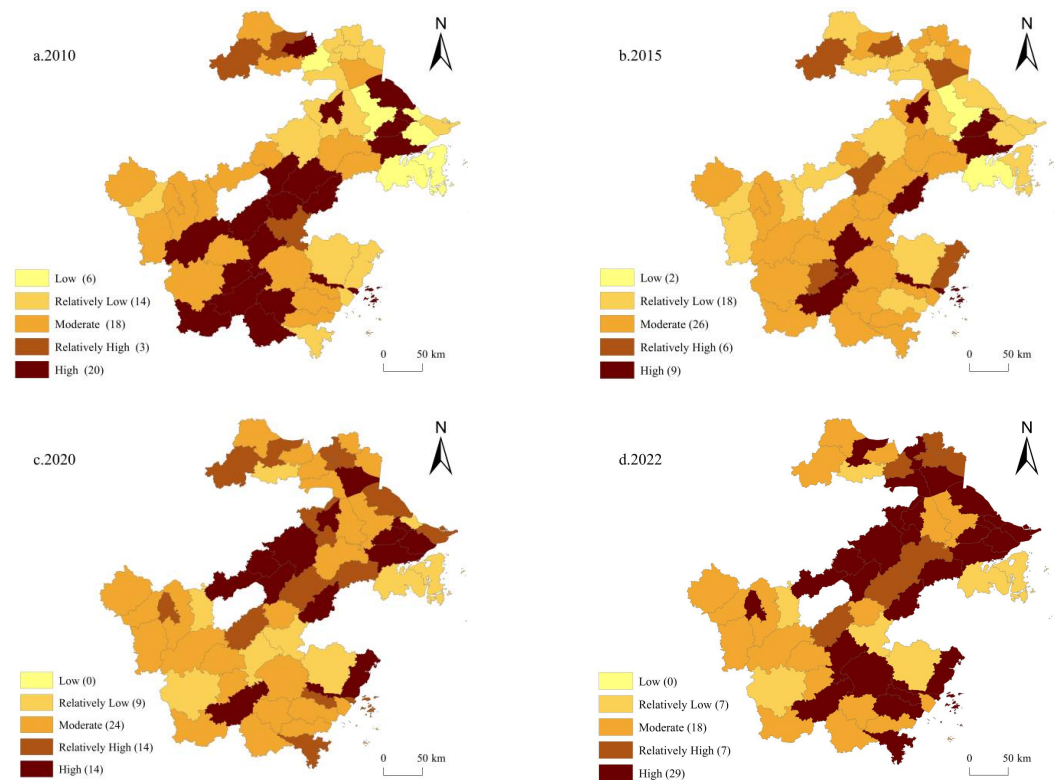


Figure 3. Spatio-temporal Evolution Maps of Land Use Efficiency in 61 Counties and Cities of Zhejiang Province in 2010, 2015, 2020, and 2022.

5.2. Direct Effect Test

5.2.1. Baseline Regression Analysis

Table 4 reports the baseline regression results of the new urbanization level on land use efficiency. After controlling for a series of regional characteristics and time effects, the regression coefficient for the new urbanization level is 0.945, which passes the significance test. This indicates that for every one-unit increase in the new urbanization level, county-level land use efficiency increases by an average of approximately 0.945 units. This result validates research Hypothesis H1, demonstrating that the process of new urbanization can effectively enhance land use efficiency.

Table 4. Baseline Regression Results.

Variable	(1)	(2)
New-type Urbanization Level	1.706 *** (0.497)	0.945 ** (0.449)
Constant	0.251 ** (0.010)	0.216 ** (0.084)
Controls	NO	YES
R^2	0.700	0.719

Note: ** $p < 0.05$; *** $p < 0.01$; Cluster-robust standard errors are reported in parentheses.

5.2.2. Endogenous Treatment

Although this study has controlled for variables affecting land use efficiency as comprehensively as possible, the complexity of reality means that omitted variable bias may persist, contributing to endogeneity in estimating the effects of new-type urbanization. Furthermore, a potential bidirectional causal relationship likely exists between new-type urbanization and land use efficiency. Additionally, factors that are difficult to quantify—such as regional cultural traits and subtle variations in policy implementation—could simultaneously influence both processes, potentially biasing conventional regression results.

