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The Impact of Land Marketization on Urban Resilience: Empirical Evidence from Chinese Cities

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Abstract: Enhancing urban resilience (UR) is the pivotal strategy for achieving sustainable development. Given that land serves as the cornerstone of urban activities, it is imperative to examine the relationship between land marketization (LM) and urban resilience amidst the profound market-oriented land reforms in China. After establishing the conceptual framework of urban resilience, this paper assesses the temporal and spatial dynamics and empirically investigates the impact of land marketization on urban resilience, drawing on data from 282 cities across China, spanning from 2001 to 2021. Our findings reveal several important insights. First, due to its public bidding and competitive pricing mechanisms, land marketization is a powerful measure to foster urban resilience and enables cities to flexibly respond to various challenges and changes. Second, the indirect mechanisms, including optimizing resource allocation, upgrading industrial structure, and fostering technological innovation, are crucial pathways through which land marketization affects urban resilience. Finally, the impact of land marketization on urban resilience varies across regions and city size. Cities with better geographic locations, larger population sizes, and lower administrative levels are more significantly affected than others. These findings reveal the importance of land marketization in strengthening urban resilience, thereby providing theoretical guidance and empirical references for cities to enhance urban resilience through land marketization.

Keywords: urban resilience; land marketization; resource allocation; industrial structure optimization; technological innovation

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1. Introduction

For cities, which are the primary engine of economic and social progress, urbanization is an irreversible globalization trend in the process of development. Based on the World Cities Report 2022, released by UN-Habitat, the urban population constituted 56% of the overall global population in 2021 and is expected to increase to 68% by 2050. As global urbanization continues to advance, natural disasters and public safety incidents such as extreme weather, earthquakes, financial crises, and the COVID-19 pandemic are occurring frequently. These calamities continuously challenge cities' capacity to withstand and mitigate risks, severely constraining safety and sustainable development [1]. Among these, developing countries bear a heavier burden from disasters compared to developed nations. In particular, China, as the largest developing country, had an urbanization rate of 66.16% in 2023, with a proportional increase in a variety of urban problems such as extreme events and natural disasters [2,3]. According to the official data, China experienced varying degrees of impact from natural disasters affecting 95,444,000 people in 2023, with direct economic losses totaling CNY 345.45 billion. Given these challenges, it has become an urgent imperative to ensure the stable and secure operation of cities and the attainment of sustainable development.

With the escalation of instability risk, resilience has been gradually incorporated into urban-planning studies, and UR has become a key strategy for achieving sustainable development. The term "resilience" stems from the Latin word "*resilio*", which means "restore to an original state" [4]. Its concept has evolved from "engineering resilience—ecological resilience—evolutionary resilience" [5]. Given the complexity of urban systems, evolutionary resilience provides a foundational framework for UR research [6]. UR is a capacity for change, adaptation, and alteration inspired by complex socio-ecological systems in response to pressures and constraints [7]. UR breaks through the traditional rigid thinking of urban safety management. Beyond focusing solely on disaster resilience, it also emphasizes the improvement of the city's adaptive, restorative, absorptive, and learning capacities through the systematic integration of elements [5]. This provides a new way of managing risks and addressing urban challenges. In recent years, the Chinese government has increasingly prioritized UR. The 14th Five-Year Plan (2021–2025) has explicitly proposed the construction of resilient cities, called for improving the level of urban governance and strengthening risk prevention and control in the megacities' governance. Concurrently, the Chinese government has launched pilot programs such as Sponge City and Climate-Adaptive City to enhance UR and foster urban development.

As the importance of UR continues to be recognized, the study of its enhancement dynamics has become a focus of scholarly research. From the point of the intrinsic economic drivers, some scholars have identified that various elements, such as human capital [8], infrastructure development [9], industrial structure [10], and innovation activities [11], all have a certain impact on UR. From the point of view of policy instruments, some scholars have revealed that the institutional environment of a region is a crucial determinant of UR [12]. Ezcurra and Rios [3] found that urban economic resilience was closely associated with the quality of local governments, noting that effective local governance can bolster urban economic resilience. Similarly, Lu and Teng [13] verified that innovative urban policies, which functioned through efficient markets and responsive governance, played a vital role in enhancing urban economic resilience. Taken together, the existing studies offer valuable insights into improving UR. However, there remains a gap in the literature regarding UR from the standpoint of land allocation.

As a crucial element and spatial foundation of urban economic activities [14], the allocation mode and efficiency of land utilization directly correlate with the resilience of cities and sustainable development. Since the reform and opening up, China's approach to land supply has experienced several revolutions, realizing a shift from allocation in a planned manner to market-oriented mechanisms by "tendering, auctioning, and listing". Unlike developed countries such as the United States, which utilize a market-oriented land allocation system, LM in China does not equate to privatization, but only the marketization of the method of offering land. Based on the data from the China Land Market Transaction Network, the proportion of urban land transferred through "tendering, auctioning, and listing" has increased significantly, rising from 46% in 2001 to 91% in 2021. This trend indicates a deepening marketization of land resources. Simultaneously, related research is emerging. Multiple studies have demonstrated that LM has generated substantial "institutional dividends", effectively addressing issues of land resource mismatches and inefficient utilization [15,16], while also fostering urban economic development [17,18]. Furthermore, research on the economic impacts of LM is expanding in the direction of adapting to the characteristics and planning of economic development. Some scholars have focused on the environmental consequences of LM, arguing that it can lower energy consumption and enhance green total factor output [19–21]. Yuan and Zhao [22] found that spatial mismatches in construction land significantly hinder the resilience of urban economies. These findings underscore the considerable influence of LM on urban system development.

To summarize, while the existing literature provides valuable insights, some limitations also remain. Specifically, despite numerous studies focusing on UR and LM separately, few have integrated them into a unified research framework. Prior research on the correlation between LM and urban development has predominantly explored economic or

ecological effects, ignoring the complexity of cities as systems comprising multiple subsystems whose interactions shape urban development. Therefore, this raises the following research question of this paper: Does LM affect the urban system resilience? And what are the specific mechanisms involved?

To answer the above questions, this paper integrates LM and UR within a comprehensive framework and analyzes their relationship. Initially, it constructs a systematic framework and a comprehensive assessment index system for UR, employing the entropy method for measurement. Subsequently, building on a robust theoretical foundation of the mechanisms through which LM affects UR, the paper empirically estimates both direct and indirect impact between the two using panel data from Chinese prefecture-level and above cities from 2001 to 2021. The conclusions drawn from this study aim to provide insights and recommendations for enhancing UR and promoting sustainable development.

The primary contribution of this study is mostly found in the following aspects: Firstly, despite a substantial body of research that has analyzed the driving factors of UR, there remains a gap in understanding the impacts of LM. Furthermore, previous studies investigating the impacts of LM have predominantly focused on economic or ecological aspects alone. UR is a multidimensional and complex system. This paper links LM with system resilience, which not only enriches the research on drivers of UR from the standpoint of land resource distribution but also broadens the investigation of the effects of LM. Secondly, this paper systematically and comprehensively analyzes the influence mechanism of LM on urban system resilience toughness from resource allocation, industrial structure upgrading, and technological innovation; opens up the "black box" of the role between the two; and improves the theoretical extension of the process of both. Thirdly, this paper utilizes data at the city level for empirical research, enabling a nuanced exploration of the influence relationship and providing practical insights for the advancement of UR systems in the new era.

The subsequent organization is as follows: The "Theoretical Analysis and Research Hypotheses" section constructs a conceptual framework for UR, develops the hypotheses, and builds a theoretical model. The "Methodology and Data Sources" section presents research methods, definitions of variables, and the research data collected. The "Empirical Results and Analysis" section reports empirical results, which include a spatiotemporal analysis, benchmark analysis, robustness test, mechanism analysis, and heterogeneity analysis. The "Discussion" presents the results, offers policy recommendations, and clarifies research limitations.

2. Theoretical Analysis and Research Hypotheses

2.1. Market-Oriented Reform History of LM in China

In developed countries, LM primarily refers to privatization. For example, in the United States, land is mainly privately owned and can be freely bought, sold, and rented within legal constraints, with prices determined by the market mechanism. In contrast, China's land system operates under a dualistic framework, where urban land is state-owned and rural land is collectively owned. Unlike the privatization model in developed countries, LM in China does not concern land ownership but rather land use rights [23,24]. Specifically, LM refers to the fact that land use rights are no longer uniformly allocated by the government but are instead distributed through market-oriented mechanisms by "tendering, auctioning, and listing".

Looking back on the development of LM in China, the urban land supply system has gone through several major reforms, realizing a shift from uniform allocation in a planned manner to market-based transfers. The evolution of its visualization is shown in Figure 1.

