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The impact of city-county mergers on urban land green utilization efficiency: evidence from China

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As an urbanization effort propelled by administrative measures, city-county merger has been particularly prevalent in the administrative district adjustments of prefecture-level cities in China. However, there has been scant research focusing on the policy's impact on the efficiency of green utilization of urban land. We selected panel data from Chinese prefecture-level cities from 2003 to 2020, employing the slack-based measure (SBM) model that accounts for undesirable outputs, in conjunction with the Malmquist-Luenberger (ML) productivity index, to measure the efficiency of green land use in cities. Building on this, we utilized the staggered difference-in-differences (DID) model to investigate the impact of policies expanding cities through land leasing on the green utilization efficiency of urban land. Our findings indicate that the city-county merger has generally led to a decline in the efficiency of green utilization of urban land. Further mechanism analysis suggests that local governments' excessive focus on land leasing for economic development, leading to a low-quality development model, is a significant factor contributing to the decline in green utilization efficiency of urban land. Specifically, the city-county merger policy indirectly reduces land green utilization efficiency by increasing industrial land leasing revenue, the number of industrial polluting enterprises, lowering the rationalization level of urban industrial structure, and raising the overachievement of urban economic growth targets. Further research reveals that the policy has heterogeneous impacts on land green utilization efficiency across different regions, city sizes, administrative levels, economic development levels, and urban planning types. The policy has a more significant inhibitory effect on land green utilization efficiency in non-eastern regions, smaller cities, peripheral cities, underdeveloped cities, and resource-based cities. Our study confirms that as a significant urbanization reform initiative, the effectiveness of the city-county merger still relies on the traditional extensive growth model based on land expansion, which is not conducive to enhancing the efficiency of green land use in cities.

KEYWORDS

administrative division adjustment, urban land green utilization efficiency, city-county merger, manage land, DID

1 Introduction

Land, as a finite and precious resource, plays a crucial role in the sustainable development of cities and the quality of life for urban inhabitants (Platt, 1995). Efficient green land use aims to minimize negative ecological impacts while fostering economic and social sustainability, optimizing land resource allocation, and enhancing land use efficiency (Pauleit and Duhme, 2000). It serves as a vital metric for assessing urban development sustainability and is pivotal in promoting cities' green and low-carbon transformations. With urban populations and economic activities expanding, the continual enlargement of urban administrative districts has become a norm. This transformation not only alters cities' spatial structures but also significantly impacts urban ecological environments, land resource allocation, and green land use efficiency.

In China, the city-county merger process, converting counties into city-administered districts, is a critical governmental tool to advance urbanization[1]. Unlike developed countries' market-driven urban models, China's urbanization is characterized by extensive, rapid, and government-led initiatives underpinned by public land ownership. The reorganization of administrative divisions has long been a focus of academic inquiry (Alesina et al., 1995; Hanes et al., 2012; Hirota and Yunoue, 2017). Proponents argue that merging administrative units breaks down market barriers, fosters agglomeration effects, and stimulates economic growth (Young, 2000; Tang and Hewings, 2017). Conversely, critics contend that such mergers can impede income growth (Hanes and Wikström, 2008), reduce economic efficiency (Blesse and Baskaran, 2016), inflate administrative costs (Zhang et al., 2023), and hinder economic development quality improvement (Hirota and Yunoue, 2017).

Academic research on land use efficiency has evolved from spatial patterns to decision-making processes and driving mechanisms (Ning et al., 2018; Platt, 1995; Zhou et al., 2020). Methodologically, evaluation indicators have shifted from single economic metrics to comprehensive multi-indicator systems integrating economic outputs and environmental impacts such as carbon emissions and land greening. Non-parametric methods like Data Envelopment Analysis (DEA) are adept at handling "multiple inputs + multiple outputs" scenarios, making them suitable for assessing urban land green utilization efficiency comprehensively (Jiao et al., 2020; Tan et al., 2021). Studies on influencing factors reveal that population size (Braid, 1988), resource endowment (Verburg et al., 2010), infrastructure (Cui et al., 2019), and land finance (Wang et al., 2021) affect land use efficiency. Urbanization is closely linked to land use, yet existing research primarily uses urban population ratios or industrial output proportions to measure urbanization levels, neglecting administratively driven "leapfrog" models like city-county mergers.

Since the 18th National Congress of the Chinese Communist Party, "ecological civilization construction" has been incorporated into the Party Constitution, elevating green development as a national priority. The "14th Five-Year Plan" emphasizes economic and intensive land use, and green urban development transformation. Despite ecological initiatives such as farmland protection and systematic restoration, challenges like high development intensity, soil pollution, and fragile ecosystems persist (Zhang et al., 2022). Research indicates significant room for improving China's land green utilization efficiency (Li et al., 2022). By 2022, China's urban area exceeded 64,000 km^2, with a 65.22% urbanization rate, heightening land and environmental pressures.

Based on panel data from Chinese prefecture-level cities (2003–2020), this study employs a staggered Difference-in-Differences (DID) model to investigate how city-county mergers influence urban land green utilization efficiency and its underlying mechanisms. We explore heterogeneous effects across cities of varying regions, sizes, administrative levels, economic development stages, and urban planning types. Our findings contribute empirical insights into advancing urbanization, transforming economic models, and achieving sustainable urban land use.

2 Theoretical analysis

2.1 City-county mergers and urban land green utilization efficiency

Theoretically, expanding administrative divisions can break down barriers and market segmentation, aiding the integration of administrative zones and unifying urban planning and land use strategies (Sharifi et al., 2023). However, such expansions also increase urban land area, leading to disordered urban growth and reduced land use efficiency (Duranton and Puga, 2020). According to the "Regulations on the Management of Administrative Divisions" issued by the State Council, changes in administrative boundaries between counties and urban districts are proposed by local governments and approved by provincial authorities (State Council, 1985). Unlike market-driven processes in Western countries, administrative changes in China lack citizen participation. While this government-led urbanization method lowers decision-making costs, city-county mergers in underdeveloped areas often reduce efficiency, exacerbate pseudo-urbanization, and deepen urban-rural polarization. Moreover, local governments at all levels in China are responsible for urban construction and local economic development (Besley et al., 2022). In the GDP-oriented promotion model, local officials may prioritize rapid, unsustainable urban development driven by self-interest. Additionally, under state-owned land policies, local governments often use land leasing to intervene in economic activities and industrial layouts, which, alongside land-based financing and investment, accelerates capital and labor influx during city-county mergers but also results in resource waste and challenges sustainable land development (Gyourko et al., 2022).

Land green utilization efficiency seeks to maximize economic benefits while protecting the environment and optimizing resource allocation (Zhou and Lu, 2023). However, post-merger, accelerated urban expansion and infrastructure development often lead to land overdevelopment and ecological damage (Chung and Lam, 2009). Cities pursuing rapid economic growth tend to prioritize economic

1 For detailed policy background, please refer to our Supplementary Material.

indicators through extensive land development and infrastructure, neglecting intensive land use and ecological concerns. This growth model may boost short-term economic metrics but can decrease land green utilization efficiency due to its extensive and unsustainable development practices and irrational spatial planning (Kalnay and Cai, 2003).

Specifically, city-county merger policies may reduce urban land economic efficiency, complicating resource allocation and reducing utilization efficiency (Jones and Hameiri, 2021). Imbalances in public infrastructure investment and research expenditures may further limit developmental potential, affecting overall economic efficiency in land use (Liu et al., 2024; Cai et al., 2022). Additionally, these policies may decentralize spatial development, triggering scattered industrial expansion and new agglomeration centers that weaken central city advantages, fostering irregular urban development (Liao et al., 2023; Rosenthal and Strange, 2020; Anas et al., 1998). Moreover, integrating formerly independent administrative units into municipal administrations increases development pressures on surrounding natural environments, potentially harming land vegetation health (Wellmann et al., 2020; Yu et al., 2018).

Therefore, we propose Hypothesis 1:

H1: City-county merger reforms reduce urban land green utilization efficiency.

2.2 City-county mergers and urban land green utilization efficiency: an analysis of mediating mechanisms

The city-county merger reform alters the authority over state-owned construction land leasing, enhancing the autonomy of prefecture-level governments over land leasing in former county areas, enabling them to generate substantial revenue from leasing residential and commercial land (Li, 2011). Concurrently, with the administrative division adjustments, prefecture-level governments, to promote land development and use within the former county areas, not only need to subsidize industrial land leasing to attract external capital but also need to increase municipal infrastructure investments to create conditions for attracting investments (Tiebout, 1956). This approach often involves large-scale land development and industrial project introduction, which, while boosting fiscal revenue and economic growth in the short term, leads to overdevelopment of land resources and a decline in utilization efficiency (Fritsch and Behm, 2021).

