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Impact of Free Trade (Pilot) Zone Establishment on Urban Land Use Efficiency—Empirical Evidence from Cities in China

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Abstract: The establishment of the Free Trade (Pilot) Zone (FTZ) is a new attempt by China to embark on modern sustainable urban planning and governmental territorial management at the development stage of a high-quality economy. As urban lands serve as the limited resource foundation for civic production and livelihoods, enhancing land use efficiency becomes a key measure to facilitate metropolitan economies of high quality. Utilizing panel data from prefecture-level cities spanning from 2005 to 2021, this study constructs a multi-period difference-in-differences model to explore the impact of FTZs on urban land use efficiency (ULUE). The results indicate that FTZs can significantly enhance urban land use efficiency, with a more pronounced policy effect observed in central cities, inland cities, and cities with higher urbanization rates. Furthermore, the FTZs also demonstrate spatial spillover effects on urban land use efficiency. This study holds great significance for relevant government departments in formulating policies to optimize land resource allocation, promote FTZ development, and foster high-quality urban planning and territorial management.

Keywords: free trade (pilot) zone; urban land use efficiency; multi-period difference-in-differences; heterogeneity analysis; spatial spillover effect

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1. Introduction

Since the reform and opening up, particularly after joining the World Trade Organization (WTO) in 2001, China's economy has experienced sustained rapid growth for many years. However, starting in 2008, China's economic growth rate has gradually slowed down, partly due to external shocks from the economic crisis and challenging external demand conditions; on the other hand, it is also closely related to internal factors such as unbalanced economic development structures and an over-reliance on external demand. Profound changes in both domestic and international environments have compelled China to proactively move from a focus on quantity to quality in its transformation. High-quality urban economic development requires the transformation and upgrading of traditional industries, optimizing the layout of emerging industries, and, simultaneously, leveraging institutional reforms to advance comprehensive reforms in urban planning, construction, and management [1,2]. The establishment of Free Trade (Pilot) Zones (FTZs) is an important measure for China to deepen reforms comprehensively and seek high-quality economic development under new circumstances.

Since the reform and opening up in 1978, China has established various special zones in response to domestic and international situations, including Special Economic Zones (SEZs), High-Tech Industrial Development Zones, National New Areas, and Free Trade (Pilot) Zones. High-Tech Industrial Development Zones and National New Areas focus on promoting high-tech products or regional development through policy incentives provided by the government. In contrast, SEZs and FTZs drive comprehensive development across China by actively opening up and integrating with international standards. However, SEZs were initially founded under a planned economy framework, aiming at facilitating the flow of goods, capital, talent, and technology through preferential policies, essentially constituting a form of "border opening". Free Trade (Pilot) Zones, on the other hand, are set up under a market economy framework, aiming to actively benchmark against international rules and create a "soft environment" that attracts, accumulates, and cultivates high-end production factors, fundamentally constituting a form of "domestic opening". Establishing FTZs is widely recognized as one of the key strategies for becoming a global hub port [3]. However, the size, geographic location, and other characteristics of FTZs vary by country or region, leading to differences in the form, positioning, and level of development of FTZs. For example, an FTZ could be as small as a duty-free shop at an airport or as large as the entire city of Hong Kong [4].

Most studies on Free Trade (Pilot) Zones focus on foreign investment management systems [5], trade supervision systems [6], financial service systems [7], etc. Within these zones, however, during the research process in the Free Trade Pilot Zones, we discovered that in addition to defining the scope and subdividing the areas of the Free Trade Pilot Zones, there are also regulations concerning the development and utilization of land and space in these zones. For instance, the "China (Shanghai) Pilot Free Trade Zone Lingang New Area Territorial Space Master Plan (2021–2035)" issued in 2021, and the "Notice on Printing and Distributing the Overall Plan of Beijing, Hunan, and Anhui (Pilot) Free Trade Zone and the Regional Expansion Plan of Zhejiang Pilot Free Trade Zone" issued by The State Council of China in 2020, all emphasize the need for the development and utilization of the free trade zone to comply with land use, ecological environmental protection, and planning regulations, aligning with territorial space planning and the requirements of economizing and intensive land use. Some free trade zones have specific strategies for intensive and sustainable urban land use. For example, the Shanghai FTZ has pioneered mixed-use land utilization, the Qingdao FTZ has implemented a flexible supply of industrial land and the 1.5-level land development model, and the Yingkou Free Trade Zone has piloted the "standard land +" system, among others.

