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The Impact of Innovative City Pilot Policy on Urban Land Green Use Efficiency: A Quasi-Natural Experiment from China

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Abstract: China's rapid urbanization has spurred significant economic growth, but it has also given rise to challenges such as urban sprawl, ecological degradation, and inefficient land use—issues that impede progress toward green and sustainable development. Land is the spatial foundation for green development, and promoting its green utilization is essential for advancing the high-quality development of urban spaces. As a concrete implementation of the innovation-driven development strategy, the National Innovative City Pilot Policy (NICPP) serves as a crucial driver in fostering high-quality development. In this context, the NICPP and green land use can be seen as two complementary components of achieving high-quality development. This study uses panel data from 266 cities across China and applies a difference-in-differences (DID) model to evaluate the effect of the NICPP on urban land green use efficiency (ULGUE), exploring the underlying mechanisms through the lenses of industrial structure and technological innovation. The results indicate that the NICPP significantly and robustly enhances ULGUE. The effect varies geographically and by city type, with the most pronounced benefits observed in eastern cities, non-resource-based cities, and non-old industrial base cities. Additionally, the NICPP contributes to improved comprehensive output benefits during land use activities and reduced pollutant emissions by optimizing industrial structures and enhancing technological innovation capacity, thereby promoting ULGUE. Therefore, in the future, the focus should be on integrating innovation with strategic policies. These findings carry profound implications for urban development in China and provide important lessons for promoting sustainable urban growth on a global scale.

Keywords: national innovative city pilot policy; land green use efficiency; difference-in-differences model; industrial structure; technological innovation



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1. Introduction

The relationship between economic growth and environmental protection, as two mutually reinforcing yet often constraining elements, has become a subject of widespread concern worldwide. In the context of globalization, achieving synergistic development between these two aspects has emerged as a major challenge for nations across the globe. The introduction of the Sustainable Development Goals (SDGs) has provided the international community with a framework for greener, fairer, and more inclusive development, while the New Urban Agenda (UN-Habitat, 2016) further underscores the urgency of guiding the sustainable development of cities—particularly in developing countries undergoing rapid urbanization and economic expansion [1]. As one of the world's most significant developing countries, China plays a pivotal role in the global urbanization process [2].

Between 2000 and 2022, China experienced rapid urbanization in both population and land use. The urbanization rate increased from 36.22% to 63.89%, while the built-up urban area expanded dramatically, from 16,221 km² to 60,721.32 km² (China, National Bureau of Statistics). The “land for development” model has driven substantial economic growth in China [3]; however, it has also led to significant challenges. On the one hand, uncontrolled urban land expansion has encroached upon vast areas of agricultural and ecological land, with more than 75% of urban land use efficiency categorized as low to medium, threatening national food security and impeding the intensification of urban economic growth [4,5]. On the other hand, the land use process has contributed to the continuous degradation of the ecological environment, with high energy consumption, carbon emissions, and pollution posing serious threats to both the living environment and public health [6–8].

Land serves as the spatial foundation for green development. Promoting the transformation of green land use is a key path to transforming the way land is used and promoting the high-quality development of territorial space, as well as an inevitable choice for achieving green and sustainable development and promoting the construction of an ecological civilization. Unlike traditional land use, green land use emphasizes ecological benefits, aiming to optimize economic returns and social welfare outputs while minimizing environmental pollution with minimal inputs. The goal is to achieve balanced and coordinated development across the economic, social, and ecological dimensions [9–11]. This means that the green utilization of land resources is not only accompanied by desired outputs such as economic benefits, but also by non-desired outputs, such as ecological pollutants, the negative externality of the green utilization of land. Therefore, many scholars construct the evaluation frameworks for urban land green use efficiency (ULGUE) from the three levels of “inputs—desired outputs—non-desired outputs”. The data envelopment approach (DEA) is often used to measure the efficiency value of multiple inputs and multiple outputs. However, the traditional DEA model does not incorporate non-expected outputs into the model, and it is impossible to realize the efficiency measurement that includes non-expected output indicators. Based on this, Tone proposed the slacks-based measure (SBM) model in 2001, which incorporates undesired outputs [12], and Li et al. used this model to investigate the ULGUE of 116 cities and identify its influencing factors [11]. However, when using the SBM model, there are often multiple efficiency values of 1, which makes it impossible to clearly distinguish the differences between decision-making units [13]. Therefore, Tone further proposed the super-efficiency SBM model in 2002 [14], which was subsequently utilized by Hu et al. to assess the ULGUE across 19 urban agglomerations in China [15]. Today, the super-efficiency SBM model has become a widely adopted method for measuring ULGUE [16]. In addition, ULGUE is affected by a combination of factors, not only related to the level of economic development, infrastructure construction, and other factors [7,17,18] but also closely related to the government’s policy intervention [19–21].

Schumpeter argued that innovation is the core driver of economic development. In line with this, the United States has adopted a specialized financial support strategy to fund long-term fundamental research initiatives aimed at accelerating technological innovation and promoting the transformation and upgrading of market structures [22]. Similarly, countries such as Japan, the United Kingdom, South Korea, and Germany have prioritized science and technology innovation as a national strategy, seeking to cultivate innovation-driven economies and enhance their national innovation capacities [23–27]. As research progresses, scholars increasingly recognize the critical role of technological innovation in advancing sustainable urban development and addressing environmental pollution [28–31]. In China’s transition from a resource-intensive development model to one focused on efficiency, the government has emphasized innovation as the central driver of economic transformation [32]. Innovation not only addresses the challenges related to diminishing returns on production factors and resource

constraints but also plays a pivotal role in reducing pollutant emissions and enhancing green productivity. China is committed to establishing itself as an innovative nation, strengthening its regional innovation systems, and promoting high-quality economic development through innovation. In 2008, Shenzhen became the first national innovative pilot city, marking the initiation of the National Innovative City Pilot Policy (NICPP). This policy is a key step in building a modern innovation system in China and directly supports the country's strategic goal of becoming an innovation-driven economy [33]. By 2022, 103 cities had joined the initiative. These pilot cities are guided by the principles of "innovation-driven" growth and "green, low-carbon" development. In response to the dual challenges of slowing economic growth and escalating environmental pollution, these cities are tasked with not only promoting independent innovation and regional development but also serving as "demonstration zones" for pollution prevention and control [33,34].