Under the pressures of officials' accountability to higher authorities and career advancement, coupled with the increasing fiscal pressures, local governments, in pursuit of short-term economic growth goals, tend to attract high-pollution, high-energy-consumption, and high-emission manufacturing industries to the merged counties (Hong et al., 2020). While these enterprises boost industrial output and employment, they also increase regional material and energy consumption, raise pollution emission levels per unit output, and cause severe environmental pollution problems.

Rationalization of the industrial structure refers to the coordinated development and optimal allocation among industries, enhancing productivity and resource allocation efficiency across sectors (Hu et al., 2023). However, after the city-county merger, local governments often prioritize the development of high-yield industries such as industrial and real estate sectors to achieve rapid economic growth, neglecting the development of agriculture and services (Yang and Wu, 2015). This irrational industrial structure hinders coordinated development among sectors, reduces resource allocation efficiency, and thus affects land green utilization efficiency.

Economic growth is the most direct and primary goal of the city-county merger reform. At the beginning of the year, local governments in China typically set economic growth targets (usually the GDP growth rate) in their government work reports. After the merger, local governments often adopt aggressive economic policies and development strategies, including large-scale infrastructure construction and industrial project introduction, to achieve economic growth targets. This excessive pursuit of economic growth, while boosting economic figures in the short term, overlooks sustainable resource utilization and environmental protection (Yu et al., 2023).

Based on the above analysis, we propose Hypothesis 2:

H2: City-county merger reduces land green utilization efficiency indirectly by boosting urban industrial land leasing revenue, increasing the number of industrial polluters, lowering the rationalization level of urban industrial structure, and exacerbating the overachievement of urban economic growth targets.

2.3 City-county mergers and urban land green utilization efficiency: a heterogeneity analysis

The eastern regions of China possess early advantages in economic development, investment attraction, talent acquisition, and infrastructure construction. Consequently, these regions achieve more effective land resource utilization and efficient urbanization processes following city-county mergers (Jiao et al., 2020). In contrast, central and western regions encounter greater challenges in economic development and resource allocation due to weaker geographical and economic foundations post-merger.

Smaller cities, with limited population size, market scale, and resource aggregation capabilities, heavily rely on large-scale land development and industrial projects to attract investment and spur economic growth post-merger. However, inadequate infrastructure and public services hinder effective support for urban expansion and industrial upgrading (Hu and Fan, 2020). Moreover, resource constraints in smaller cities lead to increased conflicts of interest between city and county governments, resulting in higher administrative integration costs post-merger (Chung and Lam, 2009).

Under the current administrative system, cities with higher administrative ranks enjoy advantages in land acquisition, financial resources, and policy support. Peripheral cities (Non-sub-provincial or non-provincial capital cities) face disadvantages in administrative rank and resource acquisition capabilities (Gao et al., 2024). Post-merger, these cities encounter greater constraints and challenges in resource allocation and policy support compared to higher-ranked cities.

Less economically developed cities have limited financial resources and often prioritize projects with immediate economic stimulus over investments in technological innovation and ecological protection post-merger (Li and Lin, 2017). Conversely, economically developed cities emphasize quality economic development and environmental protection, utilizing scientific planning and technological innovation to enhance land green utilization efficiency.

Resource-based cities, reliant on natural resource extraction and processing industries such as minerals and forestry, lack incentives for improving resource utilization efficiency through technological innovation (Ruan et al., 2020). Post-merger, these cities continue to prioritize resource industries in land development and industrial growth, leading to deindustrialization and neglect of manufacturing and high-tech sectors (Yin and Miao, 2024). This results in resource misallocation and reduced land green utilization efficiency due to the entrenchment of production factors within the resource industry system.

Based on the above analysis, we propose Hypothesis 3:

H3: City-county mergers exert a more pronounced inhibitory effect on land green utilization efficiency in non-eastern regions, smaller cities, peripheral cities, underdeveloped cities, and resource-based cities.

Finally, Figure 1 provides a visual summary of the theoretical analysis discussed above.

3 Research design

3.1 Model setting

3.1.1 Data envelopment analysis

Data Envelopment Analysis (DEA) is a non-parametric statistical method used to evaluate the production efficiency of Decision Making Units (DMUs) across multiple inputs and outputs. Tone (2004) developed the Slacks-Based Measure (SBM) model incorporating undesirable outputs to assess economic and environmental efficiency. Building on this, we utilize the Malmquist-Luenberger (ML) productivity index to measure green land use efficiency (Boussemart et al., 2003).

Suppose there are n DMUs, with each city treated as a DMU $(n = 1, 2, 3, \ldots, n)$. Each DMU includes inputs, desirable outputs, and undesirable outputs represented by vectors $\mathbf{X}, \mathbf{Y}, \mathbf{Z}$. Specifically, $\mathbf{X} = [\mathbf{x_1}, \ldots, \mathbf{x_n}] \in \mathbb{R}^{m\times n}$, $\mathbf{Y} = [\mathbf{y_1}, \ldots, \mathbf{y_n}] \in \mathbb{R}^{s_1\times n}$, and $\mathbf{Z} = [\mathbf{z_1}, \ldots, \mathbf{z_n}] \in \mathbb{R}^{s_2\times n}$. The efficiency measure is defined as:

$$E(x,y,z) = \begin{cases} \rho = \min \dfrac{1 - \frac{1}{m}\sum_{i=1}^{m} \frac{s_i^x}{x_{ij}}}{1 + \frac{1}{s_1 + s_2}\left(\sum_{r=1}^{s_1} \frac{s_r^y}{y_{rj}} + \sum_{k=1}^{s_2} \frac{s_k^z}{z_{kj}}\right)} \\ \mathbf{x_j} = \mathbf{X\lambda} + \mathbf{s^x} \\ \mathbf{y_j} = \mathbf{Y\lambda} - \mathbf{s^y} \\ \mathbf{z_j} = \mathbf{Z\lambda} + \mathbf{s^z} \\ \mathbf{s^x} \geq 0, \mathbf{s^y} \geq 0, \mathbf{s^z} \geq 0, \boldsymbol{\lambda} \geq 0 \end{cases} \tag{1}$$

In Equation 1, $\mathbf{s^x} \in \mathbb{R}^m$, $\mathbf{s^y} \in \mathbb{R}^{s_1}$, and $\mathbf{s^z} \in \mathbb{R}^{s_2}$ represent the slacks for inputs, desirable outputs, and undesirable outputs, respectively. ρ denotes the efficiency value, where m, s_1, and s_2 are the numbers of variables for inputs, desirable outputs, and undesirable outputs.

Based on the efficiency values derived from the SBM model incorporating undesirable outputs, the ML productivity index is computed to determine green land use efficiency for each DMU, as shown in Equation 2:

$$ML^{t+1}(x^t, y^t, z^t, x^{t+1}, y^{t+1}, z^{t+1}) = \left[\frac{E^t(x^{t+1}, y^{t+1}, z^{t+1})}{E^t(x^t, y^t, z^t)} \cdot \frac{E^{t+1}(x^{t+1}, y^{t+1}, z^{t+1})}{E^{t+1}(x^t, y^t, z^t)}\right]^{\frac{1}{2}} \tag{2}$$

3.1.2 Staggered DID

The city-county merger reform in China presents characteristics akin to a quasi-natural experiment. Therefore, we apply a staggered difference-in-differences (DID) approach, controlling for individual and time fixed effects to mitigate potential sample selection biases. This method ensures the DID model's objectivity, treating the treatment variable as quasi-random:

$$LGUE_{ct} = \beta_0 + \beta_1 Merger_c \times Post_{ct} + \beta_2 IS_{ct} + \beta_3 DO_{ct} + \beta_4 UT_{ct} + \beta_5 ERI_{ct} + \sigma_c + \sigma_t + \varepsilon_{ct} \tag{3}$$

Here, β_0 denotes the intercept, a constant not varying across time or entities. The dependent variable $LGUE_{ct}$ measures urban land green utilization efficiency, with subscripts denoting city c and time t. $Merger_c \times Post_{ct}$ represents the interaction effect of city-county mergers at time t in city c. $Merger_c$ is a dummy variable indicating implementation of the city-county merger policy (1 if implemented between 2004 and 2020, 0 otherwise), while $Post_{ct}$ indicates timing of policy implementation (1 if implemented in city c at time t, 0 otherwise). Control variables $IS_{ct}, DO_{ct}, UT_{ct}, ERI_{ct}$ may influence $LGUE$. σ_c and σ_t represent city and time fixed effects respectively, and ε_{ct} is the error term. Our focus is on β_1, the coefficient indicating the net impact of city-county mergers on urban land green utilization efficiency.