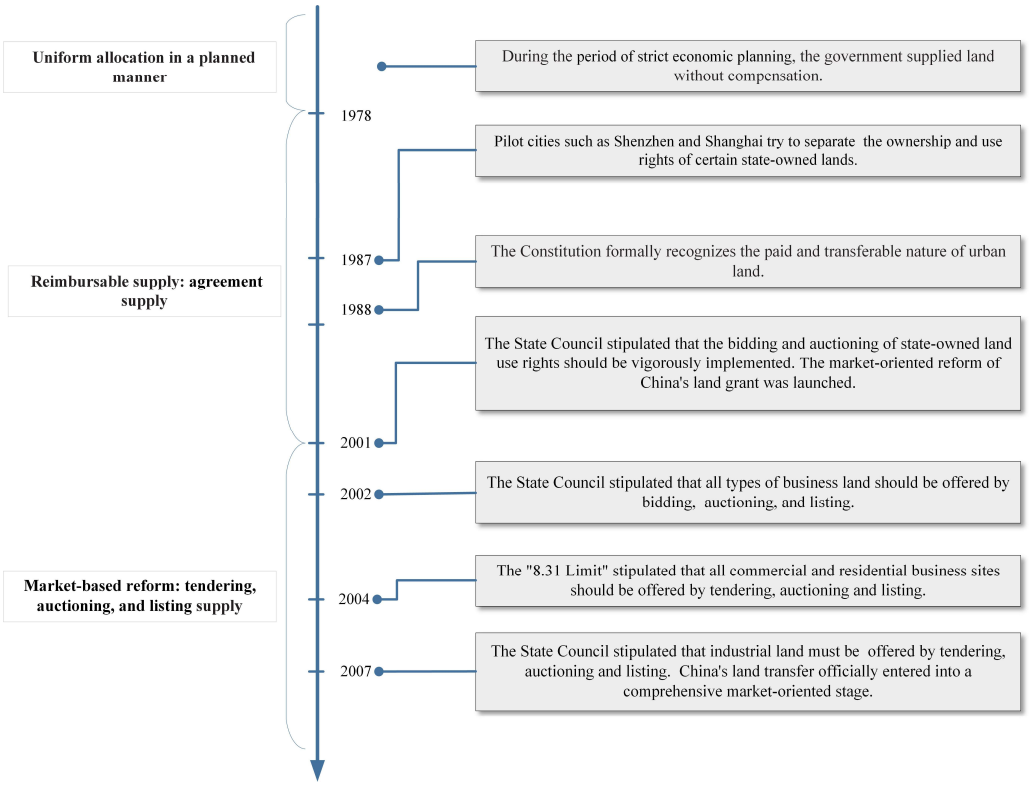


Figure 1. Evolutionary path of land marketization reform in China.

Before 1978, during China's period of strict economic planning, all land was allocated gratuitously by the government.

With the wave of reform and opening up sweeping across China, coupled with significant economic and social changes, the gratuitous allocation of land is increasingly incompatible with contemporary development needs. Consequently, reforms began to reshape the land supply system. In 1987, pilot cities such as Shenzhen and Shanghai led the way by separating the ownership and use rights of certain state-owned lands. Subsequently, in 1988, the revision of the Constitution formally recognized the paid and transferable nature of urban land use rights, heralding the advent of a land market economy.

In the 1990s, urban land was mainly offered by agreement; the local governments promoted economic growth and urban development by the mode of "land for development", such as attracting investments with low-priced land or supplying high-priced commercial and residential land [20]. However, in the new development stage, the effectiveness of "land for development" continued to decline [25], problems such as inefficient misuse of land were becoming more pronounced [26], and environmental pollution continued to worsen [27,28]. To reverse this situation, the Chinese government has initiated a market-based reform of land supply.

In 2001, the State Council of the People's Republic of China (the PRC) issued the Circular on Strengthening the Management of State-Owned Land Assets, advocating for the vigorous implementation of bidding and auctioning processes for state-owned land use rights. This marked the beginning of market-oriented reforms in China's land offer system [17]. In 2002, the Ministry of Land and Resources of the PRC explicitly promoted land market reform [29], promulgating the Regulations on the Transfer of State-owned Land Use Rights by Public Tendering, Auctioning and Listing of Quotation, which specified that all types of operational land should be offered by "tendering, auctioning and listing". Subsequently, in 2004, the Ministry of Land and Resources of the PRC, in conjunction with the Ministry of Supervision, issued the Notice on Continuing to Carry Out Law Enforcement Supervision on the Tendering, Auction, and Listing of Operational Land Use Rights. This notice mandated that, starting 31 August 2004, land for urban

operational construction, such as commercial and residential land, can be sold only by tendering, auctioning, and listing. In 2007, the Ministry of Land and Resources of the PRC revised and re-issued the Regulations on the Transfer of State-owned Land Use Rights by Public Tendering, Auctioning, and Listing of Quotation, further stipulating that industrial land must also be transferred by the market-oriented methods of "tendering, auctioning, and listing", replacing the traditional agreement and allocation methods. Consequently, China's land transfer system officially entered a comprehensive market-oriented phase [30]. Nevertheless, due to various factors, implementation gaps remain in different regions, thus providing a valuable basis for the analysis in this paper.

2.2. Systems Framework of UR

Since the late 1990s, resilience has been incorporated into urban-planning studies and extensively applied to analyze complex urban development systems [10,31]. In its early stages, UR primarily focused on disaster prevention and mitigation in response to climate change and sudden disasters [32–34]. However, with the rapid agglomeration of the urban population and the ongoing advancement of economic and social development, cities have increasingly evolved into "adaptive complex systems" similar to ecosystems. This evolution has heightened the uncertainty surrounding urban security. In this context, the concept of UR has expanded from merely responding to individual types of disasters to focusing on the construction of a comprehensive urban security system. UR now refers to a city's ability to withstand, adapt to, and recover from various shocks and pressures. It aims to achieve a synergy between overall disaster resilience and sustainable development, viewed from both systemic and functional perspectives.

Cities are intricate systems comprising the interaction between natural, economic, political, technological, social, and other subsystems [35]. This complexity forms the basis of UR, which involves the integrated development of four dimensions: economy, ecology, society, and infrastructure.

In summary, based on the principles of urban resilience and the inherent characteristics of cities, as well as existing research, this paper proposes a conceptual framework for UR: in the face of pressure or disturbances, the four subsystems—economy, ecology, society, and infrastructure—interact and influence each other to form a complex urban resilience system, achieving the unity of disaster resistance and sustainable development. The constructed urban system resilience framework is illustrated in Figure 2.

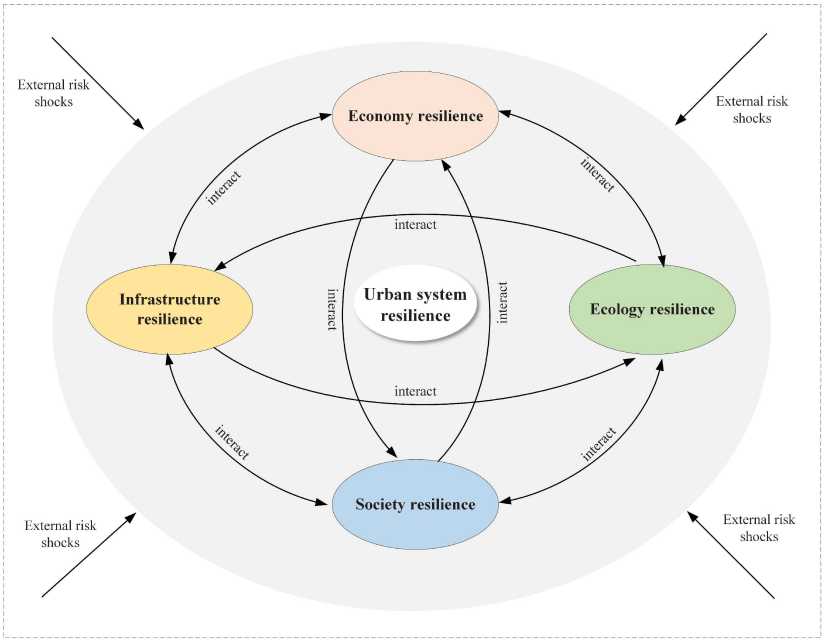


Figure 2. The system framework of urban multidimensional resilience.

2.3. The Effect of LM on UR

Land holds diverse values in terms of economy, ecology, and society [36], serving as the foundation and facilitator of urban economic and social advancement. LM involves allocating land use rights through market-based methods such as tendering, auctioning, and listing [29]. This approach harnesses supply-demand dynamics, competition, and pricing mechanisms in land resource allocation. It progressively enhances the recognition and utilization of land's diverse values through market mechanisms [37], thus bolstering cities' resilience against external risks and achieving sustainable development.

Firstly, land transfer fees constitute a significant source of government revenue [38,39]. The competitive pricing mechanism of LM fosters a sustained increase in land fees and mortgage borrowing, alleviating financial pressures and easing budgetary constraints on the government [19,40–42]. This not only compensates for the budgetary deficit in infrastructure development and improves urban infrastructure conditions but also increases government fiscal investments in education and healthcare [43], thereby improving social welfare and support systems. This effectively manages external risks and enhances the comprehensive resilience of the city. Secondly, within a market economy system, the principle of "survival of the fittest" prevails. Public bidding and competitive pricing facilitate the optimal land allocation to users, thereby enhancing the effectiveness of resource distribution [30] and avoiding risks associated with resource mismatch, ultimately bolstering UR [44].