Innovation is a critical driver of green and low-carbon development. In the context of the new era, the construction of innovative cities and the green utilization of land serve as both the foundational drivers and target functions for achieving the high-quality development of urban society and economy [28]. These two elements are intrinsically connected. As land is the spatial foundation for green development, the economic, social, and ecological outcomes of the NICPP can significantly influence land use systems. From the perspective of land use, an important question arises: Does the implementation of the NICPP positively affect ULGUE? If so, what is the mechanism underlying this effect? This paper addresses these questions by exploring whether the national policy, which aims to enhance regional innovation systems and promote innovation-driven development, can facilitate the green transformation of land use. This inquiry holds both theoretical and practical importance, as it contributes to resolving the conflict between economic growth and environmental protection.

This paper is organized to achieve the following primary objectives: First, we develop a theoretical framework to analyze the impact of the NICPP on ULGUE. Second, using panel data from 266 cities, we empirically evaluate the effect of the NICPP on ULGUE through a difference-in-differences (DID) model. Lastly, we investigate the underlying mechanisms and explore how the impact of the NICPP on ULGUE varies across cities with different characteristics.

2. Theoretical Analysis and Research Hypothesis

2.1. Impacts of NICPP on ULGUE

During the policy implementation process, the central government places significant emphasis on the development of pilot cities. These cities can only pass the acceptance evaluation by meeting the required assessment criteria. In 2016, China introduced the *Guidelines for the Construction of Innovative Cities*, which explicitly incorporated green development indicators, such as the comprehensive energy consumption per 10,000 yuan of GDP and the proportion of days with the air quality meeting or exceeding level 2 throughout the year as part of the assessment criteria for innovative cities. These assessment indicators will have a push and constraint effect on the pilot cities. The assessment indicators influence the government's development strategy. On the one hand, local government officials are forced to increase their efforts in environmental governance, urge enterprises to pay attention to environmental protection in the production process, and reduce the number of environmental violations in their jurisdiction [35]. On the other hand, local governments are integrating low-carbon, energy-saving, and environmentally friendly elements into urban management and construction, strengthening the construction of green infrastructure such as public transportation and parks, promoting the application of green technologies, and guiding residents to develop green consumption patterns and lifestyles [34,36]. Land

serves as the fundamental foundation for human production and daily activities. Under the guidance of policies, localities can optimize land use patterns, reduce non-environmentally friendly energy consumption in the land use process, and reduce pollutant emissions, thus promoting ULGUE. Therefore, the following hypothesis can be proposed:

H1. *The implementation of the NICPP can generally promote ULGUE.*

2.2. Influencing Mechanisms

2.2.1. Industrial Structure

The pilot policies for innovative cities play a crucial role in optimizing industrial structures, thereby contributing to the enhancement of ULGUE. A key objective of the NICPP is to refine and improve the industrial structure [28]. On one hand, the *Guidelines for the Construction of Innovative Cities* outline specific criteria for the development of high-tech industries. These include indicators such as the number of high-tech industries, knowledge-intensive services, high-tech enterprises, and main business revenue. Only those pilot cities that meet these assessment standards will successfully pass the evaluation. This approach encourages local governments to place greater emphasis on fostering high-tech industries as part of their efforts to advance the construction of innovative cities [37]. Pilot cities leverage financial tools such as subsidies, taxes, and other measures to regulate the economic activities of various market participants. This strategy facilitates the shift of industries from being labor-intensive and capital-intensive to focusing more on knowledge-intensive and technology-driven sectors [38]. On the other hand, the NICPP encourages traditional industries to undergo green transformation through new technological transformation, the application of cleaner production equipment, and the improvement of the enterprise management mode [39]. For example, Qinhuangdao City's "Opinions on Building an Innovative City" mentions the application of new technologies to transform and upgrade traditional industries and encourages the promotion and use of energy-saving and environmentally friendly technologies. There are also some highly polluting and emitting enterprises that will be relocated out of the pilot area through industrial transfer. This process contributes to the transformation and upgrading of the industrial structure within the jurisdiction [40,41].

The transformation and upgrading of industrial structure determines the direction of economic development and the quality of environmental protection [42], which acts on the ULGUE by improving comprehensive output and reducing environmental pollution. Specifically, on the one hand, the growth of high-tech industries and the transformation of traditional sectors contribute to optimizing land use patterns. This process adjusts the allocation of production factors, such as land, capital, and labor, reduces energy and resource consumption during production, enhances overall output efficiency in land use, and positively influences the improvement of ULGUE [43]. On the other hand, the optimization and upgrading of the industrial structure can significantly reduce environmental pollutant emissions, minimizing the negative environmental impacts of land use, thereby leading to improved ULGUE [13,43]. Therefore, Hypothesis 2 is proposed:

H2. *The NICPP affects ULGUE through the transformation and upgrading of industrial structures.*

2.2.2. Technological Innovation

Innovation serves as a critical catalyst for both economic growth and societal transformation [44]. Improving technological innovation capacity is the direct goal of the NICPP, while technological progress is an effective means to solve environmental problems [31,45]. The NICPP mainly improves technological innovation capacity in three ways. Specifically, firstly, the *Guidelines for the Construction of Innovative Cities* clearly state that it is necessary

to guide social capital to invest in innovation. They advocate for banks and other financial institutions to offer support through investments, financing, and loans for enterprise R&D activities. This approach aims to address the challenges of limited and costly financing for businesses, thereby easing their financial constraints [34,39]. In addition, the pilot policy encourages local governments to boost financial support for science, technology, and education. Localities reduce the cost of R&D and provide external incentives for firms' innovation activities through special funds, direct subsidies, and loan interest subsidies [37,46]. For example, Xi'an has set up a special fund for innovative cities, which is used for the construction of incubators, science and technology public service platforms, and other infrastructures. Secondly, the *Guidelines for the Construction of Innovative Cities* highlight the importance of building strong teams of innovative talent. Pilot cities are actively exploring modes of talent cultivation and improving policies on the introduction of talent and service guarantee measures. Pilot cities are actively exploring new talent cultivation models while enhancing policies for talent recruitment and service guarantees. By offering domestic and international talent benefits such as research funding, housing, education, healthcare, and a conducive development environment, these cities can attract high-caliber professionals. This approach raises the level of human capital, provides intellectual backing for technological innovation, facilitates the transformation of innovation outcomes, and ultimately advances technological innovation levels [30,41]. Thirdly, in contrast to non-pilot cities, pilot cities can overcome spatial and temporal barriers to the flow of innovative resources by enhancing infrastructure such as network information systems and transportation networks. This improvement reduces issues related to information delays and asymmetry during innovation processes, fostering a favorable external environment for innovation activities. As a result, it contributes to the enhancement of urban innovation levels [47–49].