To address this issue, this study employs an instrumental variable (IV) approach, utilizing the capacity of medical and health service supply—measured by the number of beds in healthcare institutions—as the instrument. This capacity is closely linked to the level of new-type urbanization, as urban population growth drives demand for medical services, thereby prompting governments to expand supply. Conversely, it is hypothesized not to directly affect land use efficiency, which is primarily determined by direct factors such as land-use planning and industrial distribution. The medical service capacity is presumed to influence land use only indirectly by promoting new-type urbanization, for instance, through optimizing population structure and fostering industrial agglomeration. Consequently, this instrumental variable is considered both relevant and exogenous, effectively mitigating endogeneity concerns.

The endogeneity problem was tested through two-stage least squares (2SLS) estimation: in the first stage, the endogenous variable new urbanization level was regressed using medical and health service supply capacity as an instrumental variable. In the second stage, the fitted value was substituted into the original model to estimate its impact on land use efficiency. The KP-LM statistic was obtained by performing a Lagrange multiplier test on the residuals of the first-stage regression, and the Wald F statistic was obtained from the joint significance test of the first-stage regression (Table 5).

Table 5. Endogeneity Test Results.

Variable	(1) First-Stage Regression	(2) Second-Stage Regression
New-type Urbanization Level		3.320 ** (1.470)
Number of Hospital Beds	0.010 *** (0.002)	
KP-LM Statistic	5.380 ($p < 0.05$)	
Wald F Statistic	18.390	

Note: ** $p < 0.05$; *** $p < 0.01$; Cluster-robust standard errors are reported in parentheses. The KP-LM statistic p -value is used to test the effectiveness of the instrumental variable; the Wald F statistic assesses the strength of the instrumental variable; the Stock-Yogo critical value is the reference value for testing weak instrumental variables. If the Wald F statistic is greater than the Stock-Yogo 10% critical value (16.38), the instrumental variable passes the test.

The results show that the KP-LM statistic (5.380, $p < 0.05$) passes the unidentifiable test, and the Wald F statistic (18.390) far exceeds the critical value, confirming the rationality and effectiveness of the instrumental variable selection. Furthermore, after controlling for endogeneity, new urbanization still has a significant positive impact on land use efficiency (3.320, $p < 0.05$), and medical and health service supply capacity is highly significant as an instrumental variable (0.010, $p < 0.01$). This result confirms the reliability of the theoretical hypotheses and demonstrates that the research conclusions are not biased by omitted variables or bidirectional causality. Therefore, after accounting for endogeneity, the results remain robust.

5.2.3. Robustness Test

To further verify the robustness of the above research conclusions, this study conducted multiple robustness tests by replacing the model, replacing the explained variables, and winsorizing (see Table 6). The following is a detailed analysis and discussion of the regression results:

Table 6. Robustness Test Results.

Variable	(1) Baseline Regression	(2) Alternative Model	(3) Replacing the Dependent Variable	(4) Winsorization Treatment
New-type Urbanization Level	0.945 ** (0.238)	0.945 ** (0.449)	0.923 ** (0.424)	0.991 ** (0.491)
Constant	0.216 ** (0.084)	0.418 *** (0.051)	0.224 *** (0.079)	0.190 ** (0.092)
R ²	0.719	0.311	0.721	0.719

Note: ** $p < 0.05$; *** $p < 0.01$; Cluster-robust standard errors are reported in parentheses.

- (1) Model replacement. After adopting the fixed-effect model and clustering the standard error, the coefficient of the new urbanization level is 0.945, which remains unchanged. This shows that the choice of model has little impact on the results and the research conclusions are robust.
- (2) Replace the explained variable. This paper uses the SBM model to recalculate land use efficiency based on the method of Song et al. [18] and conducts a robustness test. The results show that the level of new urbanization is still significantly positive, indicating that even if the measurement method of the explained variable is changed, the impact of urbanization level remains robust, verifying the reliability of the baseline regression results.
- (3) Winsorization. Considering that outliers in the sample may affect the regression results, this study applies a bilateral 5% winsorization to the core explanatory variable, the level of new urbanization. The regression results show that the coefficient has increased slightly and remains significantly positive. This indicates that even after removing outliers, the impact of urbanization level remains significant and consistent in direction.

5.3. Impact Mechanism Analysis

5.3.1. Mediation Effect Test

To verify the indirect mechanism of new urbanization on land use efficiency, this paper adopts the mediation effect model for testing, and the results are shown in Table 7.