According to the analysis provided above, this paper proposes the following research hypotheses:

Hypothesis 1 (H1). *LM effectively boosts UR.*

2.4. The Underlying Mechanism of Resource Allocation

LM plays a crucial role in fostering UR through effective resource allocation. On the one hand, LM helps alleviate resource misallocation and optimizes resource allocation. Given land's essential role in production and social functions, it must be combined with labor, capital, and other factors of production to realize its full potential [45]. The consequences of marketizing land transfer on resource allocation stem from the ability to reverse the resource mismatch of production resources. Firstly, LM facilitates more efficient resource allocation by reducing government control over factor markets, thereby enabling factors to move freely between regions and sectors according to market principles [46]. This accelerates the reallocation of production factors from sectors or industries with lower marginal productivity to those with higher productivity rates [47,48]. Secondly, LM stimulates market competition [23], forcing outdated production capacities to exit. This process releases productive resources previously tied up in inefficient sectors, allowing them to be redeployed to more efficient and advantageous sectors, thereby contributing to improved overall resilience and sustainability in urban systems.

On the other hand, effective resource allocation plays a crucial role in promoting UR. Economic growth primarily stems from two main sources: enhancing the utilization of factor inputs and optimizing the allocation of production factors [49]. The effectiveness of resource allocation is the key to releasing economic "dividends" [50]. Prior research has demonstrated that resource mismatch hinders the realization of scale and agglomeration effects, leading to reduced economic output while exacerbating regional "low-end locking". This also increases resource depletion rates and complicates environmental governance, thereby impeding economic growth and green development [51–53]. That is to say, when production factors are effectively allocated, they can maximize energy efficiency, providing robust support for economic growth and fostering innovations in total factor productivity [54]. Meanwhile, effective resource allocation enables urban systems with the capability to manage and adapt swiftly to unforeseen disruptions, facilitating quick recovery to normal operations and mitigating adverse impacts on urban development [55], thus realizing sustainable regional development.

According to the analysis provided above, this paper presents the subsequent research hypotheses:

Hypothesis 2 (H2). *LM drives UR by optimizing resource allocation*.

2.5. The Underlying Mechanism of Industrial Structure Optimization

LM plays a crucial role in enhancing UR by optimizing industrial structures. On the one hand, LM helps stimulate the optimization of industrial structures. Firstly, the competitive bidding of LM has formed cost constraints on land prices, leading to a crowding-out effect on local industries characterized by low value added, high pollution, and high energy consumption, forcing them to either exit the industry or undergo the transformation [20,24,56]. Secondly, the increase in land price sets a threshold effect, which acts as a barrier for field enterprises, so that the industries with high intensification and profitability, which align with the region's development plan, can be attracted or encouraged to establish operations [16]. This facilitates the optimization and upgrading of the regional industrial structure. In addition, LM improves market competitiveness and fairness and effectively avoids vicious competition and rent-seeking corruption in land transfer [57]. It makes the government take competitive strength as the benchmark in "selecting winners" and avoids providing land support for industries characterized by significant pollution, energy consumption, and emissions under administrative intervention [58]. This approach encourages diverse industries to move toward higher value-added segments of the value chain, thereby fostering overall industrial structure enhancement.

On the other hand, optimizing industrial structure significantly contributes to UR. Firstly, industrial structural optimization brings the "structural dividend" [59]. This makes the input factors flow from low-efficiency and low-value-added sectors to high-efficiency and high-value-added sectors, increasing the accumulation of production factors, increasing social productivity, promoting regional economic growth [60], and bolstering resilience against risks. Secondly, industrial structure optimization promotes the establishment of a diversified industrial structure [10], effectively dispersing risks caused by exogenous shocks, improving the ability of the overall system to withstand shocks [61], and aiding in the restoration and adaptation of urban systems following disruptive events [62]. Simultaneously, industrial structure optimization makes the service transformation of economic structure, mitigating negative externalities stemming from ecological and environmental pollution, promoting green development [20,63], and, thus, improving the ecological resilience of the city.

In general, LM drives the optimization of industrial structure by squeezing out low-value-added industries and favoring high-value-added industries. This enhances the adaptive capacity of urban systems, disperses risks caused by external shocks, and strengthens UR. According to the analysis provided above, this paper proposes the following research hypotheses:

Hypothesis 3 (H3). *LM drives UR by improving industrial structure optimization*.

2.6. The Underlying Mechanism of Technological Innovation

LM plays a crucial role in driving UR through the effect of technological innovation. On the one hand, it enhances urban technological innovation level. Firstly, the institutional environment is of utmost importance in all aspects of innovation [64]. Compared with the non-market-oriented transfer methods such as agreement-based, the information on LM is open and transparent, effectively suppressing the problem of rent-seeking and corruption, and reducing land violations [57,65]. This creates a market environment of fair competition where innovation becomes the most effective way for enterprises to gain a competitive edge, thereby boosting enterprise innovation capabilities. Secondly, financial constraints are the main "roadblock" to innovation. LM aids in mitigating the financial limitations faced by local governments [66]. This enables governments to increase continuous investment in urban innovation, which not only increases R&D investments and

reduces R&D risks but also signals strong support for innovation [18,67,68]. This sustained support continually stimulates innovation motivation. Meanwhile, LM raises land element costs, compelling enterprises to engage in research and technological innovation to cope with cost pressures [69,70], in turn, improving the city's technological innovation.

On the other hand, technological innovation promotes UR. First, it unleashes economies of scale, continuously improving labor productivity and economic efficiency and leading to high-quality economic growth [71]. This provides sufficient financial support for disaster prevention, mitigation, and reconstruction, thereby bolstering UR [72]. Secondly, with the improvement of technological innovation capacity, advancements in energy technologies, and equipment upgrades, coupled with the development of new alternative energy sources, optimize the energy structure and enhance energy efficiency [73,74]. This fosters green and efficient resource and space utilization, realizing UR governance and high-quality development. Thirdly, cities with stronger technological innovation capacities are better equipped to generate new productive activities and form new comparative advantages in response to external shocks, thereby better coping with the creative destruction caused by such shocks [11,62]. This contributes to sustained system resilience.

According to the analysis provided above, this paper presents the subsequent research hypotheses:

Hypothesis 4 (H4). *LM drives UR by improving technological innovation*. Synthesizing the above analysis, this paper draws the corresponding theoretical mechanism framework diagram, as shown in Figure 3.

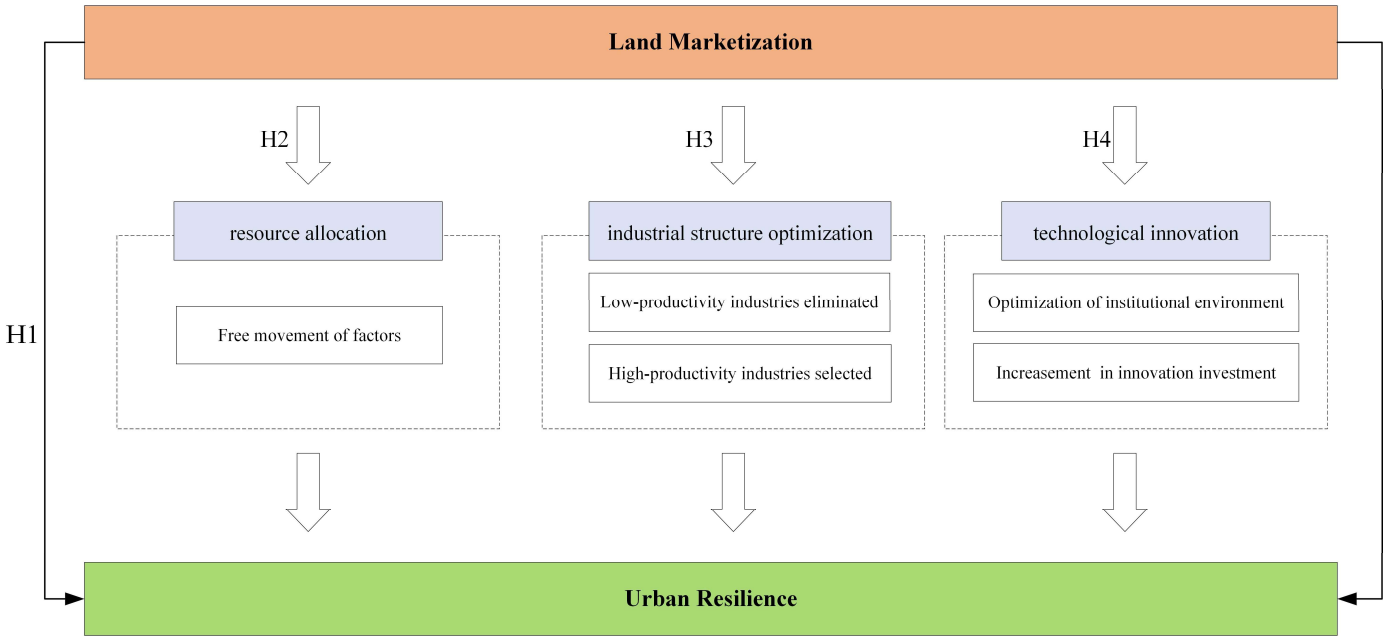


Figure 3. Theoretical framework.