Technological innovation is the intrinsic driving force for promoting the green utilization of urban land. Technological innovation mainly affects ULGUE through the following aspects. Specifically, on the one hand, improving technological innovation helps to reduce the consumption of resources and energy from the production link and promotes the formation of specialized production processes, thus improving the efficiency of resource utilization and productivity and promoting the transformation of commodity results, which will improve the comprehensive output of the land use process, and have a positive impact on the enhancement of ULGUE [15,50]. On the other hand, improving technological innovation capacity can promote the development of green and low-carbon technologies. Optimized energy-saving and emission reduction, pollution and carbon reduction, and renewable energy technologies can directly reduce pollutant emissions in the process of land use, thus promoting the green and sustainable development of land [28,30]. The application of some advanced technologies can also provide secondary treatment of pollutant emissions, thus promoting the improvement of environmental quality. In summary, the following hypothesis is proposed in this section:

H3. *The NICPP influences urban land green use efficiency through technological innovation effects.*

As discussed earlier, Figure 1 summarizes the mechanism through which the NICPP influences ULGUE.

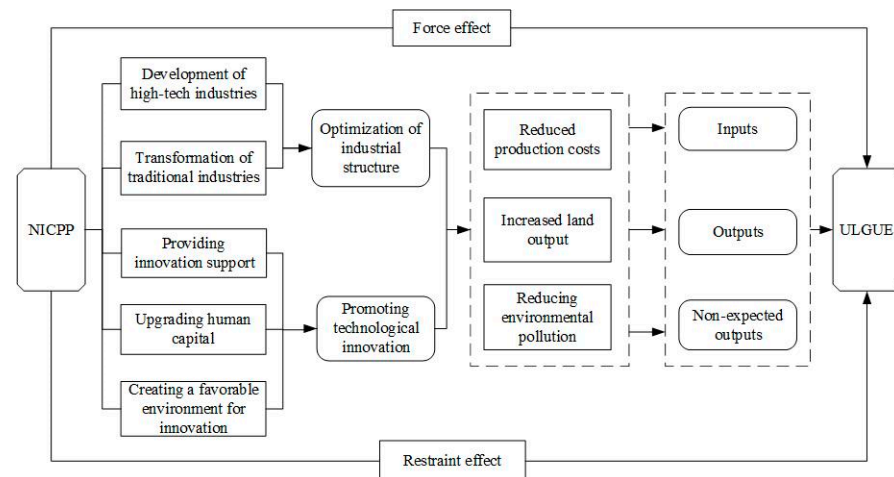


Figure 1. The impact mechanisms of the NICPP on ULGUE.

3. Empirical Design

3.1. Data and Sample Selection

China approved seven batches of innovative pilot cities in 2008, 2010, 2011, 2012, 2013, 2018, and 2022. Considering that the research period of this study is 2004–2020 and it does not cover 2022, this study analyzes the 25 pilot cities announced in 2022 as a control group. Concurrently, due to the lag in the effect of policy implementation, the national innovative pilot cities announced in 2018 are excluded. In addition, considering the availability and comprehensiveness of the data, this study excludes the cities with serious missing data. Finally, this study covers 266 cities in China from 2004 to 2020, including 58 innovative pilot cities and 208 non-pilot cities. The study area is illustrated in Figure 2.

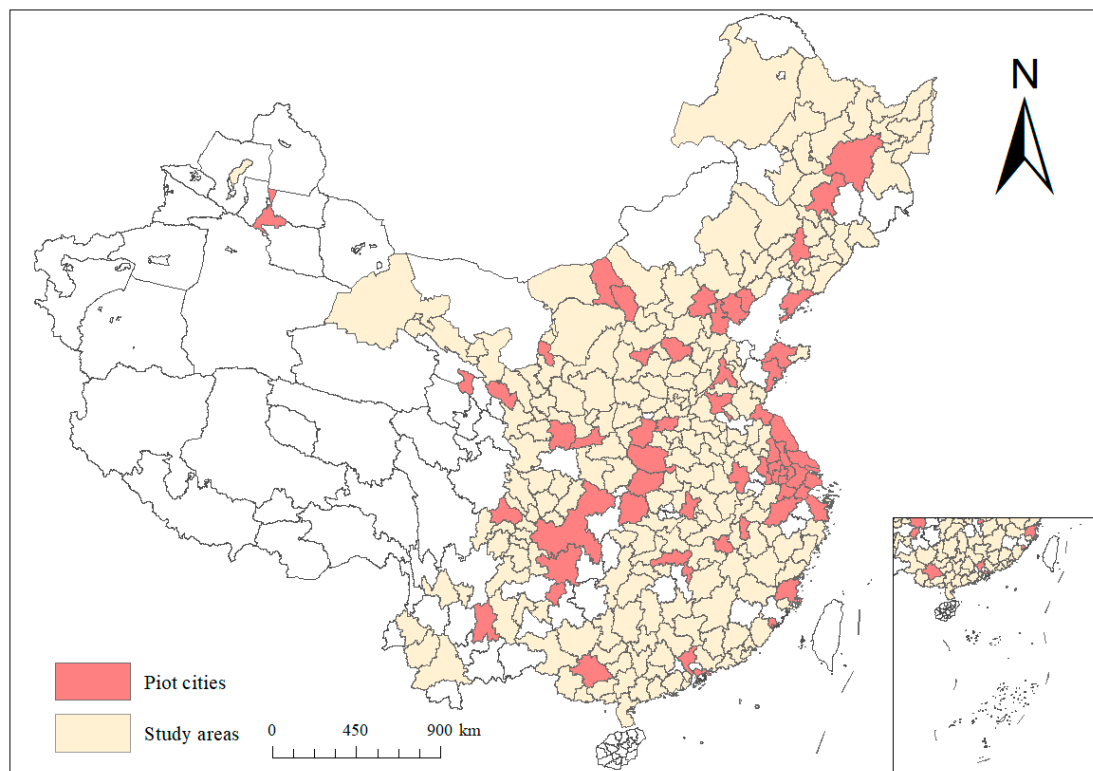


Figure 2. Study area.