The parallel trends assumption is fundamental to the validity of the Difference-in-Differences (DID) method. It posits that, in the absence of intervention, the outcome variables for both the treatment and control groups would follow the same trend. The validity of this assumption is crucial for attributing the observed effects to the intervention rather than to other factors. Therefore, following the approach of Beck et al. (2010), we expand Equation 3 to conduct the parallel trends test:

$$LGUE_{ct} = \phi_0 + \sum_{i=-3}^{3} \phi_i Merger_c \times Post(i) + \phi_4 IS_{ct} + \phi_5 DO_{ct} + \phi_6 UT_{ct} + \phi_7 ERI_{ct} + \sigma_c + \sigma_t + \varepsilon_{ct} \tag{4}$$

In Equation 4, $Post(i)$ represents the dummy variable for the timing of policy implementation, which takes the value one in the i^{th} year after (before) the policy implementation, and 0 otherwise. In the time series analysis of policy implementation, we designate any time point more than

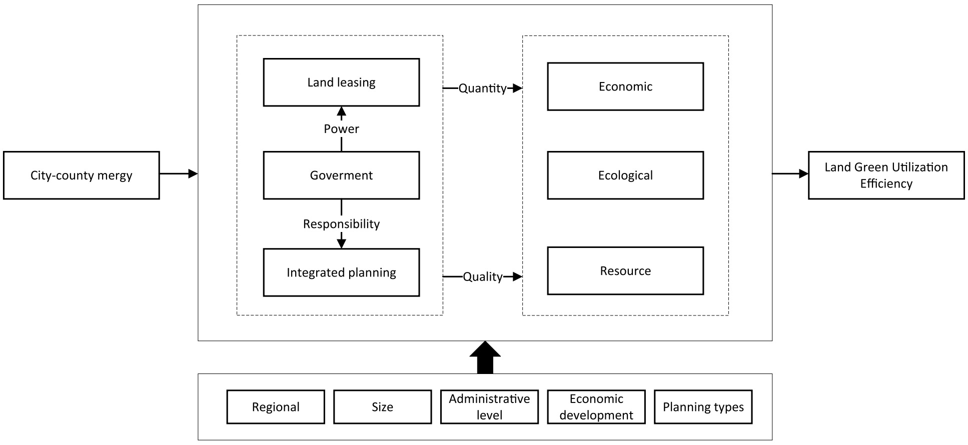

FIGURE 1
Theoretical logic diagram.

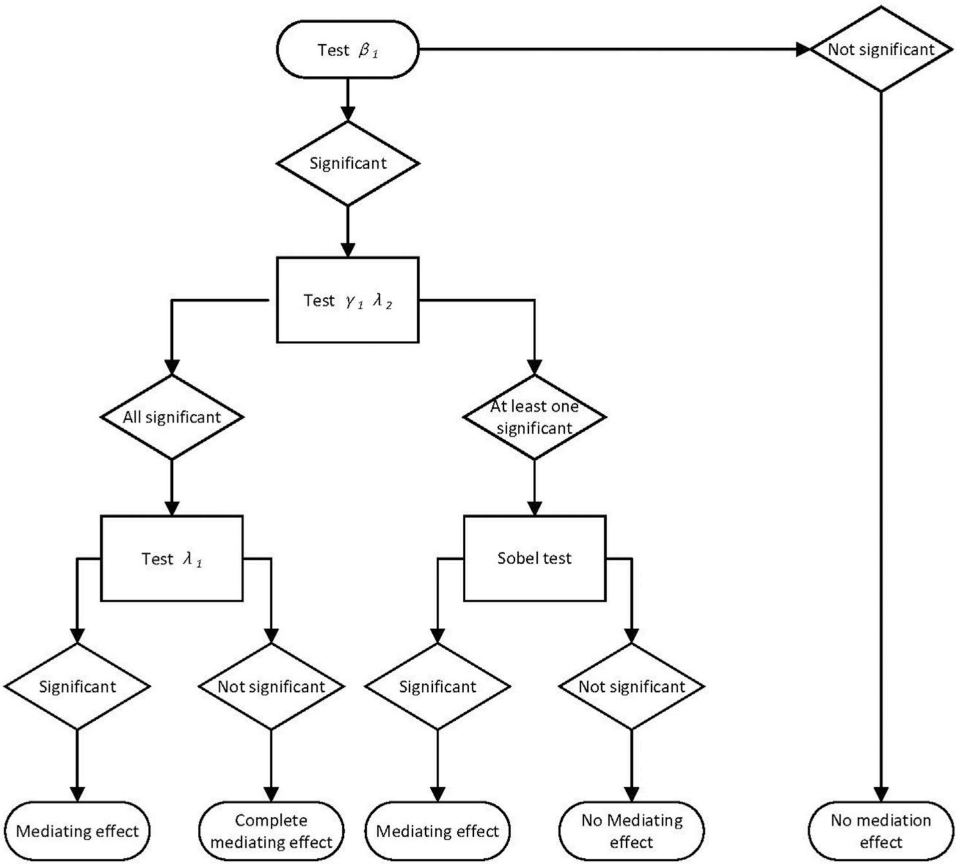

FIGURE 2
Mediation effect testing process.

3 years after the policy implementation as "the third year" to standardize the comparison of long-term effects. Similarly, any time point more than 3 years before the policy implementation is also labeled as "the third year".

3.1.3 Mediation effect model

The mediation effect model, often referred to simply as mediation, is utilized in statistical analysis to elucidate the mechanism by which an independent variable affects a

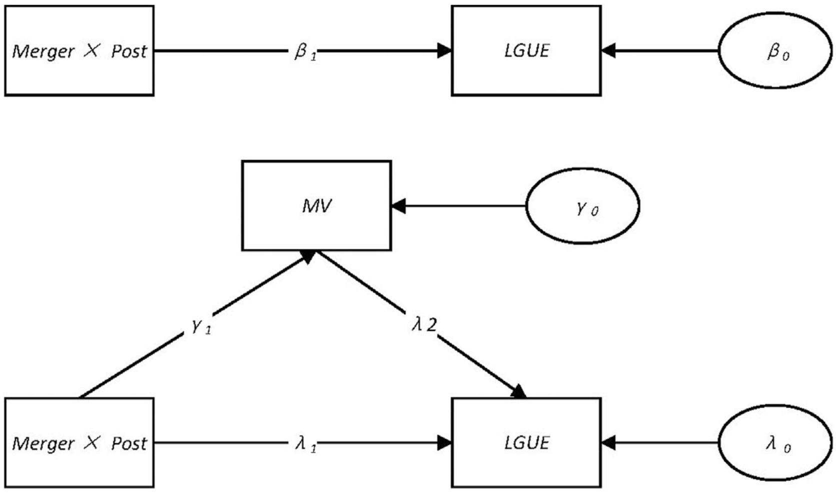

FIGURE 3
Diagram illustrating the meaning of the mediation effect.

dependent variable through one or more intermediary variables known as mediators (Zhao et al., 2010).

$$MV_{ct} = \gamma_0 + \gamma_1 Merger_c \times Post_{ct} + \gamma_2 IS_{ct} + \gamma_3 DO_{ct} + \gamma_4 UT_{ct} + \gamma_5 ERI_{ct} + \sigma_c + \sigma_t + \varepsilon_{ct} \quad (5)$$

$$LGUE_{ct} = \lambda_0 + \lambda_1 Merger_c \times Post_{ct} + \lambda_2 MV_{ct} + \lambda_2 IS_{ct} + \lambda_3 DO_{ct} + \lambda_4 UT_{ct} + \lambda_5 ERI_{ct} + \sigma_c + \sigma_t + \varepsilon_{ct} \quad (6)$$

Here, MV_{ct} represents the mediating mechanism variable under examination, with the other variables retaining their definitions as outlined in Equation 3.