3. Methodology and Data Sources

3.1. Model Design

To evaluate the impact of LM on UR, this paper constructed the following panel regression model, referencing Peng et al. [21]:

$$UR_{i,t} = \alpha_0 + \alpha_1 LM_{i,t} + \sum \alpha_2 control_{i,t} + Year_{i,t} + \mu_{it} + \varepsilon_{it} \quad (1)$$

where i represents the city, t represents the year, UR is the level of urban resilience, LM is the level of land marketization, $control$ is a set of control variables affecting UR, $Year$ represents the time-fixed effects, μ represents the city-fixed effects, and ε is the random perturbation term.

3.2. Definitions of Variables

3.2.1. Urban Resilience

Urban resilience (*UR*): As the conceptual framework constructed earlier, UR is a comprehensive resilience that includes four subsystems of resilience: economy, ecology, society, and infrastructure. Based on the foregoing studies [75–79], this paper adopts a comprehensive approach to measure the comprehensive UR index. The evaluation index system includes four guideline layers of economy, ecology, society, and infrastructure, integrating a total of 16 indicators. Following dimensionless normalization of the underlying data for each indicator layer, this paper uses the entropy value method to comprehensively provide a holistic assessment of resilience for each city. The indicator system is shown in Table 1.

Table 1. The index system of UR.

Target Layer	Criteria Layer	Indicator Layer	Attribute
Urban resilience (UR)	Economy resilience	Revenues from local budgets	+
		Total industrial output value above designated size	+
		GDP growth rate	+
		Retail sales of consumer goods	+
	Ecology resilience	The percentage of green space in urban areas	+
		Green area	+
		Harmless treatment rate of household garbage	+
		Amount of SO_2 emissions	-
	Society resilience	The quantity of hospital and health center beds of public transport vehicles per 10,000 individuals.	+
		Students in higher education per 10,000 people	+
		Per capita public library holdings	+
		Scientific research and technology practitioners	+
	Infrastructure resilience	Income from postal operations	+
		The number of public transport vehicles per 10,000 individuals	+
		Actual area of roads at year-end	+
		Road freight volume	+

(1) Economy resilience: The urban economy serves as the intrinsic driving force behind urban development. Economy resilience refers to the ability of the urban economic system to withstand external shocks and recover by adjusting its economic structure in response to both internal and external disturbances [80]. Four representative indicators were selected for evaluation: revenues from local budgets, total industrial output value above designated size, GDP growth rate, and retail sales of consumer goods, which indicate production capability, economic potential, and economic stability.

(2) Ecology resilience: Urban ecosystems are the spatial carriers of urban activities. Ecology resilience denotes the capacity of cities to repair and maintain functionality in the face of environmental challenges, such as natural disasters and pollution [79]. Four representative indicators were selected for evaluation: the percentage of green space in urban areas, green areas, the harmless treatment rate of household garbage, and the amount of SO_2 emissions, which indicate the ability to recover from pollution, ensure ecological security, and manage the urban environmental pressures.

(3) Society resilience: The urban society subsystem is crucial for urban development. Society resilience encompasses the essential safeguards for maintaining orderly city development during crises [81]. Four representative indicators were selected for evaluation: the quantity of hospital and health center beds of public transport vehicles, students in higher education, per capita public library holdings, and scientific research and technology practitioners, which represent the city's ability to provide social public services such as healthcare and education.

(4) Infrastructure resilience: Urban facilities are the material foundation of urban development. Infrastructure resilience denotes the capacity to provide public services in an orderly manner to safeguard residents' well-being in the face of risks [82]. Four

representative indicators were selected for evaluation: income from postal operations, the number of public transport vehicles per 10,000 individuals, the actual area of roads at year-end, and road freight volume, which measures the level of municipal facilities such as transportation and living in the city.

3.2.2. Land Marketization

Land marketization (*LM*): The existing literature mainly measures LM through two methods: the proportional method and the weighted method [30,41,83]. The proportional method is to calculate the proportion of land (whether in terms of number of lots, area, or price) offered via tender, auction, or listing to all land transactions. The weighted method is based on the proportional method and applies a weighted average of land transaction methods and prices to measure the level of land market transfer. Given the gap between the actual land supply price and the prevailing market price, this paper draws on the methods akin to those proposed by Qian and Mou [83] and Liu et al. [41]. Specifically, it chooses the price-weighted and the proportion of numbers to measure the level of urban LM. The specific formula is as follows:

$$LM = \sum_{i=1}^{n} Z_i f_i / \sum_{i=1}^{n} Z_i \quad (2)$$

where LM is the level of land marketization, Z_i denotes the parcels of land that are offered through diverse ways of transaction, and f_i represents the price weight of each transaction method. Concerning the computation of price weights, this paper adopts the fixed-price weight method, referring to the research of scholars such as Liu et al. [41], etc. The mean price of the land offered by auction during the sample period is taken as the baseline, assigned a weight of 1. Each other transaction mode's weight is then determined by the ratio of its average price to this benchmark price. Furthermore, to ensure the reliability of the benchmark research findings, this paper constructs five indicators to measure the degree of LM. Additionally, four alternative algorithmic indicators are used as robustness tests, as detailed in Table 2.

Table 2. Five indices to measure the level of land marketization.

Variables	Code	Definition
Index of land marketization	LM	Weighting method, the price-weighted and the proportion of the number
Index1 of land marketization	LM_1	Proportionality method, the ratio of the area of land marketed to the area of land total sales
Index2 of land marketization	LM_2	Proportionality method, the ratio of the number of lands marketed to the number of land total sales
Index3 of land marketization	LM_3	Proportionality method, the ratio of the price of land marketed to the price of land total sales
Index4 of land marketization	LM_4	Weighting method, the price-weighted and the proportion of area

3.2.3. Mechanism Variables

(1) Resource allocation (*RA*): Efficient resource allocation refers to the optimal distribution of resources where factors move freely, maximizing social output within market mechanisms. Conversely, resource mismatch implies a deviation from this state. In this paper, resource mismatch is a metric used to quantify the extent of resource allocation in cities. Drawing on the studies of Hsieh and Klenow [84] and Liu and Xia [85], the level of resource mismatch in each city is measured using the production function method.

In the first step, calculate the marginal output of the factors by using the production functions. The production function is supposed to follow a C-D production function model, where there are constant returns to scale, as specified in the following formula:

$$Y_{i,t} = AK_{it}{}^{\alpha} L_{it}^{\beta} \quad (3)$$

Taking the natural logarithm on both sides simultaneously, the collation can be obtained:

$$lnY_{i,t} = lnA + \alpha lnK_{it} + \beta L_{it} + +\varepsilon_{it} \quad (4)$$

The marginal output of capital is $\alpha Y_{i,t}/K_{it}$, and the marginal output of labor is $\beta Y_{i,t}/L_{it}$. The output variable (Y_{it}) is expressed in terms of the real GDP of each city with 2001 as the base period; the labor input (L_{it}) is measured by the quantities of employed persons at the year's end in each city; and the capital input (K_{it}) is quantified using the fixed capital stock in each city, which is computed by using the perpetual inventory method.

In the second step, calculate market distortions. Assuming that the price of capital is r and the price of labor is w, market distortions are measured based on the deviation of the marginal output of factors from their prices, respectively. They are as follows:

$$distK_{i,t} = |\alpha Y_{it}/r_{it}K_{it} - 1| \quad (5)$$

$$distL_{i,t} = |\beta Y_{it}/w_{it}L_{it} - 1| \quad (6)$$

Then, calculate the overall level of market distortion level by combining the distortions of capital and labor factors:

$$dist_{i,t} = distK_{it}^{\frac{\alpha}{\alpha+\beta}} \times distL_{it}^{\frac{\beta}{\alpha+\beta}} \quad (7)$$

where r is the basic price, which is set to 10%, representing a 5% depreciation rate with a 5% real interest rate, and w is the price of labor, expressed in terms of the mean wage of employed persons for the year in each city.

In the third step, calculate the resource allocation efficiency. The degree of resource mismatch in each city, which serves as a proxy variable for the efficiency of resource allocation, is measured by calculating the ratio of the value taken by each city to the greatest value among all cities in the year. It is specified as follows:

$$Mis_{i,t} = dist_{it}/\max(dist_t) \quad (8)$$

(2) Technological innovation (*TI*): This paper uses the logarithmic value of granted invention patents to measure the level of technological innovation in cities, referencing Aghion et al. [86].