The regulations on land development and the pioneering land use models in Free Trade Pilot Zones naturally raise questions: Can the establishment of these zones affect the land use efficiency of their host cities? If so, are there regional differences in the effects? Is there a spillover or suction effect on the land use efficiency of neighboring cities? Answering these questions not only helps in a more comprehensive evaluation and understanding of the construction effectiveness of the Free Trade Pilot Zones but also holds significant practical importance for China in further improving the development of these zones.

Based on this, the paper first uses the Super-Efficiency Slacks-Based Measure (Super-SBM) method to calculate the urban land use efficiency of 297 Chinese cities from 2005 to 2021. Then, using a multi-period Difference-in-Differences (DID) approach, it focuses on examining the impact of China's Free Trade Pilot Zones on urban land use efficiency. Furthermore, the paper discusses the heterogeneous effects and spatial effects of the Free Trade Pilot Zones on urban land use efficiency (ULUE). The marginal contribution of this paper is primarily twofold. Firstly, while most studies on pilot free trade zones focus on trade and economic development, few scholars delve into the efficiency of land resource utilization. This paper bridges this gap by examining the construction of FTZs in conjunction with urban land use efficiency, thus enriching the research perspective on FTZs and factors influencing ULUE. Secondly, the research significance is underscored by China's economic transition from high-speed growth to high-quality growth. Rational allocation of land resources becomes imperative for urban economic transformation. Therefore, exploring the impact of pilot free trade zone policies on urban land use efficiency holds great importance in strengthening policy evaluation and design by relevant government departments, thereby enhancing the government's role as the "visible hand" in the market economy.

The structure of the remaining sections of the paper is organized as follows: Section 2 is the literature review and research hypothesis; Section 3 describes the policy background, research design, and data description; Section 4 presents the analysis of empirical results and robustness tests; Section 5 conducts further analysis; Section 6 draws conclusions and discusses policy implications.

2. Literature Review and Research Hypothesis

2.1. Literature Review

2.1.1. Research on FTZ Policy

Free Trade Zones (FTZs) serve as significant mechanisms for countries to adapt to globalization and cultivate comparative advantages in global trade [8]. Ghosh et al. [9] conducted an empirical test on the geographical and economic spillover effects of free trade zones in the United States using the propensity score matching method. They found that FTZs contribute to the growth of non-manufacturing industries, with the positive impact exhibiting spillover effects, particularly within a 5-mile radius of the FTZs. Similarly, some scholars conducted a comparative study of the Masan Port Free Trade Zone and the Customs Free Trade Zone (CFZ) in South Korea, revealing that FTZs outperform CFZs in terms of economic development strategy, industrial structure, and investment promotion [10]. Since the establishment of the Shanghai FTZ in 2013, China's pilot FTZ policy has not only expanded trade openness and attracted foreign investment but has also undertaken key tasks such as fostering further reforms and institutional innovation [11]. Several studies have indicated that this policy can enhance trade efficiency by reducing trade costs [12] and, to some extent, improve trade structure by increasing the share of general trade while reducing the share of processing trade [13].

In addition, pilot free trade zones can effectively facilitate in the attraction of international capital and the expansion of domestic capital abroad [14]. Further analysis of the heterogeneous effects of FTZs reveals that cities that implemented special economic zone policies early tend to experience greater success in attracting foreign capital. This phenomenon may be attributed to the lagged effects of FTZ implementation and supportive policies [15]. It is noteworthy that studies have demonstrated that FTZs can generate external agglomeration effects, leading to knowledge spillovers and technological innovation through collaboration and exchange with neighboring cities [16,17].

An important advantage of FTZs in fostering knowledge spillovers lies in their conducive institutional environment [18], which provides a solid foundation for enhancing innovation capacity [19]. While the environment is a crucial aspect of FTZs, research on the impact of FTZ policies on the environment has not yielded a unified conclusion. Some scholars argue that trade liberalization can enhance environmental quality through technological progress and effectively address the tension between demand and resources [20]. Wang et al. [21] found that the pilot free trade zone policy effectively improves urban green total factor productivity, with this impact gradually increasing over time. Hu et al. [22] also support this view. However, some scholars argue that the establishment of free trade zones can lead to an environmental "policy trap", exacerbating environmental constraints [23]. Grossman and Krueger [24] identified that due to the interaction of scale, structural, and technological effects, environmental quality can significantly decrease with the promotion of free trade zones. Similarly, Liu et al. [25] confirmed that trade liberalization could harm the environment in developing countries.