Table 7. Mechanism Test Results.

Variable	(1) New-Type Urbanization Level	(2) Land Use Efficiency
Industrial Structure Upgrading	7.382 *** (1.863)	0.846 * (0.449)
New-type Urbanization Level		0.014 * (0.007)
Constant	−1.022 *** (0.306)	0.230 *** (0.032)
R ²	0.599	0.692

Note: * $p < 0.1$; *** $p < 0.01$; Cluster-robust standard errors are reported in parentheses.

Mechanism tests show that new urbanization significantly promotes the upgrading of industrial structure (7.382, $p < 0.01$), which in turn has a positive impact on land use

efficiency (0.014, $p < 0.1$). After introducing mediating variables, the regression coefficient decreases, indicating that the direct effect of new urbanization is less than the total effect, confirming that the upgrading of industrial structure plays a partial mediating role. This suggests that new urbanization indirectly improves land use efficiency by promoting the transformation of industries toward high-value-added industries.

5.3.2. Analysis of Spatial Spillover Effects

The results of the spatial autocorrelation test are shown in Figure 4, which shows that there is significant spatial dependence between new urbanization and land use efficiency.

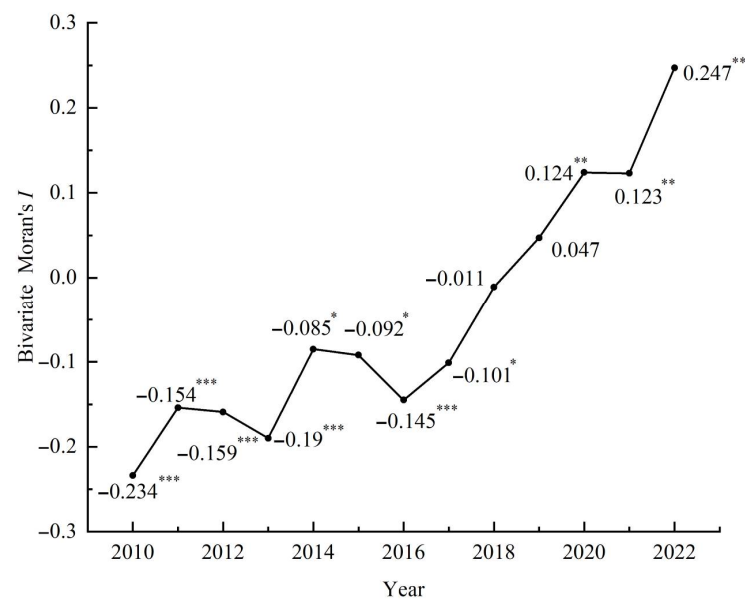


Figure 4. Bivariate Global Moran's I. Note: * $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$; Cluster-robust standard errors are reported in parentheses.

The bivariate Moran's I index from 2010 to 2022 shows that the spatial correlation between the two shows a phased evolutionary characteristic: In the early period (2010–2017), there was a negative correlation (-0.234 *** in 2010), indicating that the land use efficiency in the surrounding areas with higher urbanization levels was relatively low during this period, and there was an obvious spatial mismatch; in the later period (2018–2022), it turned into a significant positive correlation (reaching 0.247 ** in 2022), indicating that the spatial positive correlation continued to strengthen. This change reflects the policy effectiveness of regional coordinated development, and the driving effect of urbanization on the land use efficiency of surrounding areas is becoming increasingly apparent. This shift from a negative to a positive correlation reflects the effectiveness of implementing coordinated regional development policies. With the advancement of policies such as infrastructure connectivity and coordinated industrial development, the positive externalities of urbanization have gradually emerged, effectively alleviating earlier spatial heterogeneity issues and forming a new pattern of coordinated regional development.

The regression results of the Spatial Durbin Model (SDM) further confirm this finding (see Tables 8 and 9). The model shows that the direct effect of new urbanization on land use efficiency is 0.680 ($p < 0.01$), the spatial spillover effect is as high as 2.176 ($p < 0.01$), and the total effect reaches 2.856 ($p < 0.01$). This result indicates that new urbanization not only significantly improves land use efficiency in the region but also significantly drives growth in surrounding areas through factors such as factor mobility and technology diffusion. The rho coefficient is 0.106 ($p < 0.05$), further confirming the presence of spatial dependence.

Table 8. Spatial Durbin Model Estimation Results.