(3) Industrial structure optimization (*IND*): This paper utilizes the ratio of the added value of the tertiary industry to the added value of the secondary industry in the region as a measure of the extent to which the regional industrial structure has been upgraded, referencing Pan and Luo [87].

3.2.4. Control Variables

Referencing Yang et al. [20] and Lu and Zeng [88], this paper selects the following indicators as control variables: urban scale (*US*), population density (*PD*), urbanization level (*UL*), financial development level (*FDL*), infrastructure level (*INL*), and foreign investment level (*FIL*). The meaning and computation procedure of the variables are illustrated in Table 3.

Table 3. Variables definition.

Variables	Code	Definition
Urban resilience	*UR*	Composite index methodology for 16 indicators.
Land marketization	*LM*	Weighting method, the price-weighted, and the proportion of number.
	RA	The level of mismatch of urban resources.
Mechanism variables	*TI*	The logarithm of patents granted for inventions.

Table 3. *Cont.*

Variables	Code	Definition
Control variables	*IND*	The ratio of the added value of the tertiary industry to the added value of the secondary industry.
	US	The logarithm of urban area.
	PD	The logarithm of persons per square kilometer.
	UL	The ratio of the population of municipal districts to the total population.
	FDL	The ratio of loans and deposits of financial institutions at year-end.
	INL	The logarithm of road area per capita.
	FIL	The logarithm of actual foreign capital.

3.3. Sample Selection and Data Sources

This paper uses panel data for 282 cities in China from 2001 to 2021. Market-based data on land transfers are sourced from the China Land Trade Network (CLTN), while patent data related to each city are derived from CNRDS's featured library through manual collation. Other city-level data are mainly obtained from the China Urban Statistical Yearbook, provincial and municipal statistical yearbooks, and the National Bureau of Statistics. In this paper, interpolation and averaging methods are employed to fill minor instances of missing data, while cities with significant data gaps are excluded from the analysis. Ultimately, this paper obtains panel data for 282 cities over 21 years in China, with 5278 observations. Descriptive statistics for each indicator selected in this paper are shown in Table 4.

Table 4. Descriptive statistics of the main variables.

Variable	Obs	Mean	Std. Dev.	Min	Max
UR	5278	2.858	4.044	0.161	59.857
LM	5278	0.749	0.178	0.356	1.066
RA	5278	0.281	0.157	0.001	1.000
TI	5278	4.223	1.990	0.000	11.280
IND	5278	0.962	0.533	0.094	5.348
US	5278	9.353	0.802	7.015	12.474
PD	5278	5.750	0.896	1.792	7.882
UL	5278	0.359	0.243	0.034	3.962
FDL	5278	0.686	0.235	0.060	7.076
INL	5278	6.929	1.027	0.693	10.393
FIL	5278	11.538	2.458	0.000	34.561

4. Empirical Results and Analysis

4.1. Analysis of UR and LM

Before proceeding to the formal empirical analysis, we first analyze the regional and temporal features of UR and LM in China using the calculated data. Figure 4 illustrates the temporal evolution since 2001. Throughout the sample period, both UR and LM show clear upward trends. In particular, UR rose from 2.000 in 2001 to 5.210 in 2021, with an increase of 160.5%, and LM rose from 0.457 in 2001 to 0.815 in 2021, with an increase of 78.48%. Especially, around 2007, there is a significant rise in the level of marketization, possibly due to the Chinese government's mandate in late 2006 requiring industrial land to be sold via tendering, auctioning, or listing in late 2006. Consequently, the land transfer market officially transitioned into full marketization, coinciding with a notable increase in marketization level in 2007. Meanwhile, UR also began to show a distinct upward trajectory, departing from its previous fluctuating pattern. The upward trends of the two are largely consistent. This initially shows that there is a positive correlation between LM and UR, thus laying the foundation for the subsequent research in this paper.

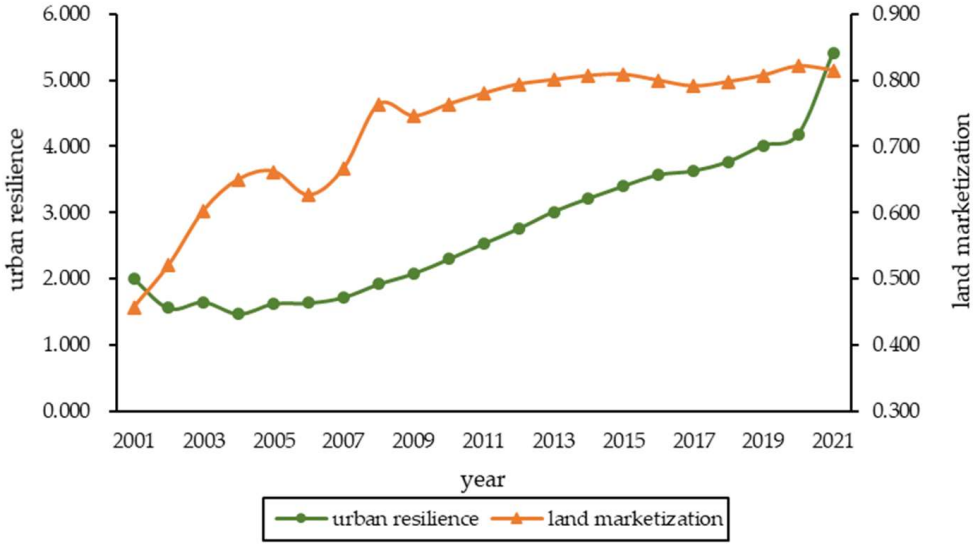


Figure 4. The time-specificity of UR and LM in China (2001–2021).

This paper spatially visualizes the levels of UR and LM in each city to analyze their spatial distribution patterns and dynamic evolution characteristics in China. In this paper, the study period from 2001 to 2021 is divided into three intervals: 2001–2007, 2008–2014, and 2015–2021. The natural breakpoints method is used to classify resilience and marketization into three levels (low, medium, and high). The spatial distributions of UR and LM are mapped in Figures 5 and 6, respectively.

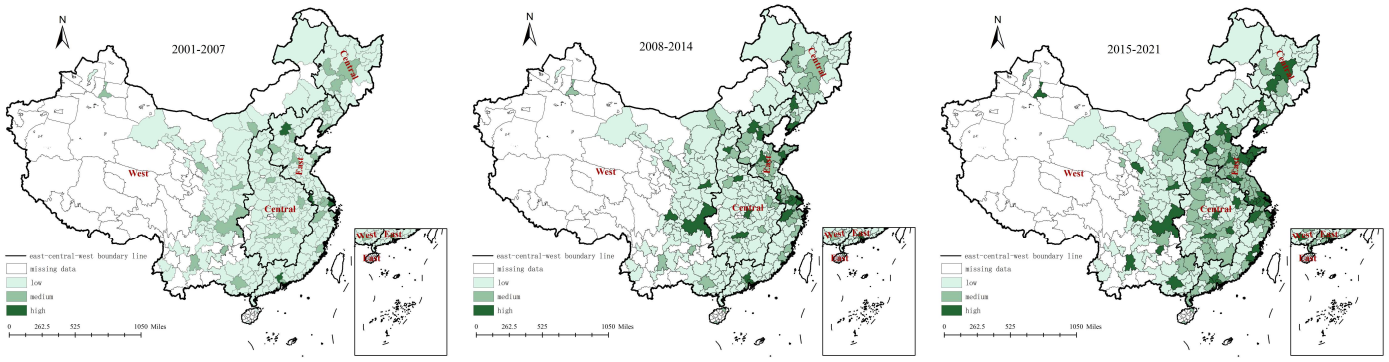


Figure 5. The spatial distribution characteristic in UR level in China (2001–2021).

As shown in Figure 5, with the rapid economic growth, improvement in urban governance, etc., the UR level of most Chinese cities has generally been rising. However, due to factors such as resource endowments, geographical location, and development foundations, there are obvious spatial differences in the development of UR from 2001 to 2021. Over time, the gap between cities has not yet narrowed substantially, culminating in a ladder characteristic of "high in the coast and low in inland areas". The high level of urban resilience is mainly concentrated in provincial capitals or sub-provincial and above cities and shows a pattern of spreading to the neighboring cities with these cities as the core.

Figure 6 shows the spatial distribution characteristics of LM in China. With the deepening of the land marketization reform, the level of LM concessions in most Chinese cities has risen, and the disparity between cities has narrowed. In the early stage (2001–2007), when the reform began, the gap in LM levels was the largest between regions, exhibiting a pattern of lower levels in the east and higher levels in the west. Following the implementation of the market-oriented reform policy of industrial land transfer in 2007, the land market entered a phase of full marketization, leading to substantial increases in LM levels across regions, with the eastern region experiencing the most significant growth. This growth is likely related to the region's earlier economic development and stronger factor market competitiveness, which facilitated

a higher rate of market-oriented land transfer reforms and, consequently, higher overall LM levels. In the third interval (2015–2021), LM levels across regions showed slight increases and reached a relatively stable state.