The mediation effect model is tested through the following steps: First, assess the direct impact of the explanatory variable, city-county merger, on the dependent variable, urban land green utilization efficiency. This involves testing the significance of the coefficient β_1 for $Merger_c \times Post_{ct}$ in Equation 3. If β_1 is not significant, further testing ceases, as the base Equation 3 already indicates a significant suppression of urban land green utilization efficiency due to city-county mergers. Second, test the significance of the regression coefficient γ_1 for the city-county merger policy on the mediating variable in Equation 5, and λ_2, the regression coefficient of the mediating variable on the dependent variable, urban land green utilization efficiency, in Equation 6. If both γ_1 and λ_2 are significant, proceed to examine the significance of the coefficient λ_1 for the city-county merger variable in Equation 6. A significant λ_1 indicates a notable mediating effect; its insignificance suggests a complete mediating effect. Third, if γ_1 or λ_2 is insignificant, conduct a Sobel test. A successful Sobel test denotes a significant mediating effect; failure indicates otherwise. The mediation effect testing process is visualized in Figure 2. In this study, a significant mediation effect implies that $Merger \times Post$ impacts $LGUE$ through the mediating variable MV, as depicted in Figure 3.

3.2 Variable construction

3.2.1 Dependent variable

Urban Land Green Utilization Efficiency ($LGUE$). The green utilization efficiency of land (LGUE) refers to the sustainable use of land through scientifically sound management and technical measures that enhance land productivity while minimizing negative environmental impacts (Den and Gibson, 2020; Ma et al., 2023). This includes maximizing economic output, protecting the ecological environment, and efficiently using resources. Specifically, LGUE encompasses the following aspects. Economic aspect, maximizing the economic output from land use, such as the output value of the secondary and tertiary industries in urban areas, given certain production technology conditions and input levels. Ecological and environmental aspect, emphasizing the protection and enhancement of the ecological environment during land use to maximize ecological benefits, such as increasing green spaces in urban built-up areas and reducing undesirable outputs like pollution and carbon emissions. Resource utilization aspect, enhancing the efficiency of inputs such as land, capital, labor, and energy through rational planning and management to reduce resource waste.

We measure the urban land green utilization efficiency using the ML index calculated based on the SBM model. The input indicators include land, labor, capital, and energy, while the output indicators are categorized into undesirable and desirable outputs. The specifics of each indicator are detailed in Table 1.

3.2.2 Explanatory variable

City-County Merger Policy ($Merger \times Post$). To represent the city-county merger policy, we use the interaction term ($Merger \times Post$) of the regional dummy variable ($Merger$) and the time dummy variable ($Post$).

TABLE 1 LGUE indicator construction system.

Firstly indicators	Secondary indicators	Indicator description	Indicator rationality
Input Indicators	Land	Urban built-up area	Reflects land resource utilization, essential for measuring land use efficiency (Hu et al., 2022)
	Capital	Urban fixed asset investment	Key for improving land use efficiency, relevant for development, growth, and protection (Li et al., 2022)
	Labor	Total number of employees in the secondary and tertiary sectors of the city	Drives economic growth and technological progress, influencing land productivity (Dong et al., 2020)
	Energy	Direct energy consumption in the city mainly includes natural gas and liquefied petroleum gas, while indirect energy consumption primarily involves electricity usage. Based on the "General Rules for Comprehensive Energy Consumption Calculation," various energy consumption figures are converted into standard coal equivalents, and the total is calculated as the city's energy consumption	Critical in land use, enhances productivity, and reduces pollution (Di et al., 2019)
Output Indicators	Desirable Outputs	Actual added value of the secondary and tertiary industries in the city	Represents urban economic activities and benefits of land use (Xie et al., 2021)
		Urban built-up area green coverage rate	Key for urban ecological quality, improves environment and life quality (Tang et al., 2021)
	Undesirable Outputs	Considering urban industrial wastewater, sulfur dioxide, and dust emissions, the city's pollution emission level is integrated after assigning weights using the entropy method	Reflects negative environmental impacts, measures ecological effects (Niu et al., 2023)
		Urban carbon dioxide emissions	Major greenhouse gas, assesses climate change impact, emphasizes environmental protection (Chen et al., 2019)

3.2.3 Mechanism variables

- Urban Government Expenditure (GE): Measured by the general public budget expenditure of the city.
- Urban Road Area (RA): Measured by the actual road area at the end of the year in the city.
- Urban Fixed Asset Investment (FAI): Measured by the total social fixed asset investment in the city. Since the total social fixed asset investment has not been published after 2017, we supplemented the data using the growth rate of total fixed asset investment for each city. The growth rates were obtained from city government reports.
- Urban GDP (GDP): Measured by the city's gross domestic product.
- Urban GDP per unit of land area (GDP_{per}): Measured by the ratio of the city's GDP to the city's land area.
- Personal Population Density (PPD): Referring to the study by Henderson et al. (2021), we calculated personal population density using LandScan population grid data, DMSP-OLS light grid data, and China's urban administrative boundary vector data. The calculation formula is as follows:

$$ppd_j = \sum_{i}^{N_j} p_{ij} \frac{p_{ij}}{p_j} \tag{7}$$

In Equation 7, i represents the grid cell, j represents the city, N_j is the number of grid cells within the city (with a light value greater than 10), p_j is the total population of the city, and p_{ij} is the population of grid cell i within city j. A higher personal population density indicates a more compact population distribution within the city.

- Normalized Difference Vegetation Index $(NDVI)$: We used the Normalized Difference Vegetation Index (NDVI) to reflect the urban spatial ecological status. The calculation formula for NDVI is as follows:

$$NDVI = \frac{(NIR - Red)}{(NIR + Red)} \tag{8}$$

In Equation 8, NIR is the reflectance in the near-infrared band, and Red is the reflectance in the red band. Higher NDVI values indicate better vegetation status.

- Industrial Land Leasing Revenue (ILR): Firstly, we collect local land leasing data from the "China Land Market Network," which consists of approximately three million records; secondly, we retain data related to industrial land use; finally, we aggregate the data by city and contract signing year to derive the annual industrial land leasing revenue for each city, serving as a proxy variable for the land leasing revenue effect.
- Per unit of land area increase in the number of polluting enterprises (PEs_{per}): First, we collect Chinese industrial and commercial enterprise registration information from the Qichacha database; second, based on the "Industry Classification Management Directory for Environmental Protection Verification of Listed Companies," we filter out enterprises in heavily polluting industries; finally, we aggregate the number of new polluting enterprises by city and registration date, then divide by the city's land area, to derive the increase in the number of polluting enterprises per unit of land area as a proxy variable for the investment attraction competition effect.

- Rationalization of Industrial Structure (RIS): We constructed an industrial rationalization indicator using the Theil index (Theil, 1967), with the specific formula as follows:

$$RIS = \sum_{i=1}^{n}\left(\frac{Y_i}{Y}\right)\ln\left(\frac{Y_i}{L_i}\bigg/\frac{Y}{L}\right) \tag{9}$$

In Equation 9, Y represents output, L represents employment, i represents industries, and n represents the number of industry sectors. A higher TL value indicates a greater deviation from the equilibrium state and a less rational industrial structure.

- Overachievement of Urban Economic Growth Targets ($OUEGT$): We used the difference between actual economic growth and the original target value to represent the overachievement of urban economic growth targets. The original growth targets are derived from the work reports of various city governments.

3.2.4 Other control variables

Drawing upon existing literature (Zhou et al., 2020; Wang et al., 2021; Cui et al., 2019), we introduce the following variables to control for other factors affecting the efficiency of green land use in cities:

- Industrial Structure (IS): Measured by the proportion of tertiary industry output value to total output value;
- Degree of Openness (DO): Measured by the actual amount of foreign capital used in a given year;
- Urben Topography (UT): Measured by the average slope of the city;
- Environmental Regulation Intensity (ERI): Measured by the proportion of investment in industrial pollution treatment to the industrial added value.

3.3 Data description

To ensure consistency, availability, and robustness of the data, we select panel data of Chinese prefecture-level cities from 2003 to 2020 as our research sample. Due to the nature of the Malmquist-Luenberger (ML) index calculation, which is akin to a "difference" analysis, our regression data start from 2004. To ensure the robustness of the results, the following data processing steps are taken: Firstly. Exclude cities that underwent city-county merger reforms before 2004. Secondly. Exclude the four municipalities of Beijing, Shanghai, Shenzhen, and Chongqing due to their administrative particularities. Thirdly. Given the significant variance in the month of city-county merger reforms and the time needed for position changes and department integration post-reform, we consider the following year of a reform that occurred in the fourth quarter as the actual year of policy implementation. Lastly. Use average growth rates to fill in minor missing data. Ultimately, we have 47 cities that underwent City-County Merger reforms (treatment group) and 102 cities that did not (control group).