SE-TLE	W·SE-TLE	rho	R ²
0.625 *** (0.222)	1.998 *** (0.419)	0.106 ** (0.049)	0.043

Note: ** $p < 0.05$; *** $p < 0.01$; Cluster-robust standard errors are reported in parentheses.

Table 9. Spatial Effects Decomposition Results.

Direct Effect	Indirect Effect	Total Effect
0.680 *** (0.219)	2.176 *** (0.551)	2.856 *** (0.583)

Note: *** $p < 0.01$; Cluster-robust standard errors are reported in parentheses.

5.4. Regional Heterogeneity Analysis

5.4.1. Differences Between Coastal and Non-Coastal Areas

The impact of new urbanization on land use efficiency exhibits significant regional and structural disparities due to differences in geographical location, resource endowments, and stages of economic development [40]. In the coastal areas of Zhejiang Province (such as Ningbo, Wenzhou, and Zhoushan), leveraging port advantages, early-opening policy dividends, and well-developed transportation networks, a development model dominated by export-oriented economy, advanced manufacturing, and modern services has been formed. The urbanization process started earlier here, with higher degrees of foreign investment and population agglomeration, leading land use to face the transformation pressure from incremental expansion to stock optimization at an earlier stage. In contrast, non-coastal areas (such as Jinhua, Quzhou, and Lishui) are more constrained by mountainous terrain and relatively weaker transportation accessibility. Their economic development exhibits more endogenous characteristics, excelling in specialized agriculture, localized industrialization, and eco-tourism. The driving force for urbanization relies more on the transformation of local labor and the radiation from regional central cities. Consequently, the intensity and pace of transformation in land development and utilization generally lag behind those of coastal areas. To further examine the aforementioned disparities, this paper categorizes the sample of 61 counties in Zhejiang Province into coastal and non-coastal regional groups based on their geographical location. Combined with quantile-based grouping regression of land use efficiency, it explores the differentiated impact mechanisms of new urbanization on land use efficiency.

The regional heterogeneity regression results in Table 10 show that the impact of new urbanization on land use efficiency exhibits significant regional disparities. In coastal areas, the coefficient is 0.904 and statistically significant at the 5% level, indicating that a one-unit increase in the new urbanization level can robustly drive an approximately 0.904-unit improvement in land use efficiency. This suggests that coastal regions, leveraging their well-developed infrastructure, industrial agglomeration, and policy guidance, have entered a stage of interactive, intensive growth characterized by a virtuous cycle between urbanization and land use intensification. In contrast, the coefficient for non-coastal areas is 0.399 and is not statistically significant. This result reveals that the positive effects of new urbanization may be subject to “conditional dependency”—under the current developmental foundations and institutional environments of non-coastal areas, improvements in the quality of urbanization have not yet been effectively translated into significant enhancements in land resource allocation efficiency.

Table 10. Heterogeneity Test Results.

Variable	(1)	(2)	(3)	(4)	(5)	(6)
	Coastal	Non-Coastal	0–25%	25–50%	50–75%	75–100%
New-type Urbanization Level	0.904 ** (0.404)	0.399 (1.006)	0.446 *** (0.138)	0.129 (0.119)	−0.644 * (0.372)	0.328 (0.289)
Constant	0.178 * (0.103)	0.337 ** (0.135)	0.178 *** (0.031)	0.354 *** (0.033)	0.571 *** (0.094)	0.825 *** (0.071)
Sample Size	338	455	194	189	186	188
R ²	0.827	0.630	0.839	0.453	0.474	0.504

Note: * $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$; Cluster-robust standard errors are reported in parentheses.