The data for the indicators covered in this study come mainly from the *China Urban Statistical Yearbook*, China's provincial statistical yearbooks, and the work websites of cities. The study period is set in 2004–2020. For the missing data of some indicators, the linear interpolation method and moving average method are used to make up the processing. The descriptive statistics of all variables are presented in Table 1.

Table 1. Descriptive statistics of variables.

Variable	Obs	Mean	SD	Min	Max
ULGUE	4522	0.350	0.261	0.008	2.064
treat × time	4522	0.133	0.340	0.000	1.000
IS	4522	0.936	0.509	0.027	9.482
lnInnovation	4522	1.200	1.288	0.000	7.777
lnPGDP	4522	10.293	0.797	7.662	13.056
lnPop	4522	5.707	0.931	1.547	7.982
Gov	4522	0.179	0.102	0.040	1.485
Traffic	4522	15.240	7.154	0.390	60.070
lnWage	4522	10.492	0.611	8.733	12.128

3.2. Model Setting

This study treats the NICPP as a quasi-natural experiment and aims to determine its net effect on ULGUE. To do so, the DID approach is employed to compare the ULGUE differences between pilot and non-pilot cities both before and after the policy's implementation. Given that the NICPP is carried out year by year in batches, there are differences in the implementation time of the policy, but the traditional DID is limited to assessing the effect of the policy at a single point in time, so this study constructs a multi-temporal DID model. The model is set as follows [37,49,51]:

$$ULGUE_{it} = \alpha + \beta treat_{it} \times time_{it} + \gamma X_{it} + \lambda_t + \mu_i + \varepsilon_{it} \quad (1)$$

where i and t are cities and years, respectively; $ULGUE_{it}$ is urban land green use efficiency; $treat_{it}$ is a city dummy variable, which assigns innovative pilot cities a value of 1 as the experimental group and non-pilot cities a value of 0 as the control group; $time_{it}$ is a time dummy variable, which assigns the year of the pilot city's policy implementation year and the year after to 1 and the year prior to the implementation of the policy to 0; X_{it} is a series of control variables; α is a constant term; β represents the net effect of the NICPP on the urban land green use efficiency, where, if β is positive, it indicates that the pilot policy of the national innovative city significantly promotes the green land use efficiency of urban land; γ is the estimated coefficients of the control variables; λ_t and μ_i are the time-fixed and individual fixed effects, respectively; and ε_{it} is a randomized perturbation term.

3.3. Variable Definition

3.3.1. Explained Variable

The explained variable is ULGUE, representing a holistic assessment of inputs and outputs within the context of land utilization processes. The essence of ULGUE is to minimize the factor inputs and environmental pollution under the premise of obtaining maximum output benefits. Therefore, with reference to the relevant literature [15,17,21,43], the ULGUE index system is constructed from the three aspects of input, desired outputs, and non-desired outputs. The input indicator level selects the built-up area, secondary and tertiary employees, and fixed asset investment, which represent land, labor, and capital factor inputs, respectively. Desired outputs mainly include economic, social, and ecological dimensions, which are characterized by the value added of secondary and tertiary

industries, general financial income of local government, and green areas, respectively. The non-desired output level is selected as industrial sulfur dioxide emissions and industrial wastewater emissions as a direct reflection of the negative externalities of social and economic activities on the environment. The super-efficiency SBM model is used to measure ULGUE. The model not only realizes the efficiency evaluation, including the non-desired outputs, but also combines the advantages of the super-efficiency model and the SBM model, which is able to decompose the decision unit with an efficiency value of 1 so as to accurately estimate the efficiency value of the decision unit [52]. The model is as follows:

$$ULGUE = \min \frac{\frac{1}{m} \sum_{i=1}^m \bar{x}_i / x_{ik}}{\frac{1}{r_1 + r_2} \left(\sum_{s=1}^{r_1} \bar{y}_s^g / y_{sk}^g + \sum_{l=1}^{r_2} \bar{y}_l^d / y_{lk}^d \right)} \quad (2)$$

$$\begin{aligned} \bar{x} &\geq \sum_{i=1, \neq k}^m \gamma x_i; \bar{y}^g \leq \sum_{i=1, \neq k}^m \gamma y_i^g; \bar{y}^d \geq \sum_{i=1, \neq k}^m \gamma y_i^d; \\ \bar{x} &\geq x_k; \bar{y}^g \leq y_k^g; \bar{y}^d \leq y_k^d; \bar{y}^g \geq 0, \gamma \geq 0 \end{aligned}$$

where *ULGUE* is the land green use efficiency; *k* is the decision unit, referring to 266 cities; *m*, *r*₁, and *r*₂ denote the type of inputs, the type of desired outputs, and the type of non-desired outputs for each decision unit, respectively; *x*_{*ik*} is the *i*th input of the *k*th decision cell; $\bar{x}_i$ is the slack in the *i*th input; $\bar{y}_s^g$ and $\bar{y}_l^d$ are the slack in the *s*th desired output and the *l*th undesired output, respectively; *y*_{*sk*}^g and *y*_{*lk*}^d are the desired outputs and undesired outputs of decision cell *k*, respectively; *x*_{*i*}, *y*_{*i*}^g, and *y*_{*i*}^d are the *i*th input, desired output, and non-desired output, respectively; $\bar{x}$, $\bar{y}^g$, and $\bar{y}^d$ are the inputs, desired outputs, and non-desired outputs that are redundant or deficient; and γ denotes the vector of weights.