Apart from the macro perspective mentioned above, a small number of scholars have examined the policy effects of free trade zones from a micro perspective. Li et al. [26] explored the influence of policies in pilot free trade zones on the development performance of port-listed companies within these zones. They concluded that port-listed companies effectively leveraged the agglomeration effect of free trade zones to access high-quality resources such as capital, management, and talent, thereby realizing long-term and rapid development. Jiang et al. [27] found that free trade zones have significantly enhanced the green total factor productivity of enterprises, with this improvement strengthening year by year.

2.1.2. The Measurement of Urban Land-Use Efficiency

Urban land serves as the spatial carrier for a city's economic, social, and environmental aspects, and its utilization efficiency is directly linked to urban socio-economic development and living environments [28]. Consequently, countries and regions around the world place great emphasis on the efficient use of land. For example, the United States has initiated smart growth and urban growth boundaries; the United Kingdom and Germany focus on compact city development [29]; the Netherlands and the Hong Kong region of China implement diversified intensive use [30,31]; and Singapore imposes land use structural constraints [32]. The measurement of land use efficiency has been continuously optimized, undergoing a transformation from single-index measurement to multi-index comprehensive measurement and then to non-parametric measurement [33–35]. Most traditional methods of measuring land use efficiency only consider a single index, such as economic aspects like land use density and unit land yield [36] or ecological [37] and social aspects [38]. Obviously, a single index cannot fully capture the relationship between various inputs and outputs in urban land use processes. Therefore, scholars have proposed multi-index comprehensive evaluation methods [39–41].

However, the multi-index comprehensive measurement method still faces challenges such as subjective index selection and weight determination [42]. As a result, non-parametric methods based on comprehensive evaluation of multiple inputs and outputs have become widely adopted. Gao et al. [43] constructed a two-stage Data Envelopment Analysis (DEA) method to measure urban construction land use efficiency, finding that efficiency during the construction phase was higher than during the production phase. Other scholars have also used DEA methods to measure urban land use efficiency from different perspectives, such as adjusting agriculture [44] and input-output structures [45], without considering non-expected outputs.

In addition to economic output, it has become consensus that non-expected outputs such as waste gas and wastewater discharge should be included in land use efficiency calculations. The Slack-Based Measure (SBM) model for land use efficiency measurement is an improvement over the traditional DEA model, as it accounts for non-expected outputs of land use, making it the mainstream method. Zhou et al. [46] and Xiao et al. [47] considered environmental pollution and carbon emissions as non-expected outputs when measuring land use efficiency. The Super-SBM model, based on non-expected output, addresses the issue of decomposing the efficiency value of effective decision-making units, preventing the loss of decision-making information in practical applications [48,49]. Furthermore, Huang et al. [50] proposed an SBM model considering global reference to address the challenge of comparing efficiency across time.

2.1.3. Factors Influencing Urban Land-Use Efficiency

Scholars have also delved into the factors influencing urban land use efficiency [51–54]. Existing research primarily examines these factors from the perspectives of economic development [55,56], market openness [57], industrial structure [58], technological innovation ability [59], city size [60] and characteristics [61], public infrastructure level [62], government behavior and policy [63,64], land system [65], and land finance [66], among others. For instance, Fan et al. [67] explored the main driving factors of land use efficiency using the grey correlation model, revealing that neglecting negative ecological impacts would lead to an overestimation of land use efficiency. Zhou et al. [68] conducted an empirical assessment of the level of land-intensive use in the Shanghai Pilot Free Trade Zone using the Delphi method and entropy value method, identifying development time, land use intensity, differences in leading functions, industrial land use structure, and diversification of employment structure as significant influencing factors.

It is evident from the existing literature that most research on Free Trade Pilot Zones (FTZs) focuses on their economic impacts, such as trade, investment, total factor productivity, and business environment. Studies on the factors affecting urban land use efficiency are also abundant. However, research specifically examining the relationship between FTZs and urban land use efficiency is very scarce, with few in-depth studies on the heterogeneity of FTZ impacts across different regions and city sizes. This paper considers the literature on measures of land use efficiency and uses the Super-SBM method to initially measure urban land use efficiency. It then treats the establishment of FTZs as a quasi-natural experiment to explore their impact on urban land use efficiency (ULUE) through a multi-period DID analysis, thus further extending the existing research findings.