Our data primarily comes from the following sources:

- Economic and Social Development Data: The urban economic and social data mainly comes from the "China City Statistical Yearbook," including indicators such as land, capital, labor, energy, fiscal revenue and expenditure, and road area. Missing indicators are supplemented from provincial and regional statistical yearbooks. The statistical yearbooks are collected and compiled by the National Bureau of Statistics. The National Bureau of Statistics is the official statistical agency of the Chinese government, known for its high authority and reliability. The yearbooks cover a wide range of socio-economic development indicators, including population, resources and environment, economic development, scientific and technological innovation, people's living standards, public services, and infrastructure.
- Administrative Division Data: Data on changes in administrative divisions comes from the Ministry of Civil Affairs of the People's Republic of China. We extracted the regions and times when city-county mergers occurred.
- China Land Transaction Data: Land transaction data is sourced from the China Land Market Website. This website is managed by the Real Estate Registration Center under the Ministry of Natural Resources, a subordinate institution of the Ministry of Land and Resources of the People's Republic of China. The "Regulations on Bidding, Auction, and Listing of State-owned Land Use Rights" stipulate that municipal and county-level government land departments must publicly announce the results of each land transaction on the China Land Market website. The public information includes land use, supply area, transaction price, and supply method.
- China Enterprise Basic Information Data: Enterprise basic information comes from the Qichacha database. This database is fully integrated and synchronized with the information from the State Administration for Industry and Commerce of the People's Republic of China, covering all types of enterprise information in mainland China, including basic enterprise information, legal proceedings, operational status, intellectual property, financial data, and corporate credit.
- Geospatial Information Data: Geospatial information data includes the Normalized Difference Vegetation Index (NDVI) data, DMSP-OLS-like data, Digital Elevation Model (DEM) data, and administrative division vector data. Geospatial information data comes from the National Earth System Science Data Center, National Science and Technology Infrastructure of China, referred to as the Center. The Center is managed by the Institute of Geographic Sciences and Natural Resources Research, Chinese Academy of Sciences, and jointly constructed with multiple research institutions. The Center contains multidisciplinary earth system science data, including information on the atmosphere, lithosphere, and land surface.

Descriptive statistics of the main variables used in this study are presented in Table 2.

4 Empirical results

4.1 Baseline results

Table 3 presents the baseline regression results of the city-county merger policy on the efficiency of urban land green utilization.

TABLE 2 Descriptive statistics.

	Variable	Number	Mean	SD	Min	Max
Dependent Variable	$LGUE$	2,533	0.991	0.053	0.704	1.176
Independent Variable	$Merger \times Post$	2,533	0.122	0.327	0	1
Mechanism Variables	GE	2,533	0.222	0.217	0.013	1.223
	RA	2,532	0.151	0.162	0.016	1.023
	FAI	2,533	1.081	1.199	0.044	6.505
	GDP	2,533	1.56	1.671	0.12	9.582
	GDP_{per}	2,533	0.157	0.207	0.002	1.334
	PPD	2,533	1.357	0.949	0.255	5.703
	$NDVI$	2,533	0.715	0.134	0.116	0.899
	ILR	2,533	0.865	1.56	0	9.502
	PEs_{per}	2,384	0.128	0.254	0.002	1.343
	RIS	2,518	0.137	0.163	0.001	1.008
	$OUEGT$	2,487	0	0.092	−0.31	1.979
Control Variables	IS	2,533	0.393	0.099	0.154	0.686
	DO	2,533	0.514	0.938	0	5.804
	UT	2,533	1.959	0.961	0.322	4.468
	ERI	2,533	0.337	0.275	0.047	1.455

Variable, The name of the variable; Number, The number of observations for each variable; Mean, The average value of the variable; SD, the standard deviation of the variable; Min, The minimum value observed for the variable; Max, The maximum value observed for the variable. Note 2: $LGUE$, Urban Land Green Utilization Efficiency; $Merger \times Post$, City-County Merger Policy; GE, Urban Government Expenditure; RA, Urban Road Area; FAI, Urban Fixed Asset Investment; GDP, Urban GDP; GDP_{per}, Urban GDP per unit of land area; PPD, Personal Population Density; $NDVI$, Normalized Difference Vegetation Index; ILR, Industrial Land Leasing Revenue; PEs_{per}, Per unit of land area increase in the number of polluting enterprises; RIS, Rationalization of Industrial Structure; $OUEGT$, Overachievement of Urban Economic Growth Targets; IS, Industrial Structure; DO, Degree of Openness; UT, Urben Topography; ERI, Environmental Regulation Intensity.

Columns (1) and (2) display the regression outcomes without individual and time fixed effects, whereas columns (3) and (4) incorporate these effects. The results demonstrate that the city-county merger policy significantly reduces the efficiency of urban land green utilization, regardless of the model specification, thus confirming hypothesis H1. Specifically, as observed in column (4), holding other conditions constant, the efficiency of urban land green utilization in the treatment group cities decreased by 0.008 units compared to the control group cities. This indicates that the city-county merger policy, while expanding the urban land use area, notably diminishes the efficiency of urban land green utilization, suggesting that the urbanization promoted by this policy may compromise the green utilization efficiency of urban land.

4.2 Robustness test

4.2.1 Parallel trends test

The parallel trend hypothesis posits that, in the absence of policy impact on the treatment group (the counterfactual), the trends of outcome variables for both the treatment and control groups should exhibit no systematic differences over time. Figure 4 illustrates that the regression coefficients of $Merger \times Post(i)$ prior to policy implementation are not statistically different from zero. This indicates no significant divergence in the trend of urban land green utilization efficiency between the control and treatment groups before policy implementation, thus confirming adherence to the parallel trend hypothesis. Consequently, the observed decline in urban land green utilization efficiency in the treatment group relative to the control group post-implementation can be attributed to the policy intervention rather than pre-existing disparities. Further examining from a dynamic perspective, the long-term effects of the policy exhibit fluctuations.

4.2.2 Excluding pandemic impact

The COVID-19 pandemic has significantly impacted economic output, potentially leading local governments to prioritize GDP growth over improvements in LGUE. This economic pressure might have prompted relaxations in regulations on polluting enterprises, thereby increasing undesirable outputs. To eliminate the influence of the pandemic on our regression analysis, we exclude data from the year 2019 onwards and re-run the regression. This approach ensures that our results are not biased by the pandemic's unprecedented effects, providing a clearer depiction of underlying trends unaffected by this global event. The test results presented in the first column of Table 4 support the conclusions of this paper.

4.2.3 Changing the dependent variable

In our primary analysis, we utilized the Malmquist productivity index to measure Urban Land Green Utilization Efficiency (LGUE), emphasizing its ability to capture both technological progress and

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TABLE 3 Basic regression results.

	(1)	(2)	(3)	(4)
VARIABLES	*LGUE*	*LGUE*	*LGUE*	*LGUE*
$Merger \times Post$	−0.021***	−0.012***	−0.008***	−0.008***
	(-6.757)	(-3.916)	(-2.722)	(-2.648)
IS		−0.105***		−0.061***
		(-7.019)		(-3.154)
DO		0.004***		−0.000
		(3.474)		(-0.040)
UT		0.001		−0.539
		(1.049)		(-1.609)
ERI		0.020***		−0.004
		(5.741)		(-1.025)
Constant Term	0.994***	1.023***	0.992***	2.074***
	(1636.863)	(216.951)	(2,627.695)	(3.152)
CITY FE	YES	YES	YES	YES
YEAR FE	YES	YES	YES	YES
Observations	2,533	2,533	2,533	2,533
Adj. R^2	0.016	0.058	0.654	0.656

***, **, and * denote significance at the 1%, 5%, and 10% statistical levels, respectively; numbers in parentheses are t-statistics. Note 2: *LGUE*, Urban Land Green Utilization Efficiency; $Merger \times Post$, City-County Merger Policy; *IS*, Industrial Structure; *DO*, Degree of Openness; *UT*, Urben Topography; *ERI*, Environmental Regulation Intensity.