3.3.2. Explanatory Variable

The key explanatory variable is *treat* × *time*, which is the interaction term between the innovative pilot policy city dummy variable and the time dummy variable. Furthermore, *treat* is the city dummy variable, with innovative pilot cities assigned a value of 1 as the experimental group and non-pilot cities assigned a value of 0 as the control group; *time* is the time dummy variable, with the year of the implementation of the policy in the pilot cities and the year after assigned a value of 1 and the year before the implementation of the policy assigned a value of 0.

3.3.3. Selection and Measurement of Other Variables

In addition to the NICPP, factors such as the level of socio-economic development, the degree of population agglomeration, the development of road transportation, and the standard of living of residents also affect ULGUE. Therefore, this paper controls for the following variables: the level of economic development (lnPGDP), measured by the logarithm of per capita GDP [20]; population size (lnPop), measured by the ratio of the total population at the end of the year to the area of the administrative area, taking the natural logarithm [13]; the degree of government intervention (Gov), measured by the proportion of the fiscal expenditure to the GDP [53]; the level of transportation facilities (Traffic), measured by the road area per capita [54]; and the standard of living of residents (lnWage), measured by the logarithm of the average salary of urban workers.

In addition, based on the theoretical analysis, the indicators are selected from the industrial structure and technological innovation effects to explore the influence mechanism of the pilot policy of national innovative cities on green land use efficiency. Referring to the existing studies, the industrial structure effect (*IS*) is measured by the ratio of the tertiary industry to the secondary industry [30]. The technological innovation effect (*lnInnovation*)

is measured by the city innovation index released by the Industrial Development Research Center of Fudan University [55], and the natural logarithm is taken.

4. Empirical Results and Analysis

4.1. Benchmark Regression Results

Table 2 reports the results of the fixed effects regressions of the NICPP on ULGUE. Column (1) presents the regression results considering only the core explanatory variable $treat \times time$ and incorporating individual fixed effect. Column (2) considers the control variables that may affect ULGUE on the basis of column (1). The results show that the regression coefficients of $treat \times time$ are 0.108 and 0.066, respectively, both significant at the 1% statistical level. Column (3) controls for the time-fixed effect on the basis of column (1), and the regression coefficient of $treat \times time$ is 0.037, which passes the significance test at the 1% level, indicating that the NICPP significantly improves ULGUE. After column (4) incorporates the control variables on the basis of column (3), the regression coefficient and significance of $treat \times time$ do not change significantly, further indicating that the implementation of the policy does promote the green and efficient utilization of urban land, thus verifying Hypothesis 1.

Table 2. Results of benchmark model.

Variable	ULGUE			
	(1)	(2)	(3)	(4)
$treat \times time$	0.108 *** (9.954)	0.066 *** (5.626)	0.037 *** (3.361)	0.045 *** (3.976)
lnPGDP		0.085 *** (6.418)		0.076 *** (5.509)
lnPop		−0.085 ** (−2.255)		−0.063 * (−1.805)
Gov		−0.068 (−1.199)		−0.101 * (−1.876)
Traffic		0.002 ** (2.394)		0.002 *** (3.017)
lnWage		−0.037 ** (−2.522)		0.021 (0.908)
Cons	0.336 *** (118.248)	0.326 (1.583)	0.356 *** (38.838)	−0.201 (−0.695)
City	Yes	Yes	Yes	Yes
Year	No	No	Yes	Yes
N	4522	4522	4522	4522
R ²	0.023	0.056	0.198	0.210

Note: ***, **, and * denote significance at the 1%, 5%, and 10% statistical levels, respectively, with t-statistics in parentheses. These notes also apply to the tables below.

Moreover, the findings regarding the control variables indicate that both the level of economic development and transportation infrastructure exert a significant positive effect on ULGUE. This can be attributed to the strong connection between economic development and economic strength, which plays a critical role in shaping the input stage of land use processes, ultimately influencing ULGUE. The advancement and enhancement of transportation infrastructure facilitate the interregional flow of resources such as technology and talent. This process optimizes industrial distribution and land utilization, thereby increasing ULGUE. Conversely, population size and government intervention negatively influence green land use efficiency. A plausible explanation is that a larger population contributes to higher pollutant emissions within the region, which subsequently hampers

green land utilization [56]. An increase in the extent of government intervention reduces the dynamism of economic development, hindering the improvement of land use efficiency.

4.2. Robustness Tests

4.2.1. Parallel Trend Tests

The premise of applying the multi-temporal DID model is to ensure that the development trend of pilot cities and non-pilot cities before the implementation of the policy is the same. Referring to Beck et al. [57], we used the event study method to verify whether the study sample had parallel trends.

Considering that the number of samples far away from the policy shock year is small and the time covered before and after the policy implementation is long (from 9 years before the pilot to 12 years after the pilot), this study sets the policy shock year $t = 0$, and the years that are more than 5 years away from the policy shock year before the implementation of the policy are grouped together as the fifth period before the implementation of the policy ($t = -5$). The years that are more than 5 years away from the policy shock year after the implementation of the policy are grouped together as the fifth period after the implementation of the policy ($t = 5$).

In addition, this study takes $t = -5$ as the base period and constructs the interaction terms pre4, pre3, pre2, and pre1 between the time dummy variable and the group dummy variable before the implementation of the NICPP. By examining the significance of the regression coefficients for these interaction terms, this study assesses whether a parallel trend exists between the experimental and control groups before the NICPP was introduced. The regression outcomes are presented in Table 3. The coefficients for pre4, pre3, pre2, and pre1 are found to be statistically insignificant, suggesting that there is no notable difference between the experimental group and the control group prior to the implementation of the NICPP, which meets the requirements of constructing the DID model.

Table 3. Parallel trend test results.