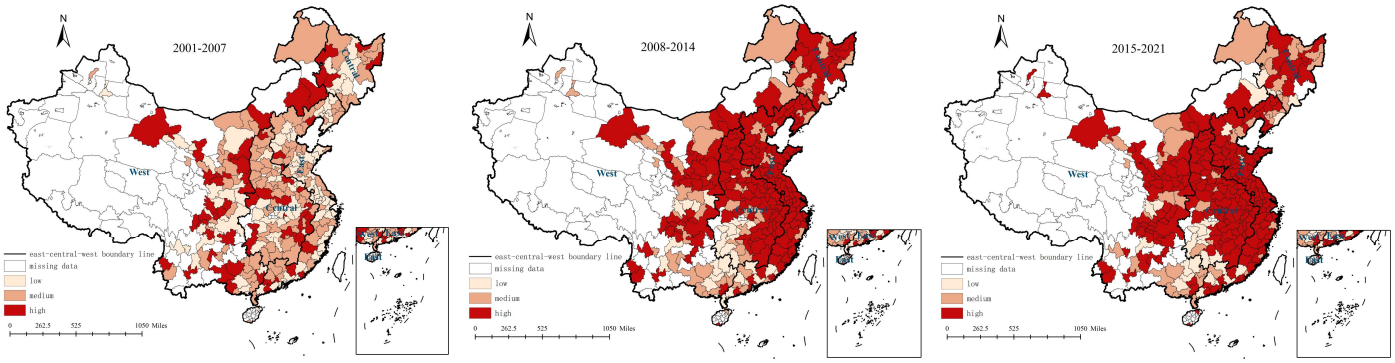


Figure 6. The spatial distribution characteristics in LM level in China (2001–2021).

4.2. Correlation Analysis

Table 5 reports the correlation coefficients for the main variables. The results show that the correlation coefficient between LM and UR is 0.061, which is significant at the 1% level, initially validating the role of LM in fostering UR. In addition, the maximum value of the correlation coefficient between the main variables was 0.700, suggesting a potential concern for multicollinearity. For this reason, we performed a variance inflation factor (VIF) test, which revealed that the values of VIF between main variables were much below 10. This indicates that the problem of multicollinearity was effectively controlled and did not affect the accuracy of the regression results.

Table 5. Correlation matrix.

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
(1) UR	1.000							
(2) LM	0.061 ***	1.000						
(3) US	−0.119 ***	−0.046 ***	1.000					
(4) PD	0.364 ***	0.034 **	−0.666 ***	1.000				
(5) UL	0.489 ***	−0.029 **	−0.479 ***	0.176 ***	1.000			
(6) FDL	0.166 ***	0.046 ***	−0.045 ***	0.010	0.142 ***	1.000		
(7) INL	0.700 ***	0.115 ***	−0.182 ***	0.492 ***	0.469 ***	0.187 ***	1.000	
(8) FIL	0.456 ***	0.112 ***	−0.157 ***	0.494 ***	0.141 ***	0.060 ***	0.569 ***	1.000

Note: Standard errors in parentheses; *** $p < 0.01$, ** $p < 0.05$.

4.3. Benchmark Regression

Table 6 reports the effect of LM on UR. In the empirical analysis, to ensure model robustness, this paper controls the double fixation of city and time and gradually adds control variables. As control variables are added incrementally, the R2 value increases from 0.356 to 0.387, indicating an improved model fit and enhanced explanatory power for UR. Specifically, column (1) demonstrates the net effect of LM on UR without additional controls. The regression coefficient is positive and statistically significant at the 1% level, suggesting that LM can effectively promote UR improvement. Columns (2)–(7) report the results after gradually adding control variables, where regression coefficients consistently show a significant positive correlation with UR at the 1% level, which suggests that there is a robust and positive correlation between LM and UR. Hypothesis 1 is verified. By controlling for time and city fixed effects, as well as control variables, the empirical analysis finds that a one-standard-deviation increase in LM and UR leads to a 7.8% increase relative to the sample average.

Table 6. Baseline regression results.

Variables	(1) UR	(2) UR	(3) UR	(4) UR	(5) UR	(6) UR	(7) UR
LM	1.395 ***	1.395 ***	1.305 ***	1.277 ***	1.226 ***	1.244 ***	1.255 ***
	(0.198)	(0.198)	(0.195)	(0.194)	(0.195)	(0.194)	(0.195)
US		0.502	1.373 ***	1.754 ***	1.758 ***	1.831 ***	1.839 ***
		(0.406)	(0.406)	(0.407)	(0.406)	(0.406)	(0.406)
PD			3.794 ***	3.670 ***	3.653 ***	3.678 ***	3.697 ***
			(0.301)	(0.300)	(0.300)	(0.300)	(0.300)
UL				2.797 ***	2.772 ***	2.972 ***	2.963 ***
				(0.372)	(0.372)	(0.375)	(0.375)
FDL					0.504 ***	0.533 ***	0.537 ***
					(0.139)	(0.139)	(0.139)
INL						−0.327 ***	−0.319 ***
						(0.086)	(0.086)
FIL							−0.022
							(0.018)
City	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year	Yes	Yes	Yes	Yes	Yes	Yes	Yes
_cons	−0.617 ***	−5.299	−34.973 ***	−38.664 ***	−38.976 ***	−37.942 ***	−37.955 ***
	(0.224)	(3.797)	(4.419)	(4.422)	(4.418)	(4.420)	(4.420)
N	5278	5278	5278	5278	5278	5278	5278
R^2	0.356	0.356	0.376	0.383	0.385	0.387	0.387

Note: Standard errors in parentheses; *** $p < 0.01$.

4.4. Robustness Checks

4.4.1. Alternative Measures of the Independent Variable

As mentioned in the benchmark regression section, this paper empirically analyzes the level of LM using the method of price-weighted land plot percentage and number percentage. To further verify the robustness of the findings, alternative measures of the independent variable are employed: LM1, LM2, LM3, and LM4, the specific measurement methods detailed in the previous section. The regression results are shown in Table 7. The results show that its main effect regression coefficients passed the test at least at the 5% significance level across all alternative measures, with all coefficients showing positive directions. This confirms the robustness of the benchmark analysis.

Table 7. Results for robustness checks—1.

Variables	(1) UR	(2) UR	(3) UR	(4) UR
LM1	0.322 **			
	(0.141)			
LM2		0.797 ***		
		(0.117)		
LM3			0.677 ***	
			(0.137)	
LM4				0.505 **
				(0.235)
Controls	Yes	Yes	Yes	Yes
City	Yes	Yes	Yes	Yes
Year	Yes	Yes	Yes	Yes
_cons	−35.848***	−37.396 ***	−36.894 ***	−35.998 ***
	(4.465)	(4.419)	(4.434)	(4.467)
N	4588	5278	5223	4588
R2	0.370	0.388	0.382	0.370

Note: Standard errors in parentheses; *** $p < 0.01$, ** $p < 0.05$.

4.4.2. Lagged Independent Variable

Considering the possibility of a lagged effect in the benchmark analysis, this paper re-runs the empirical regression after lagging the dependent variables by one period. The results can be seen in column (1) of Table 8. The results demonstrate that the estimated coefficients of the regression remain positive and statistically significant at the 1% test level. This confirms that the benchmark regression results of this paper are still robust.

Table 8. Results for robustness checks—2.

Variables	(1) L.UR	(2) Sample Interval 2007–2021	(3) GMM
L.UR			1.211 ***
			(0.114)
LM	1.338 ***	1.255 ***	0.245 **
	(0.184)	(0.195)	(0.118)
Controls	Yes	Yes	Yes
City	Yes	Yes	Yes
Year	Yes	Yes	Yes
_cons	−31.306 ***	−37.955 ***	2.855
	(4.011)	(4.420)	(2.970)
AR(1)			0.078
AR(2)			0.503
Hansen P			0.146
N	4948	5278	4948
R2	0.415	0.387	

Note: Standard errors in parentheses; *** $p < 0.01$, ** $p < 0.05$.

4.4.3. Changing the Sample Interval

At the end of 2006, China's State Council issued a policy requiring industrial land to be sold through "tendering, auctioning, and listing", thereby marking the full marketization of China's land transfer market. To account for the policy change, this paper restricts the sample period to 2007–2021 and re-runs the empirical regression. The results are presented in column (2) of Table 8. The results show that the regression coefficient remains significantly positive at the 1% level, indicating the benchmark regression results of this paper are still robust.

4.4.4. Endogeneity Analysis

There may be endogeneity problems between LM and UR, mainly in the form of reverse causality and unobservable omitted variables. Moreover, the current UR may be affected by the past UR. To solve the above endogeneity problems, this paper uses a systematic GMM estimation method for endogeneity testing, and the results are shown in column (3) of Table 8. The result shows that the regression coefficient is 1.211 and passes the 1% significance level test, and the endogeneity test results continue to support the benchmark regression results. The P-values of residual autocorrelation tests AR (1) and AR (2) and the Hansen test indicate the validity of the system GMM method, which further supports the reliability of the benchmark regression results.