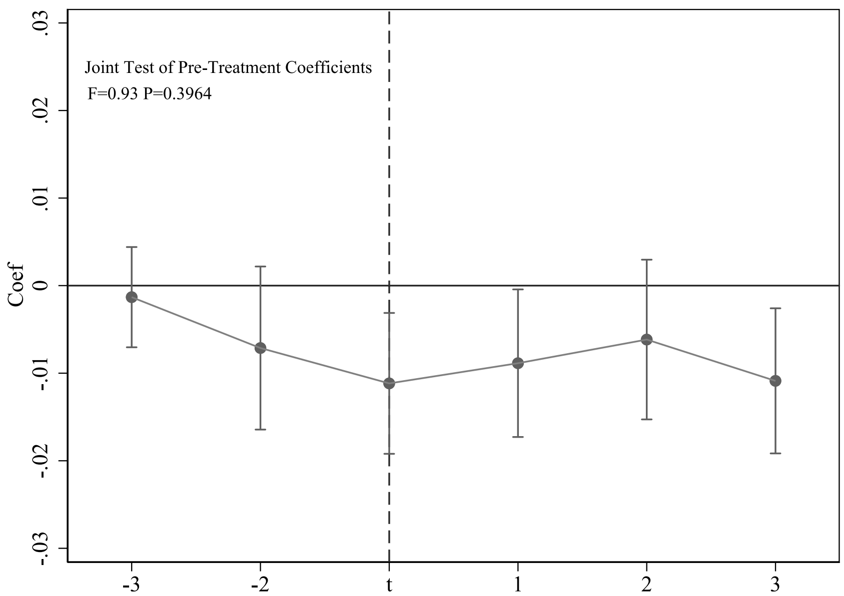

FIGURE 4
Parallel Trends Test. Note: The vertical axis represents the regression coefficients of $Merger \times Post(i)$. The lines with capped spikes indicate the confidence intervals of the regression coefficients. The horizontal axis represents the value of i in $Post(i)$, indicating the i-th year after (or before) the policy implementation.

TABLE 4 Robustness test.

VARIABLES	(1)	(2)	(3)
	$LGUE$	$LGUE_{CHANGE}$	$LGUE$
$Merger \times Post$	−0.006**	−0.012***	−0.013***
	(-2.314)	(-3.391)	(-2.707)
IS	−0.028*	0.043*	0.022
	(-1.746)	(1.695)	(0.273)
DO	−0.003***	−0.001	−0.003
	(-3.483)	(-0.325)	(-0.751)
UT	−0.147	1.052**	−2.005*
	(-0.573)	(2.586)	(-1.743)
ERI	−0.002	−0.005	0.011
	(-0.577)	(-0.991)	(0.997)
Constant Term	1.303**	−1.135	4.893**
	(2.588)	(-1.423)	(2.201)
CITY FE	YES	YES	YES
YEAR FE	YES	YES	YES
Observations	2,235	2,533	2,128
Adj. R^2	0.112	0.651	0.808

***, **, and * denote significance at the 1%, 5%, and 10% statistical levels, respectively; numbers in parentheses are t-statistics. Note 2: $LGUE$, Urban Land Green Utilization Efficiency; $LGUE_{CHANGE}$, Changing the measurement method for calculating Urban Land Green Utilization Efficiency; $Merger \times Post$, City-County Merger Policy; IS, Industrial Structure; DO, Degree of Openness; UT, Urben Topography; ERI, Environmental Regulation Intensity. Note 3: The first column presents the results after excluding the pandemic impact; the second column shows the results after changing the dependent variable; the third column displays the results using the PSM-DID method.

efficiency improvements. To validate the robustness of our findings, we also conducted tests using static efficiency scores. The results presented in the second column of Table 4 corroborate the conclusions drawn in this paper. This complementary approach provides a baseline measure of efficiency, strengthening confidence in our findings and ensuring that observed effects are not solely reliant on the chosen methodological framework.

4.2.4 PSM-DID test

In the robustness check section, we employ the PSM-DID (Propensity Score Matching DID) method to validate the causal effects identified in our primary analysis. PSM-DID enhances the credibility of our findings by addressing potential biases and confounders that could affect treatment effect estimations. The results presented in the third column of Table 4 reinforce the core conclusions of this paper. By matching units with similar characteristics, PSM ensures comparability between treated and control groups, thereby mitigating selection bias. Integrating PSM with DID provides a robust basis for causal inference, reaffirming our primary analysis results across different methodological frameworks.

4.3 Further analysis and mechanism examination

The city-county merger, as a policy promoted by local governments to expand administrative areas, has been observed to reduce the efficiency of green land use. However, it is crucial to clarify the underlying reasons for this effect. Investigating this issue not only helps validate the robustness of the aforementioned results but also aids in identifying the mechanisms at play.

4.3.1 Analysis of direct outcomes of city-county mergers

As discussed in the theoretical analysis, city-county mergers alter the structure of urban land use. Under pressure to achieve promotion, local governments may initiate large-scale infrastructure development to rapidly urbanize areas previously managed by counties. This process attracts factors such as labor and capital, stimulating economic growth. However, this factor-driven, extensive economic growth model tends to neglect environmental protection and does not contribute to improving economic growth quality. Therefore, our primary focus is to examine whether the city-county merger policy has fostered a development model that sacrifices the efficiency of green land use.

We investigated this phenomenon from three perspectives: fiscal expenditure, economic growth, and spatial structure.

Using Equation 3, we conducted regressions with urban government expenditure, urban road area, and urban fixed asset investment as dependent variables to explore the direct outcomes of city-county mergers on urban fiscal spending. The regression results are presented in Table 5, indicating a significant increase in urban fiscal expenditure, urban road area, and urban fixed asset investment due to the city-county merger policy. Next, regressions were performed with urban GDP and urban GDP per unit of land area as dependent variables to analyze the direct outcomes of city-county mergers on urban economic growth. Columns (1)–(2) of Table 6 show that while the city-county merger policy significantly boosted urban GDP, it also had a notable inhibitory effect on urban GDP per unit of land area. Finally, regressions with urban personal population density and urban NDVI as dependent variables aimed to explain the direct outcomes of city-county mergers on urban spatial structure. Columns (3)–(4) of Table 6 present empirical evidence indicating that city-county mergers significantly reduce urban personal population density and NDVI.

In summary, our findings demonstrate that the implementation of city-county merger policies boosted the total urban economy by increasing fixed asset investment and large-scale transportation infrastructure construction. However, this growth has been accompanied by a decrease in urban GDP per unit of land area and adverse impacts on population distribution, resource allocation, and urban ecological health. This form of pseudo-urbanization undermines genuine urban development goals and compromises the sustainable capacity of urban land, thereby validating H2[2].

4.3.2 Mechanism testing of mediation effects

The above analysis indicates that the city-county merger policy has led to a low-quality economic growth model. Furthermore, following Zhao et al. (2010), we employed a mediation effect model to test whether the city-county merger policy inhibits the improvement of urban land green utilization efficiency through increasing industrial land leasing revenue, the number of industrial polluting enterprises, lowering the rationalization level of urban industrial structure, and exacerbating the overachievement of urban economic growth targets.

The results of the mediation effect model are detailed in Table 7. Columns (1) and (2) of Table 7 reveal a significant increase in local industrial land leasing revenue due to the city-county merger policy, which subsequently hampers urban land green utilization efficiency. Thus, confirming the mediation effect of land leasing revenue. Columns (3) and (4) show a notable rise in heavy polluting enterprises following the policy, which significantly undermines urban land green utilization efficiency, confirming the mediation effect of competition in attracting investments. Columns (5) and (6) demonstrate that the policy increases the irrationality of the urban industrial structure, leading to a decrease in urban land green utilization efficiency. Hence, confirming the mediation effect of industrial structure rationalization. Columns (7) and (8) indicate that the policy contributes to the overachievement of urban economic growth targets, subsequently reducing land green utilization efficiency. Thus, confirming the mediation effect of overachieving economic growth targets.

Based on these findings, the mechanism testing of mediation effects reveals that the city-county merger policy indirectly diminishes land green utilization efficiency by enhancing industrial land leasing revenue, increasing the number of industrial polluting enterprises, lowering the rationalization level of urban industrial structure, and exacerbating the overachievement of urban economic growth targets. Therefore, confirming H2.

4.4 Heterogeneity analysis

4.4.1 Regional heterogeneity of cities

Given significant disparities in institutional environments and economic development levels across regions in China, we investigated the impact of the city-county merger policy on cities in Eastern China and those outside the Eastern region. Regression results are presented in columns (1) and (2) of Table 8. These findings indicate that the city-county merger policy significantly reduces land green utilization efficiency in non-Eastern cities, while showing no significant effect on land green utilization efficiency in Eastern cities.

4.4.2 City size heterogeneity

In large cities, the main urban area holds an absolute advantage over counties. In contrast, smaller cities exhibit narrower economic gaps between the main urban area and counties, with county economies sometimes surpassing those of the main urban area. This disparity leads to distinct administrative coordination challenges. Therefore, we examined the heterogeneous impact of the city-county merger policy on cities of varying sizes. Cities were categorized into large and small based on median population size for grouped regression analysis. Results are shown in columns (3) and (4) of Table 8, indicating that the city-county merger policy significantly reduces land green utilization efficiency in small cities, while showing no significant effect on large cities.