Variables	ULGUE
pre4	0.002 (0.114)
pre3	0.007 (0.272)
pre2	0.034 (1.370)
pre1	0.027 (1.113)
Control variables	control
Cons	−0.235 (−0.809)
City	Yes
Year	Yes
N	4522
R ²	0.211

4.2.2. Placebo Tests

To exclude the impact of unrelated random factors on the results, a placebo test was performed to assess the NICPP's promotional effect on ULGUE. Specifically, a sample of 58 cities was randomly designated as the “pseudo-experimental” group, whereas the remaining 208 cities comprised the “pseudo-control” group. The timing of the policy implementation was also randomly assigned to establish the interaction term between city

dummies and time dummies for the 500 groups. The Stata 15.1 software was used to repeat 500 independent regressions to obtain the regression coefficients of the interaction terms in the 500 regressions. Figure 3 shows the kernel density distribution of the regression coefficients and the scatter plot of p -values. The result shows that the regression coefficients of the interaction terms are mainly concentrated around 0 and follow a normal distribution, which is significantly different from the actual policy regression coefficient of 0.045. Furthermore, the majority of p -values exceed 0.1, successfully fulfilling the placebo test criteria. This suggests that the estimation results presented in this paper remain unaffected by extraneous random factors, thereby reinforcing the robustness of the findings.

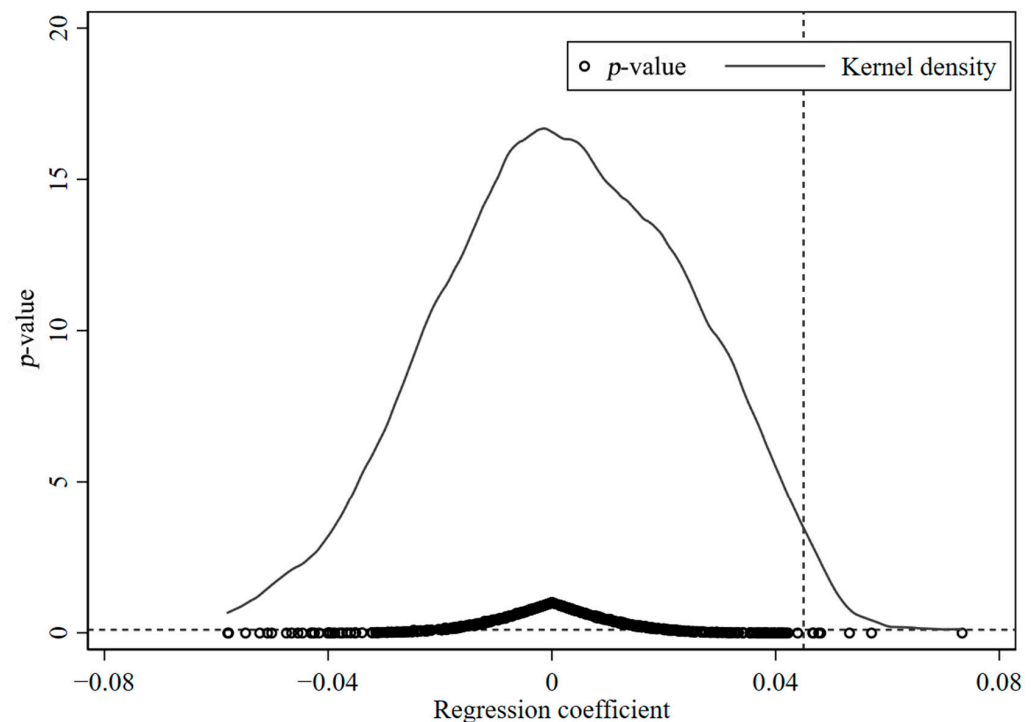


Figure 3. Placebo test results.

4.2.3. PSM-DID Method Estimation

To mitigate estimation bias stemming from the non-randomness of pilot city selection and other unobservable factors, propensity score matching was performed before applying the multi-temporal DID model. In particular, the control variables were established as matching criteria, employing the nearest neighbor matching technique to identify the most suitable control group for the pilot cities. Any cities that could not be adequately matched were excluded from the analysis, thereby ensuring that no substantial differences existed between the experimental and control groups prior to the intervention. Ultimately, the multi-temporal DID approach was employed to reassess the effect of the NICPP on ULGUE, with the findings presented in column (1) of Table 4. The outcomes reveal that the regression coefficient for $treat \times time$ remains significantly positive, suggesting that the NICPP's influence on ULGUE is robust.

Table 4. Robustness test results.

Variables	PSM-DID	Eliminating the Influence of Other Policies	
	(1)	(2)	(3)
$treat \times time$	0.044 ** (2.322)	0.044 *** (3.916)	0.044 *** (3.772)
Smart city		control	
Low-carbon city			control
Control variables	control	control	control
Cons	−0.462 (0.835)	−0.205 (−0.709)	−0.200 (−0.692)
City	Yes	Yes	Yes
Year	Yes	Yes	Yes
N	3828	4522	4522
R ²	0.219	0.210	0.210

4.2.4. Eliminating the Influence of Other Policies

During the sample study period, the pilot policies of smart cities and low-carbon cities may interfere with the estimation results. Consequently, to eliminate the impact of these policies, the two aforementioned policies are constructed as interaction terms in the previous way and regressed according to Equation (1). The regression results are displayed in columns (2) and (3) of Table 4. Upon controlling for the effects of both policies, it is evident that the regression coefficients of $treat \times time$ remain statistically significant and positive, aligning with the benchmark regression results. This consistency suggests the robustness of the findings presented in this paper.

5. Further Analysis

5.1. Mechanism Test

As mentioned in the previous theoretical analysis, the mechanism of the NICPP on ULGUE can be categorized into the industrial structure effect and technological innovation effect. On this basis, *IS* and *lnInnovation* serve as the explained variables, while the interaction term $treat \times time$ functions as the explanatory variable and is regressed separately by using the multi-temporal DID model. The outcomes of these regressions are presented in Table 5.

Table 5. Mechanism analysis results.

Variables	(1) <i>IS</i>	(2) <i>lnInnovation</i>
$treat \times time$	0.137 *** (7.467)	0.932 *** (39.577)
Control variables	control	control
Cons	4.496 *** (9.522)	2.462 *** (4.062)
City	Yes	Yes
Year	Yes	Yes
N	4522	4522
R ²	0.498	0.846

Column (1) of Table 5 indicates that the regression coefficient for the core explanatory variable $treat \times time$ is 0.137, which is significant at the 1% level. It shows that the NICPP has significantly promoted the transformation and upgrading of local industrial structures. China carries out the construction of innovative cities according to the principle of “pilot first, accumulate experience, and gradually roll out”; the implementation of the policy

creates top-down pressure on local governments, thus forcing localities to carry out industrial structure adjustment in accordance with the construction program. Consequently, the allocation of resource factors towards the service sector is enhanced. This sector is distinguished by its minimal pollution and energy consumption, coupled with a substantial return on investment. Compared with the secondary industry, which is dominated by heavy industry, the dominance of the tertiary industry helps to improve the comprehensive output of the production process and reduce environmental pollution, thus promoting the green utilization of land. Hypothesis 2 is verified.