4.5. Mechanism Analysis

The previous theoretical analysis shows that LM can enhance UR through resource allocation, industrial structure upgrading, and technological innovation. To empirically verify whether the mechanism effects hold, the mediation model is constructed, referencing Baron and Kenny [89]:

$$UR_{i,t} = a_0 + a_1 LM_{i,t} + \sum a_2 control_{i,t} + Year_{i,t} + \mu_i + \varepsilon_{it} \quad (9)$$

$$M_{i,t} = b_0 + b_1 LM_{i,t} + \sum b_2 control_{i,t} + Year_{i,t} + \mu_i + \varepsilon_{\mathrm{it}} \quad (10)$$

$$UR_{i,t} = c_0 + c_1 LM_{i,t} + c_2 M_{i,t} + \sum c_3 control_{i,t} + Year_{i,t} + \mu_i + \varepsilon_{\mathrm{it}} \quad (11)$$

where Formula (9) represents the impact of LM on UR, Formula (10) represents the impact of LM on mechanism variables, and Formula (11) is used to verify the existence of mechanism effects. Moreover, M denotes the mechanism variables, including resource mismatch (RA), technological innovation (TI), and industrial structure optimization (IND). The meanings of the remaining variables are consistent with those in Formula (1). Table 9 reports the empirical regression results.

Table 9. Results for the mechanism analysis.

Variables	(1) UR	(2) RA	(3) UR	(4) TI	(5) UR	(6) IND	(7) UR
LM	1.255 ***	−0.017 *	1.194 ***	0.494 ***	1.004 ***	0.031	1.223 ***
	(0.195)	(0.010)	(0.191)	(0.060)	(0.193)	(0.028)	(0.192)
RA			−3.602 ***				
			(0.274)				
TI					0.508 ***		
					(0.046)		
IND							1.055 ***
							(0.098)
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
City	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year	Yes	Yes	Yes	Yes	Yes	Yes	Yes
_cons	−37.955 ***	0.671 ***	−35.540 ***	−14.400 ***	−30.634 ***	2.045 ***	−40.112 ***
	(4.420)	(0.225)	(4.349)	(1.358)	(4.415)	(0.630)	(4.375)
Sobel Z		7.669 ***		13.17 ***		2.729 ***	
Bootstrap test		[0.261, 0.447]		[0.968, 1.344]		[0.040, 0.276]	
N	5278	5278	5278	5278	5278	5278	5278
R2	0.387	0.432	0.408	0.855	0.402	0.519	0.401

Note: Standard errors in parentheses; *** $p < 0.01$, * $p < 0.1$.

Columns (2)–(3) of Table 9 show the results of the tests of the mechanism effect of resource mismatch. Column (2) reports that the regression coefficient of LM on resource mismatch is −0.017, which is significantly negative at the 10% test level. It is important to mention that when resource mismatch increases, the efficiency of resource allocation decreases. Hence, the process of LM can enhance the effectiveness of resource allocation. In column (3), both the regression coefficients of LM and resource mismatch pass the 1% significance level test, and the regression coefficient of c1 = 1.194 is smaller than a1 = 1.255 for LM, which indicates that LM can indirectly promote UR through resource allocation, and the mediating effect is established, so H2 is verified. Meanwhile, the indirect effect of both passing the Soble test and Bootstrap test and H2 is once again verified by calculating the mediating effect of resource allocation as approximately 0.049 of the total effect.

Columns (4)–(5) of Table 9 show the results of the tests of the mechanism effect of technological innovation. In column (4), the regression coefficient of LM on technological innovation is 0.494, which is significantly positive at the 1% test level. In column (5), the regression coefficients of LM and technological innovation on UR both pass the 1% significance level test, and the regression coefficient of c1 = 0.508 is smaller than a1 = 1.255 for LM, which indicates that LM can indirectly promote UR through the effect of resource allocation, and the mediating effect is established, so H3 is verified. Meanwhile, the indirect effect of both passing the Soble test and Bootstrap test, H3 is once again verified. Additionally, the mediating effect of technological innovation was calculated to be about 0.200 of the total effect.

Columns (6)–(7) of Table 9 show the results of the tests of the mechanism effect of industrial structure optimization. In column (7), similar to the previous section, the empirical regression coefficients of LM and industrial structure optimization on UR are both significantly positive at the 1% level. However, in column (6), the regression coefficient of LM on industrial structure optimization is 0.031, which does not pass the test of significance level. At this time, the result of the Soble test Z value is 2.729, which is significant at the 1% statistical level, and the Bootstrap indirect effect estimate shows a confidence interval of [0.040, 0.276], which does not contain 0, indicating that the mediating effect of industrial structure optimization exists. H4 is verified. Additionally, the mediating effect of technological innovation was calculated to be about 0.026 of the total effect.

4.6. Heterogeneity Analysis

4.6.1. Regional Heterogeneity

Owing to China's expansive land area, there is a noticeable spatial variation in the distribution of natural resources and economic development levels throughout the eastern, central, and western regions. Moreover, the level of LM varies across these regions. This paper further explores whether the effects of LM on UR differ across different geographies.

In this paper, the 282 sample cities are divided into three regions, namely East, Central, and West, based on their geographical position (shown in Appendix A). An empirical regression analysis is then conducted sequentially, controlling for the city-fixed and city-fixed effects. The results are presented in Table 10. The results indicate that the regression coefficients of LM on UR are significantly positive at the 1% test level in either region. Additionally, these coefficients exhibit a declining trend from East to West. This may be due to the higher economic development levels, and the more perfect market mechanism in eastern cities, resulting in enhanced land allocation and utilization efficiency, thereby boosting UR more significantly. Conversely, in the western region, characterized by remoteness; initial resource scarcity; abundant land resources, leading to lower land cost; and a more complex institutional environment, LM plays a less pronounced role in promoting UR.

Table 10. The results of the regional heterogeneity analysis.

Variables	(1) Eastern Cities	(2) Central Cities	(3) Western Cities
LM	1.035 **	1.023 ***	0.650 ***
	(0.438)	(0.175)	(0.241)
Controls	Yes	Yes	Yes
City	Yes	Yes	Yes
Year	Yes	Yes	Yes
_cons	−244.658 ***	−5.495	−35.460 ***
	(26.133)	(3.505)	(5.156)
N	1922	1935	1421
R2	0.477	0.507	0.531

Note: Standard errors in parentheses; *** $p < 0.01$, ** $p < 0.05$.

4.6.2. Urban-Scale Heterogeneity

This paper divides the sample cities into two groups based on the administrative level, with the higher the administrative level, the larger the city size: sub-provincial and higher cities, and prefectural cities. The results are shown in columns (1)–(2) in Table 11. The results indicate that the promotion effect of LM is stronger in prefecture-level cities, whereas the regression coefficient for sub-provincial and above cities does not pass the significance level test. This disparity may stem from the fact that central cities with higher administrative levels, like sub-provincial and above cities, wield greater control over administrative resources and developmental positioning. Consequently, they are less reliant on land finance revenues compared to neighboring prefectural cities. Therefore, the influence of LM on UR is not as pronounced in these areas.

Further, this paper divides the sample cities into two groups based on population, with the larger the population, the larger the city size: large cities (with populations of 1 million and above) and small–medium cities (with populations below 1 million). The results are shown in Table 11 in columns (3)–(4). The results show that the impact of LM is more pronounced in larger cities. This trend may be attributed to the larger cities having more comprehensive systems and fully utilizing market mechanisms in their land markets. On the contrary, smaller cities, constrained by their scale of economic development, are eager to seek economic growth paths and rely excessively on land finance revenue. However, the market mechanism is imperfect; they still rely on the past methods of land allocation, such as favoring large-scale industrial transfers and restricting the supply of commercial and residential land, to drive regional economic development. This approach, however, may not effectively enhance urban resilience.

Table 11. The results of the urban-scale heterogeneity analysis.

Variables	(1) Cities at the Sub-Provincial Level and Above	(2) Prefecture-Level Cities	(3) Small- and Medium-Sized Cities	(4) Large Cities
LM	−0.410	0.941 ***	0.378 ***	1.075 ***
	(1.646)	(0.112)	(0.100)	(0.381)
Controls	−21.617 ***	0.835 ***	−0.295	1.372 *
City	Yes	Yes	Yes	Controls
Year	Yes	Yes	Yes	Yes
_cons	134.107 **	−16.827 ***	0.377	−44.419 ***
	(52.898)	(2.519)	(4.448)	(8.664)
N	391	4887	2714	2564
R2	0.798	0.509	0.588	0.493

Note: Standard errors in parentheses; *** $p < 0.01$, ** $p < 0.05$, and * $p < 0.1$.