5.4.2. Regional Differences in Efficiency Levels

Further regression analysis was conducted by grouping regions based on different levels of land use efficiency (see Columns (3)–(6) of Table 10). The results indicate that the impact of new urbanization on land use efficiency varies markedly across different efficiency intervals. Low-Efficiency Group (0–25%): The regression coefficient for new urbanization is 0.446, which is statistically significant at the 1% level. This indicates a strong and reliable statistical relationship between the level of urbanization and efficiency improvement in counties with the lowest land use efficiency. The urbanization process likely generates a significant catch-up effect by filling infrastructure gaps and promoting the initial agglomeration and intensive use of production factors. Medium-Low Efficiency Group (25–50%): The coefficient for new urbanization is 0.129 and is not statistically significant. This result suggests that once land use efficiency rises above the lowest levels, the marginal effect of mere urban expansion on improving land use efficiency diminishes rapidly. Further efficiency gains may depend more on other underlying drivers, such as industrial restructuring and technological upgrading. Medium-High Efficiency Group (50–75%): The coefficient for new urbanization is −0.644, which is statistically significant and negative at the 10% level. This statistically significant negative effect implies that for regions at this developmental stage, if the urbanization model is not optimized accordingly, they are more susceptible to falling into an extensive development path characterized by land resource misallocation and disorderly spatial expansion, thereby exerting an observable dampening effect on land use efficiency. High-Efficiency Group (75–100%): The coefficient for new urbanization is 0.328 and is not statistically significant. This result indicates that for counties where land use efficiency is already high, their spatial utilization patterns tend to be mature and stable. Further advancement of urbanization is unlikely to produce a direct, statistically discernible boost to the efficiency metric. Sustained optimization of efficiency will rely more on refined urban governance and functional upgrading.

In summary, the impact of new urbanization on land use efficiency has obvious regional and group differences. The urbanization process in coastal cities has formed a relatively mature model that can effectively promote land use efficiency. However, non-coastal cities need to further optimize their urbanization pathways, improve resource allocation efficiency, and prevent inefficient urbanization expansion. Urbanization has a significant impact on improving land use efficiency in inefficient areas, indicating that areas with low land use efficiency should further promote infrastructure development, optimize industrial layout, and promote the rational use of land resources. In regions with medium to high land efficiency, urbanization may have a negative impact on land use efficiency. It is necessary to optimize urban development models and strengthen land use supervision to avoid inefficient land use caused by overdevelopment. Government fiscal spending can help improve land use efficiency to a certain extent. It is recommended to strengthen fiscal support, especially for non-coastal and low-efficiency areas, optimize funding allocation, and improve the efficiency of land resource utilization.

6. Conclusions and Discussions

6.1. Research Conclusions

Based on panel data from 61 counties in Zhejiang Province from 2010 to 2022, this study empirically investigates the impact of new urbanization on land use efficiency by employing two-way fixed effects model, mediation effect model, and spatial spillover model. The following conclusions are drawn:

First, both the level of new urbanization and land use efficiency in Zhejiang Province showed an overall upward trend during the observation period. Their spatial distributions exhibited a gradient pattern of “coastal areas higher than inland areas, and northern higher than southern” demonstrating strong spatial synergy. This suggests a potential coordinated evolutionary relationship between the two processes.

Second, the baseline regression results indicate that the level of new urbanization has a significantly positive direct impact on land use efficiency. Further mediation effect tests reveal that industrial structure upgrading plays a partial mediating role in this pathway. These findings collectively show that new urbanization not only directly enhances land use efficiency but may also indirectly improve resource allocation efficiency by promoting industrial structure optimization.

Third, spatial econometric regression results confirm a significantly positive spatial spillover effect of new urbanization on land use efficiency. This implies that the development of new urbanization in one region not only improves local land use efficiency but may also positively drive efficiency in neighboring areas through spatial linkage mechanisms such as factor flow, technology diffusion, or policy demonstration.

Fourth, the impact of new urbanization on land use efficiency exhibits clear regional and developmental stage heterogeneity. From a geographical perspective, its promoting effect is significant and stronger in coastal areas, whereas it is statistically insignificant in non-coastal areas. This disparity may stem from the more favorable location, mature industrial agglomeration, and effective market mechanisms in coastal areas, which provide more sufficient conditions for translating urbanization into efficiency gains. From an efficiency-level perspective, the enhancing effect of new urbanization is most pronounced in counties with low land use efficiency, which may correspond to the “catch-up effect” generated by infrastructure construction and factor agglomeration in the early stages of urbanization. However, in counties where land use efficiency is already at medium-high levels, this enhancing effect diminishes or even turns negative. This key finding indicates that once regional development surpasses a specific stage, if the urbanization process continues with an extensive expansion model instead of focusing on structural optimization and quality improvement, it may inhibit land use efficiency due to resource misallocation. In high-efficiency counties, the marginal effect of urbanization becomes insignificant, suggesting that land use patterns in these areas have stabilized. Further efficiency improvements will depend more on refined urban governance and profound structural transformation rather than mere expansion of urbanization scale.