The data presented in column (2) of Table 5 reveal that the coefficient for $treat \times time$ stands at 0.932, exhibiting a statistically significant positive value at the 1% level. This indicates that the NICPP contributes to the enhancement of the local innovation capacity. The implementation of the policy creates a favorable institutional environment for localities, attracts talents, capital, and other core elements in innovation activities to gather, and promotes the R&D activities and the output of results of innovation subjects in the pilot cities, which, in turn, improves the level of technological innovation. Technological innovation not only improves resource allocation but also increases the utilization rate and productivity of production factors, thus driving the growth of ULGUE. Hypothesis 3 is verified.

5.2. Heterogeneity Analysis

Considering the large differences in economic development level, resource endowment, and other factors among cities, the impact of the NICPP on ULGUE may be heterogeneous. The sample is categorized into eastern, central, and western regions based on geographic location to investigate the varying effects of the NICPP on ULGUE across these distinct areas. At the same time, the cities are categorized into resource-based cities, non-resource-based cities, old industrial base cities, and non-old industrial base cities according to the type of cities to explore the impact on the implementation of the NICPP. Figure 4 illustrates the geographic distribution of urban areas.

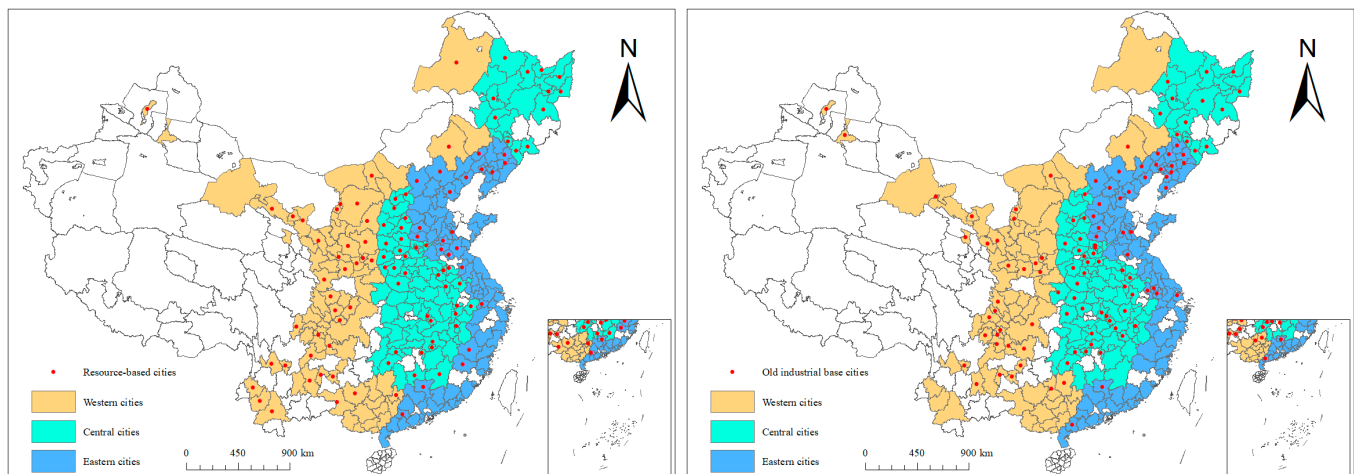


Figure 4. The spatial distribution of cities.

From columns (1)–(3) in Table 6, it is evident that the NICPP has the highest effect on enhancing ULGUE in the east, followed by the central region, while its influence in the western region has not yet been highlighted. The underlying cause of this phenomenon may be attributed to the superior economic development, technological infrastructure, human capital, and overall infrastructure in the eastern and central regions compared to the western region. Consequently, the NICPP is positioned to more effectively facilitate the advancement of green technological innovation and the sustainable transformation of the

industrial structure in urban areas of the eastern and central regions, thereby enhancing ULGUE. The western region faces constraints due to its geographical location, backward technology level, and weak industrial base, which weaken the driving effect of the policy.

Table 6. Heterogeneity analysis results.

Variables	(1) Eastern	(2) Central	(3) Western	(4) Resource	(5) Non-Resource	(6) Old Industrial Base	(7) Non-Old Industrial Base
treat × time	0.068 *** (3.395)	0.033 * (1.682)	−0.003 (−0.154)	−0.009 (−0.376)	0.069 *** (5.170)	0.045 *** (3.282)	0.063 *** (3.309)
Control variables	control	control	control	control	control	control	control
Cons	1.790 *** (2.608)	−1.056 ** (−2.231)	−2.178 *** (−4.505)	0.086 (0.197)	−0.602 (−1.514)	1.526 *** (3.787)	−1.815 *** (−4.201)
City	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	1513	1615	1394	1836	2686	1921	2601
R ²	0.220	0.212	0.300	0.208	0.223	0.229	0.221

The NICPP has a significantly greater positive driving effect on non-resource-based cities and non-old industrial basis cities than on resource cities and old industrial base cities, as can be shown in Table 6’s columns (4)–(7). This could be attributed to the industrial structure of resource-dependent cities and legacy industrial-base cities, which are marked by elevated levels of pollution, significant energy consumption, and high emissions. It is also easy for production path dependence to develop, which leads to difficulties in industrial transformation, thus weakening the effect of the policy. Non-resource-based cities and non-old industrial base cities, with their good industrial and innovation bases, are more conducive to the formation of new technologies, emerging industries, innovative business models, and green economy practices under the impact of the policy, thus promoting ULGUE.