5. Conclusions and Discussion

5.1. Conclusions

China, as the world's largest developing country and the second-largest economy, plays a crucial role in achieving the Sustainable Development Goals (SDGs) through its efforts to promote UR. This paper investigates the direct and indirect effects of LM on UR using panel data from Chinese prefecture-level and above cities, spanning from 2001 to 2021. The main findings are as follows: (1) LM efficiently facilitates UR, and the results remain strong even after undergoing several robustness tests. (2) The mechanism analysis shows that LM serves not only a direct role but also an indirect role through resource allocation, industrial structure optimization, and technological innovation. (3) The heterogeneity analysis shows that cities with better geographic locations, larger population sizes, and lower administrative levels are more effective in improving UR as a result of LM.

5.2. Discussion

More specifically, our empirical analysis is divided into two primary components. The first part examines the direct impact of LM on UR. The second part analyzes the path of influence between the two on this basis, aiming to open the "black box" of the impact process of LM on UR.

Firstly, the results show that LM plays a significant positive role in the enhancement of UR. Specifically, when LM increases by one standard deviation, the mean value of UR increases by 7.8% accordingly. Previous studies have shown that LM can promote economic growth, ecological protection, etc. [18,20]. Our results once again confirm the positive outcomes and expand the research on LM effects by focusing on urban system resilience. As the carrier of urban production activities, LM effectively mitigates rent-seeking and corruption [57], addresses mismatches and inefficiencies in land resources [15], relieves the pressure on urban finances, fosters infrastructure improvement, and strengthens the ability to deal with various external shocks.

Secondly, in promoting UR, LM serves not only a direct role but also an indirect role through resource allocation, industrial structure optimization, and technological innovation. These findings are consistent with those of previous research, which indicates that resource allocation, industrial structure upgrading, and technological innovation are pivotal for enhancing urban risk management and UR [10,12,90]. Specifically, these three effects contribute to a more sensitive perception of urban risk, a better response when risk occurs, and a faster repair after disaster, thereby contributing to sustainable urban resilience.

Thirdly, the effect of LM areas varies across cities. This promotion effect is significantly stronger in large cities than in small- and medium-sized cities. Additionally, it is more pronounced in the eastern regions of the country compared to the central and western regions and is greater in prefectural-level cities than in cities at the sub-provincial level and above.

5.3. Policy Suggestions

Based on the results described above, some policy recommendations are presented for promoting UR.

Firstly, we recommend continuously improving the market-oriented land transfer system. The empirical data demonstrate that LM contributes to the enhancement of resilience. Hence, local governments must persist in advancing market-oriented land reforms through enhancing the land system. On the one hand, it is necessary to clearly define the authority and obligations of local governments during the land transfer process. On the other hand, it is necessary to enhance the oversight and evaluation of the land transfer activities carried out by local governments. This is to ensure that the land transfer procedures are legal and the land use is in compliance with the law.

Secondly, we recommend optimizing resource allocation and stimulating efficiency. From the empirical results, LM can enhance UR through resource allocation. Therefore, government departments should foster a favorable market environment that promotes the unrestricted flow of various production factors and ensures their optimal allocation. Additionally, collaboration among various stakeholders—universities, research institutes, and enterprises—should be encouraged to develop a comprehensive talent cultivation system. This approach involves optimizing talent development pathways, promoting the rational allocation of labor resources, and ultimately driving improvements in UR.

Thirdly, we recommend formulating a comprehensive development strategy and effectively promoting industrial structure upgrading and transformation. The empirical results demonstrate that LM can promote UR through industrial structure upgrading. Therefore, government departments should focus on optimizing the city's economic structure. On the one hand, it is essential to refine and enhance industrial service policies, guiding the market to create a fair development environment and accelerating the upgrading of industrial structures. On the other hand, establishing an effective capacity exit mechanism is necessary to bolster local industrial competitiveness and upgrade capacity. This approach will stimulate market demand, accelerate industrial adjustment within the service industry, and promote the rationalization of regional industries.

Fourthly, deepen technological innovation. The empirical results show that technological innovation is an important path to promote UR. To this end, the government should increase the new investment in scientific research, rationally allocate innovation support funds, and improve the depth of technological research and development to enhance the resilience of the city. Additionally, the government can improve the policy support for technological innovation, optimize the innovation environment, and release more innovative kinetic energy, thereby improving the quality and efficiency of urban resilience development.

Lastly, we recommend implementing regional differentiation policies. The heterogeneity analysis reveals variations in the influence of LM across different regions. Therefore, when pushing the land marketization reform, it is crucial to thoroughly consider the distinctive features of various regions and designate targeted policy initiatives according to local conditions. In the West or the smaller cities, it is crucial to tap the potential of the LM; improve the market environment; and pay attention to the contributions of science and technology, capital, and other elements to enhance the city's resilience development more vigorously.

5.4. Limitations

Although this paper provides a detailed empirical analysis of the relationship between LM and UR, it still has certain limitations. First, this paper explores the transmission mechanism of LM on UR from allocation effect, structural effect, and technology effect. However, in both theoretical construction and empirical testing, there are still several factors that remain unaddressed, such as the spatial spillover effect of the influence and the moderating effect. Future research should aim to deepen the theoretical model by incorporating adjustment variables, spatial spillovers, and other relevant factors. Secondly, this paper

controls the city-fixed effects, a series of control variables, and examines heterogeneity related to the size or area of cities during empirical analysis. To a certain extent, the external disturbing factors affecting the resilience of the city were controlled. However, each city possesses different levels of political, economic, cultural, and natural environments, all of which have an impact on UR. Future research should consider these diverse factors more comprehensively when selecting sample cities, thereby providing a more nuanced understanding of the relationship between LM and UR.

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

Appendix A

Table A1. List of cities.

Region	City
East	Handan Huludao Quzhou Weifang Huzhou Qingyuan Meizhou Quanzhou Shaoxing Taizhou Longyan Heze Cangzhou Dezhou Huaian Guangzhou Jinzhou Zaozhuang Wuxi Chaozhou Ningbo Yangjiang Dandong Liaocheng Chaoyang Shijiazhuang Tieling Ningde Panjin Jinhua Rizhao Jining Suzhou Zibo Changzhou Zhenjiang Nanjing Yingkou Shanwei Yangzhou Tianjin Xingtai Benxi Hangzhou Taizhou Fushun Zhangzhou An'shan Qinhuangdao Haikou Fuzhou Qingdao Langfang Heyuan Nanping Foshan Lianyungang Zhongshan Huizhou Zhangjiakou Suqian Fuxin Jiaxing Xiamen Dongguan Shenzhen Hengshui Maoming Nantong Zhanjiang Jieyang Tangshan Zhoushan Jinan Beijing Shantou Chengde Sanming Zhuhai Dalian Yunfu Linyi Wenzhou Weihai Xuzhou Sanya Putian Jiangmen Shenyang Baoding Tai'an Yancheng Zhaoqing Liaoyang Yantai Shaoguan Lishui Shanghai Dongying Binzhou
Central	Anyang Anqing Baicheng Xinxiang Shuangyashan Yongzhou Jingzhou Yiyang Suizhou Jingdezhen Datong Changsha Xinyu Liaoyuan Luohe Nanchang Suzhou Jinzhong Zhangjiajie Zhengzhou Tonghua Loudi Luoyang Pingdingshan Huaibei Huaihua Daqing Jixi Bengbu Sanmenxia Taiyuan Huangshan Linfen Siping Yichun Fuyang Jingmen Jilin Songyuan Ji'an Bozhou Jiujiang Zhoukou Lu'an Shuozhou Ma'anshan Xinzhou Chizhou Wuhan Xiaogan Lvliang Zhuzhou Qitaihe Yichun Heihe Huangshi Yuncheng Zhumadian Yangquan Changde Jiamusi Nanyang Changchun Yichang Jiaozuo Jincheng Xuancheng Chenzhou Hegang Hefei Changzhi Yingtan Xianning Puyang Qiqihar Harbin Xuchang Huanggang Pingxiang Kaifeng Hengyang Baishan Huainan Suihua Shiyan Hebi Xiangyang Wuhu Xinyang Ganzhou Xiangtan Mudanjiang Tongling Ezhou Shangqiu Shangrao Yueyang Fuzhou Chuzhou Shaoyang
West	Yulin Tianshui Wuhai Zigong Hohhot Guangyuan Ankang Jiuquan Baise Baoshan Yulin Liupanshui Panzhihua Lijiang Xining Tongchuan Guyuan Laibin Lanzhou Xi'an Dingxi Guiyang Guang'an Chongqing Yinchuan Chongzuo Shangluo Wuzhou Yibin Guigang Nanning Dazhou Lincang Longnan Ziyang Qujing Yan'an Wuwei Jinchang Guilin Jiayuguan Luzhou Zhangye Deyang Zunyi Chifeng Leshan Ordos Bazhong Mianyang Yuxi Hanzhong Liuzhou Meishan Pingliang Hulunbuir Qingyang Kunming Qingzhou Tongliao Zhaotong Ya'an BayanNur Ulanqab Karamay Weinan Shizuishan Fangchenggang Hezhou Baiyin Baoji Urumqi Suining Xianyang Anshun Neijiang Wuzhong Nanchong Chengdu Beihai Hechi

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