4.4.3 Urban administrative level heterogeneity

China's administrative structure distinguishes between central cities (sub-provincial cities and provincial capital cities) and peripheral cities (ordinary prefecture-level cities), influencing administrative level and resource acquisition. This distinction implies differing impacts of the city-county merger policy on land green utilization efficiency in these two city types. We categorized cities into central and peripheral based on administrative level for grouped regression analysis. Results in columns (5) and (6) of Table 8 reveal that the city-county merger policy significantly reduces land green utilization efficiency in peripheral cities, while showing no significant effect on central cities.

4.4.4 Heterogeneity in urban economic development

Cities at different stages of economic development possess distinct economic foundations and development goals. Thus, we assessed the impact of the city-county merger policy on land green utilization efficiency across cities categorized as developed and underdeveloped based on median *per capita* GDP. Regression results in columns (7) and (8) of Table 8 indicate a significant

2 The theoretical rationale posits that city-county merger policies have triggered a low-quality urban development pattern, compromising green land utilization efficiency. These policies drive fiscal expenditures, particularly in infrastructure, fostering economic growth at the expense of environmental quality. This process damages internal agglomeration economies, promotes urban sprawl, and adversely affects urban vegetation health.

TABLE 5 The impact of fiscal expenditure structure.

VARIABLES	(1)	(2)	(3)
	GE	*RA*	*FAI*
$Merger \times Post$	0.092***	0.054***	0.495***
	(3.739)	(4.329)	(3.437)
IS	0.019	0.074	−0.307
	(0.183)	(1.484)	(-0.517)
DO	0.050***	0.008	0.524***
	(3.381)	(1.472)	(7.783)
UT	−1.865	−2.470*	−9.002
	(-0.708)	(-1.894)	(-0.637)
ERI	0.024	−0.003	0.181*
	(1.153)	(-0.217)	(1.664)
Constant Term	3.821	4.950*	18.433
	(0.741)	(1.938)	(0.666)
CITY FE	YES	YES	YES
YEAR FE	YES	YES	YES
Observations	2,533	2,532	2,533
Adj. R^2	0.856	0.920	0.828

***, **, and * denote significance at the 1%, 5%, and 10% statistical levels, respectively; numbers in parentheses are t-statistics. Note 2: *GE*, Government Expenditure; *RA*, Road Area; *FAI*, Fixed Asset Investment; $Merger \times Post$, City-County Merger Policy; *IS*, Industrial Structure; *DO*, Degree of Openness; *UT*, Urben Topography; *ERI*, Environmental Regulation Intensity.

inhibitory effect on land green utilization efficiency in cities with lower economic development levels, while showing no significant impact on cities with higher economic development levels.

4.4.5 Heterogeneity in urban planning types

Resource-based cities play a pivotal role in China's economy but face unique challenges in sustainable development compared to non-resource-based cities. Reflecting on the "National Sustainable Development Plan for Resource-based Cities", we categorized cities into resource-based and non-resource-based types. Results in columns (9) and (10) of Table 8 demonstrate that the city-county merger policy significantly reduces land green utilization efficiency in resource-based cities, while showing no significant impact on non-resource-based cities.

5 Discussion

5.1 Theoretical contributions

Firstly, this study extends the theoretical perspective of new economic geography on urban scale expansion, emphasizing agglomeration economies and economies of scale to optimize urban land intensive use. Existing research predominantly examines the economic impacts of urban scale expansion from a market perspective, neglecting the influence of local government behaviors (Frick and Rodríguez-Pose, 2018; Lu et al., 2021; Post and Kuipers, 2023). While some studies focus on the effects of city-county mergers in China, they primarily address economic development outcomes with limited attention to land intensive use (Chen et al., 2024). Our research focuses on the administrative expansion of cities through city-county mergers in China, empirically demonstrating that this policy inhibits improvements in land green utilization efficiency. This finding not only expands public policy factors influencing land intensive use during urban expansion but also offers policy recommendations for urban scale expansion from a green development perspective.

Secondly, this study explains why administrative expansion (city-county mergers) reduces urban land green utilization efficiency from the perspective of local government behaviors, enriching theories of fiscal decentralization and officials' promotion tournaments. Our study moves beyond theories of enterprise heterogeneity (Naito, 2017), path dependence (Giannakis and Bruggeman, 2020), and industrial evolution (Clark and Sudharsan, 2020), expanding new economic geography theory from the viewpoint of local government behavior. Under China's authoritarian system of fiscal decentralization, local officials prioritize economic scale to meet central government economic targets, often overlooking land intensive use. Moreover, competitive pressures among local governments, driven by promotion tournaments, lead to negative economic consequences that reduce land green utilization efficiency.

Thirdly, situated within the institutional context of a transitioning nation with a strong government, this study

TABLE 6 Land leasing and Growth Demand.

	(1)	(2)	(3)	(4)
VARIABLES	*GDP*	GDP_{per}	*PPD*	*NDVI*
$Merger \times Post$	0.640***	−0.182***	−0.796***	−0.005*
	(3.564)	(-5.455)	(-6.665)	(-1.886)
IS	−0.273	−0.054	0.640	−0.003
	(-0.338)	(-0.424)	(1.450)	(-0.176)
DO	0.357***	0.025	−0.047	−0.003
	(3.190)	(1.649)	(-0.679)	(-1.650)
UT	−35.312*	0.167	9.931	2.222***
	(-1.824)	(0.071)	(1.272)	(6.537)
ERI	0.062	0.003	0.048	−0.009***
	(0.420)	(0.199)	(0.778)	(-2.775)
Constant term	70.546*	−0.141	−18.242	−3.631***
	(1.857)	(-0.031)	(-1.190)	(-5.464)
CITY FE	YES	YES	YES	YES
YEAR FE	YES	YES	YES	YES
Observations	2,533	2,533	2,533	2,533
Adj. R^2	0.876	0.755	0.863	0.979

***, **, and * denote significance at the 1%, 5%, and 10% statistical levels, respectively; numbers in parentheses are t-statistics. Note 2: *GDP*, urban GDP; GDP_{per}, urban GDP per unit of land area; *PPD*, Personal Population Density; *NDVI*, Normalized Difference Vegetation Index; $Merger \times Post$, City-County Merger Policy; *IS*, Industrial Structure; *DO*, Degree of Openness; *UT*, Urben Topography; *ERI*, Environmental Regulation Intensity.

explores the heterogeneous impacts of urban scale expansion on land green utilization efficiency, deepening the study of land green utilization efficiency. Unlike research in developed Western countries focusing on voters (Hilber and Robert-Nicoud, 2013; Garnett, 2012), urban morphology (Wang and Debbage, 2021), and regulation (Pendall et al., 2018), our study delves deeper into the performance incentives of local officials regarding the effects of urban scale expansion on land green utilization efficiency. This approach offers insights into the fundamental drivers of land use dynamics and optimization.

5.2 Policy recommendations

Our research findings indicate that while the city-county merger policy has expanded urban development, it has also led to inefficient land green utilization. In 2022, the National Development and Reform Commission (NDRC) emphasized cautious and stringent control over city-county mergers. Based on our findings, the policy implications are as follows:

Streamline intergovernmental relationships: City-county mergers enhance overall economic development but decrease land green utilization efficiency. Policies should promote coordination across government levels and integrate urban planning to align the goals of city, county, and district administrations. By preventing conflicts of interest and administrative redundancies, sustainable land use can be ensured. Adjusting GDP-focused performance criteria is essential to drive governmental function transformation and system reform.

Prioritize long-term planning: Mechanism analysis reveals that city-county mergers often lead to inefficient land green utilization due to expansive, short-term development goals. China should establish a comprehensive evaluation framework emphasizing long-term planning and environmental sustainability. Financial incentives should encourage cities to adopt green infrastructure and renewable energy initiatives. Supporting local green technology startups can foster innovation in sustainable practices and industrial upgrading.

Adapt policies to local contexts: Empirical results highlight varied impacts across regions, with greater inefficiencies observed in non-Eastern, smaller, economically underdeveloped, and resource-based cities. China's city-county merger policy must account for regional disparities. Tailored policies should balance local contexts with overarching developmental goals, ensuring cautious implementation where conditions are less favorable for mergers.