6. Discussion

Innovation is crucial in addressing the inherent tension between economic growth and environmental sustainability [46]. Due to its inherent uncertainties, innovation often necessitates external support to manage associated risks effectively [58]. Bekhet and Latif emphasize that integrating innovation with strategic policies is instrumental in fostering sustainable urban development [59]. As a centralized form of external support, the NICPP combines innovation with policy implementation and plays a key role in advancing sustainable urban development in China. This study investigates the potential of the NICPP to promote green and sustainable urban land use, focusing on ULGUE. Our findings indicate that the NICPP has significantly enhanced ULGUE, consistent with prior studies that underscore the pivotal role of innovation in sustainable urban development. For instance, empirical studies by Ehigiamusoe et al. and Ibrahim in Malaysia and Egypt, respectively, demonstrate that innovation policies effectively lower carbon emissions and enhance environmental quality [60,61]. While previous studies have highlighted the positive effects of innovation policies in mitigating carbon and pollutant emissions [28,45,62], this paper extends the research on the aspect of the green sustainability effects of innovation policies by quantifying ULGUE and demonstrating the effectiveness of the NICPP.

The analysis of the mechanisms reveals that the NICPP fosters advancements in ULGUE through two primary channels: facilitating industrial structure upgrades and enhancing urban technological innovation capabilities. Both factors synergistically drive green land utilization. The construction principles and assessment criteria for China’s

innovative cities are intricately linked to industrial structure optimization and technological innovation [30,49]. These criteria encompass dimensions of technology, systems, and ecology, while the guiding principles emphasize green, low-carbon, and innovation-driven development [62]. This dual approach emphasizes the importance of combining green development goals with innovation strategies. Through policy guidance and support, cities are more strategically equipped to attain economic development while prioritizing sustainable resource use and environmental protection.

Moreover, the policy's impact varies across regions and city types. A stronger positive effect on ULGUE is observed in eastern cities, consistent with earlier findings [34]. The eastern region, benefiting from a favorable geographical location, a more open market environment, and extensive policy support, outperforms the central and western regions in economic development, infrastructure, and technological accumulation [36]. These advantages provide fertile ground for the effective implementation of the NICPP [46]. In addition, the policy's effects are less pronounced in resource-based cities, which have traditionally relied on the extraction and utilization of natural resources such as land, water, forests, and minerals. While this resource-intensive development model has driven economic growth to some extent, it has also led to environmental degradation, inefficient land use, and an overly simplistic industrial structure [11,63]. These challenges hinder resource-based cities from attracting high-end talent, adopting advanced technologies, and fostering new industries [30]. This study also confirms the result that the implementation of the NICPP significantly influences the ULGUE of non-resource-based cities, whereas its influence on resource-based cities is not significant.

7. Conclusions and Policy Implications

Utilizing panel data from 266 cities in China spanning the years 2004 to 2020, the super-efficiency SBM model, which incorporates undesirable outputs, is employed to assess ULGUE. By constructing a multi-temporal DID model, the policy effect of the NICPP on ULGUE is explored, and its mechanism is clarified. It is found that the NICPP significantly promotes improvement in ULGUE, and the conclusion still holds under various robustness tests. Based on the findings from the mechanism analysis, the NICPP can facilitate the transformation and enhancement of industrial structures while boosting technological innovation capabilities. This, in turn, can elevate the overall output of land utilization processes and decrease pollutant emissions, subsequently impacting ULGUE. Moreover, the NICPP exerts a more pronounced positive impact on ULGUE in non-industrial bases, non-resource-based cities, and those located in the east-central region. Drawing on the findings discussed above, the following policy suggestions are proposed:

Firstly, it is essential to summarize successful experiences and continuously advance the development of innovative cities. Governments should establish cross-regional and cross-industry exchange platforms, regularly hosting activities such as experience-sharing meetings, seminars, and forums. These platforms can facilitate the identification and dissemination of best practices, successful cases, and advanced models in innovative city construction, ultimately forming a replicable and scalable framework for innovation-driven green development. Second, the principles of green land utilization should be deeply integrated into all aspects of innovative city development. This includes strengthening the evaluation of key areas such as green development and land use efficiency. Lastly, robust monitoring and assessment mechanisms should be implemented for the progress of innovative city construction, enabling dynamic adjustments to the list of pilot cities based on performance and evolving priorities.

Secondly, the multidimensional role of pilot policies in advancing the sustainable use of urban land must be emphasized. Pilot cities should leverage the advantages of these

policies by fostering a conducive environment for innovation, prioritizing the cultivation of innovative talent, increasing investments in dedicated funds for scientific and technological innovation, and establishing robust mechanisms to ensure the success of technological advancements. Furthermore, leveraging policy incentives, cities should support the growth of high-tech and green industries, enable the eco-friendly transition of conventional sectors, and foster the development of regional green industrial clusters.

Thirdly, respect regional differences and implement city-specific policies. Development plans and support measures must be customized to the unique characteristics and resource advantages of each region. In the eastern region, efforts should focus on advancing high-tech research, development, and application to drive the transition toward intelligent and digitalized production methods. The central and western regions should seize the opportunities presented by innovative city initiatives, promote the green transformation and upgrading of traditional industries, and achieve efficient resource recycling alongside sustainable ecological improvements. For resource-based and old industrial-base cities, priority should be given to phasing out outdated, high-energy-consuming, and environmentally detrimental production capacities. Through technological innovation and industrial upgrading, these cities can establish green, low-carbon, and circular economic systems. Additionally, leveraging local resource endowments, distinctive green industrial chains should be developed in areas such as renewable energy, energy efficiency, environmental sustainability, and advanced materials. These emerging industries will provide a fresh impetus for sustainable urban development.

The study period spans from 2004 to 2020, while the most recent cohort of innovative city pilots was launched in 2022. Consequently, the analytical framework and conclusions of this paper do not directly account for the implementation effects of this latest cohort. Considering that these new pilot cities may have drawn upon the experiences of earlier pilots—incorporating advancements in planning concepts, policy design, and technological innovation—it is worth investigating whether they have achieved a more substantial impact on ULGUE. Future investigations ought to explore the enduring effects of the NICPP on ULGUE, as well as potential synergies with other environmental and social policies. Additionally, subsequent research could analyze how variations in governance models or institutional arrangements influence the implementation of such policies.

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