6.2. Discussions

6.2.1. Policy Implications

Based on the research conclusions, this paper derives the following policy implications:

The core theoretical implications of this study are as follows: First, by identifying industrial structure advancement as a key mediating variable, this study reveals that the urbanization process can indirectly optimize resource allocation by promoting industrial structure upgrading. Second, this study confirms the existence of significant spatial spillover effects from new urbanization on land use efficiency, highlighting the necessity of adopting a spatially linked perspective when analyzing urbanization effects. Third,

this study demonstrates that the impact of new urbanization on land use efficiency is not singular or linear; instead, it exhibits significant condition-dependent and path-dependent characteristics. Its effectiveness is simultaneously moderated by both geographical location and the stage of development.

The practical implications of this study are as follows: First, governments should resolutely promote high-quality urbanization and industrial upgrading. It is essential to consistently focus on enhancing the quality of new urbanization, strengthening the orientation toward green and intensive development and actively leveraging industrial structure advancement—a key mediating channel. Through policy guidance, land factors should be directed toward high-value-added industries to achieve systematic improvements in efficiency. Second, differentiated intervention measures that precisely match regional endowments and developmental stages should be implemented. Regarding geographical differences, coastal areas should focus on the optimization of existing stock and functional upgrading, deepening spatial renewal and intensive utilization. Non-coastal areas, in contrast, should concentrate on improving infrastructure and cultivating distinctive industrial clusters to accumulate initial developmental conditions. Concerning differences in efficiency levels, in low-efficiency areas, the catch-up effect of urbanization can be utilized to reinforce incremental quality improvement and infrastructure investment. In medium-to-high-efficiency areas, a shift toward stock optimization and risk prevention is imperative. Extensive expansion must be strictly controlled, with urban renewal and redevelopment serving as the primary pathways.

6.2.2. Comparison with Existing Literature, Limitations and Future Prospects

Compared with existing research, this study shifts the commonly focused perspective from the provincial or city level down to the county-level scale. Through an empirical analysis of 61 counties in Zhejiang Province, it reveals the local variations in the relationship between new urbanization and land use efficiency within finer geographical units. This micro-perspective forms a useful contrast and supplement in terms of scale and methodology with international research focusing on functional urban areas [45]. Building on this micro-perspective, the research not only confirms the direct promoting effect of new urbanization but also, further through a mediation model, identifies the key transmission role played by industrial structure advancement. This provides evidence from Chinese counties for understanding the specific pathways through which urbanization affects land use efficiency, engaging in theoretical dialog with global studies that focus on other moderating variables such as “initial per capita land consumption,” thereby jointly revealing the complexity of this relationship [46]. Furthermore, by introducing spatial econometric models, this paper breaks through the traditional analytical framework limited to local effects and empirically demonstrates the significant spatial spillover effects of new urbanization on the land use efficiency of surrounding areas, providing important empirical evidence for understanding regional coordinated development. This finding both differs from and resonates with the complex picture observed by Hou et al. [47] in global megacities, where “land use efficiency still shows significant regional differentiation under compact trends” together illustrating the multidimensional nature of the spatial effects of urbanization.

Simultaneously, this study also has certain limitations, mainly reflected in the following aspects: Regarding the sample scope and data availability, this research focuses solely on 61 counties in Zhejiang Province. Due to the systematic lack of key disaggregated data in official statistics and other reasons, 29 counties were excluded from the study. While this ensures the integrity and comparability of the panel data, thereby supporting rigorous econometric analysis, it inevitably affects the comprehensiveness of spatial coverage. Therefore, the generalizability of the research conclusions needs to be further tested with more

comprehensive county-level datasets or in other regional contexts. Regarding the measurement of variables and the exploration of mechanisms, the constructed indicators for new urbanization and land use efficiency, as well as the examined transmission pathways, may not fully capture multidimensional characteristics and complex nonlinear mechanisms.

Future research can deepen along the following directions: First, expanding the geographical scale to conduct cross-regional comparisons and test the applicability of the research conclusions across different developmental stages and institutional environments. Second, constructing a more systematic analytical framework that integrates economic, social, environmental, and other multidimensional indicators, and exploring more diverse transmission mechanisms such as technological progress and institutional innovation, thereby forming a more universal and explanatory theoretical understanding. Third, future research should strive to obtain more granular data to better capture subtle spatial interactions and heterogeneity within metropolitan areas, thereby overcoming the current data limitations imposed by aggregated statistical reporting.

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