5.3 Limitations and future directions

Enhancement and comparison of research scope. In 2022, the National Development and Reform Commission (NDRC)

TABLE 7 Mediating effect analysis.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
VARIABLES	*ILR*	*LGUE*	PEs_{per}	*LGUE*	*RIS*	*LGUE*	*OUEGT*	*LGUE*
$Merger \times Post$	0.552**	−0.007**	0.074**	−0.004**	0.061***	−0.007**	0.027**	−0.006**
	(2.581)	(-2.391)	(2.133)	(-2.021)	(2.870)	(-2.302)	(2.394)	(-2.171)
ILR		−0.002**						
		(-2.071)						
PEs_{per}				−0.007**				
				(-2.306)				
RIS						−0.015*		
						(-1.693)		
$OUEGT$								−0.019***
								(-2.687)
IS	−0.061	−0.062***	0.023	−0.037**	−0.186*	−0.062***	−0.025	−0.056***
	(-0.074)	(-3.137)	(0.153)	(-2.439)	(-1.762)	(-3.247)	(-0.657)	(-2.967)
DO	0.550***	0.001	0.031	−0.001	−0.003	−0.000	0.002	0.001
	(4.629)	(0.615)	(1.338)	(-1.548)	(-0.385)	(-0.082)	(1.087)	(0.314)
UT	−17.485	−0.567*	−13.456***	−0.116	−0.026	−0.523	−0.433	−0.604*
	(-0.693)	(-1.724)	(-3.515)	(-0.500)	(-0.016)	(-1.574)	(-0.838)	(-1.792)
ERI	0.218	−0.004	0.031	−0.002	−0.009	−0.005	−0.010	−0.005
	(1.138)	(-0.947)	(1.260)	(-0.419)	(-0.535)	(-1.085)	(-1.292)	(-1.167)
Constant term	34.702	2.130***	26.435***	1.246***	0.258	2.046***	0.854	2.197***
	(0.701)	(3.295)	(3.522)	(2.737)	(0.079)	(3.132)	(0.843)	(3.323)
CITY FE	YES	YES	YES	YES	YES	YES	YES	YES
YEAR FE	YES	YES	YES	YES	YES	YES	YES	YES
Observations	2,533	2,533	2,384	2,384	2,518	2,518	2,487	2,487
Adj. R^2	0.575	0.657	0.707	0.038	0.710	0.656	0.115	0.666

***, **, and * denote significance at the 1%, 5%, and 10% statistical levels, respectively; numbers in parentheses are t-statistics. Note 2: $LGUE$, Urban Land Green Utilization Efficiency; ILR, Industrial Land Leasing Revenue; PEs_{per}, per unit of land area increase in the number of polluting enterprises; RIS, Rationalization of Industrial Structure; $OUEGT$, Overachievement of Urban Economic Growth Targets; $Merger \times Post$, City-County Merger Policy; IS, Industrial Structure; DO, Degree of Openness; UT, Urben Topography; ERI, Environmental Regulation Intensity.

introduced stricter controls on city-county mergers to curb rapid and unplanned urban expansion. This policy adjustment has the potential to mitigate some of the observed inefficiencies in land green utilization highlighted in our study. Consequently, these changes could significantly influence our conclusions. Future research should compare the impacts on land green utilization efficiency between cities that underwent city-county mergers before and after 2022. This comparison would facilitate an assessment of how stricter controls affect land use practices, economic growth, and environmental sustainability.

Refinement of research methods. We employed the SBM-ML method to assess land green utilization efficiency and the staggered DID method to examine the effects of city-county mergers. While these methodologies yielded valuable insights, future studies could benefit from real-time and more granular data on land use patterns and urban development, leveraging advancements in 5G, artificial intelligence, big data, and machine learning. These technological advancements offer the potential for more precise evaluations and deeper insights into the impacts of city-county mergers on land green utilization efficiency.

Limited scope of study subjects. Our study concentrated on eligible prefecture-level cities in China, characterized by a distinctive administrative system. While this approach provides valuable insights into city-county mergers in the Chinese context, it limits the generalizability of our findings to countries with different administrative structures and urbanization processes. Future research should incorporate comparative analyses involving countries with both similar and dissimilar administrative frameworks. This broader approach will contribute to a more comprehensive understanding of how diverse administrative systems influence land green utilization efficiency.

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TABLE 8 Heterogeneity analysis.

	Eastern cities	Non-eastern cities	Large cities	Smaller cities	Central cities	Peripheral cities	Developed cities	Under-developed cities	Resource-based cities	Non-resource-based cities
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
VARIABLES	*LGUE*	*LGUE*	*LGUE*	*LGUE*	*LGUE*	*LGUE*	*LGUE*	*LGUE*	*LGUE*	*LGUE*
Merger × Post	−0.003	−0.007*	−0.002	−0.010**	−0.009	−0.008***	−0.003	−0.014***	−0.004	−0.012*
	(-0.772)	(-1.859)	(-0.524)	(-2.161)	(-1.251)	(-2.729)	(-0.642)	(-2.660)	(-1.167)	(-1.912)
IS	−0.094*	−0.044*	−0.020	−0.075***	−0.092	−0.055***	−0.082***	−0.041	−0.063***	−0.062*
	(-1.764)	(-1.829)	(-0.832)	(-2.979)	(-1.135)	(-2.728)	(-2.974)	(-1.297)	(-2.646)	(-1.966)
DO	−0.002	0.001	0.002	0.000	0.002	−0.002	0.002	−0.002	−0.000	0.002
	(-0.622)	(0.365)	(0.635)	(0.058)	(0.763)	(-0.647)	(0.593)	(-0.785)	(-0.011)	(0.293)
UT	−0.143	−0.835**	−0.783*	−0.300	−2.948***	−0.334	−0.705	−0.776	−0.803*	−0.007
	(-0.256)	(-2.153)	(-1.774)	(-0.613)	(-4.143)	(-0.958)	(-1.371)	(-1.611)	(-1.857)	(-0.012)
ERI	−0.010	−0.000	−0.009*	−0.002	0.008	−0.006	−0.007	0.001	−0.003	−0.008
	(-1.289)	(-0.080)	(-1.765)	(-0.409)	(1.033)	(-1.174)	(-0.830)	(0.106)	(-0.793)	(-0.990)
Constant term	1.298	2.688***	2.537***	1.609*	6.757***	1.670**	2.332**	2.611**	2.652***	1.029
	(1.260)	(3.431)	(2.922)	(1.678)	(4.874)	(2.435)	(2.432)	(2.620)	(3.013)	(0.906)
CITY FE	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
YEAR FE	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Observations	765	1768	1258	1273	289	2,244	1253	1269	1428	1105
Adj. R^2	0.732	0.626	0.757	0.563	0.541	0.670	0.678	0.636	0.678	0.629

***, **, and * denote significance at the 1%, 5%, and 10% statistical levels, respectively; numbers in parentheses are t-statistics. *LGUE*, Urban Land Green Utilization Efficiency; *Merger × Post*, City-County Merger Policy; *IS*, Industrial Structure; *DO*, Degree of Openness; *UT*, Urben Topography; *ERI*, Environmental Regulation Intensity.

6 Conclusion

The city-county merger policy represents a prominent strategy employed by governments in China to foster urbanization through expansive land use. Given the current context where ecological improvements lag behind urban economic development, it is imperative to scrutinize the impact of city-county mergers on land green utilization efficiency within the framework of urban expansion. Using panel data spanning from 2003 to 2020, we assessed urban land green utilization efficiency using the SBM-ML method. Subsequently, we applied a staggered DID approach to analyze the effects and mechanisms of city-county mergers on urban land green utilization efficiency. In summary, our study yields the following key findings:

First, the city-county merger policy significantly inhibits urban land green utilization efficiency. Second, compared to cities without city-county mergers, those implementing this policy have increased fiscal expenditure, road area, fixed asset investment, and GDP, but significantly reduced land GDP, personal population density, and NDVI. Third, mediation effect tests reveal that the city-county merger policy worsens land green utilization efficiency by increasing industrial land leasing revenue, the number of industrial polluting enterprises, lowering the rationalization level of industrial structure, and exacerbating the overachievement of economic growth targets. Fourth, heterogeneity analysis indicates that the detrimental effect of the city-county merger policy on land green utilization efficiency is more pronounced in non-Eastern regions, smaller cities, peripheral cities, economically underdeveloped cities, and resource-based cities.

Data availability statement

The original contributions presented in the study are included in the article/Supplementary Material, further inquiries can be directed to the corresponding author.

Author contributions

MZ: Conceptualization, Formal Analysis, Methodology, Software, Visualization, Writing–original draft, Writing–review and editing. XX: Conceptualization, Funding acquisition, Validation, Writing–review and editing. YL: Conceptualization, Writing–review and editing.

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Conflict of interest

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

Publisher's note

Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fenvs.2024.1418982/full#supplementary-material

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