2.2. Research Hypothesis

Enhancing the efficiency of land resource allocation is a crucial element in the development strategies of each Free Trade Pilot Zone. For instance, "In the Free Trade Pilot Zones, land is supplied based on the industrial chain, with integrated supply for multiple plots of land involved in the key links and core projects of the industrial chain. There is also support for localities in prioritizing the reasonable land use needs of the Free Trade Pilot Zones when arranging land use plans". Specifically, the Free Trade Pilot Zones have achieved success in models of efficient land use. For example, the Shanghai Free Trade Pilot Zone pioneered a pilot for mixed-use development, innovatively planning the unified construction of research and development facilities and production plants after land acquisition by businesses within the zone, thus achieving efficient land use [69]. Additionally, the Free Trade Pilot Zones explore the implementation of a "negative list", improve legal regulations such as intellectual property protection and arbitration judicial review, continually expand the areas of openness, and enhance the level of trade and investment facilitation, which benefits the improvement of the business environment and leads to an upgrade in the industrial structure within the zone [70], thereby enhancing urban land use efficiency. Accompanying the institutional innovations of the Free Trade Pilot Zones are reductions in institutional transaction costs and the inflow of high-quality investments and high-level talents, which favor technological innovation and, in turn, boost urban land use efficiency [71].

Based on the aforementioned analysis, this paper proposes Hypothesis 1:

H1: *Pilot free trade zone policies can enhance urban land-use efficiency within the zone.*

The policy of establishing pilot free trade zones does not solely aim at the development of the city where they are located; it also considers whether the free trade zone impacts surrounding cities. If so, further investigation is needed to determine whether it is a spillover effect or a siphon effect. Upon reviewing the overall plans for the construction of pilot trade zones, many emphasize the goal of forming high-standard and high-quality pilot free trade zones with outstanding radiation-driving effects within three to five years of reform and exploration. Existing research also indicates that Free Trade Pilot Zones indeed can produce significant positive spillover effects [72–74].

Based on this, it is inferred that the improvement effect of pilot free trade zones on urban land use efficiency can extend to surrounding cities, exerting a positive spillover effect on their land use efficiency. Therefore, Hypothesis 2 is proposed:

H2: *The construction of pilot free trade zones can enhance the land-use efficiency of surrounding cities through spillover effects.*

Due to differences in resource endowment, geographical location, and policy environment, cities will inevitably experience varying levels of development. Since China's reform and opening up, cities in coastal areas and the eastern regions have vigorously developed export-oriented economies, capitalizing on their geographical advantages and policy incentives. They have consequently accumulated significant capital, technology, and high-quality labor. With the initiatives of "Developing the West" and the "Rise of the Central Region", the central and western regions of China have seized the opportunity to achieve relatively rapid development. The differences in industrial structures and economic development gaps between regions have gradually narrowed.

However, there are still significant disparities in development between regions. Cities in the central and western regions of China have relatively weaker geographical conditions, resource endowments, and policy environments, which make them less attractive for factor agglomeration. However, the construction of Free Trade Pilot Zones (FTZs) facilitates the revitalization of production factors and optimizes resource allocation [75]. Consequently, this paper posits that the impact of FTZ policies varies among cities in the eastern, central, and western regions, as well as between coastal and inland areas, with potentially greater policy marginal utility for cities in the central and western regions, as well as for inland cities. Furthermore, considering that land is a core element of urbanization, the policy effects of FTZs on Urban Land Use Efficiency (ULUE) may differ depending on the level of urbanization. During urbanization, land use methods are optimized, and the extensive use of land shifts toward conservation and intensification, thereby enhancing land use efficiency [76,77]. Therefore, this paper argues that the establishment of FTZs has a more pronounced policy effect on land use efficiency in cities with higher rates of urbanization.

Building on this, Hypothesis 3 is proposed:

H3: *The Free Trade Pilot Zone policy has a more significant impact on cities in the central and western regions, inland cities, and cities with high urbanization rates.*

Figure 1 describes the theoretical hypotheses framework.

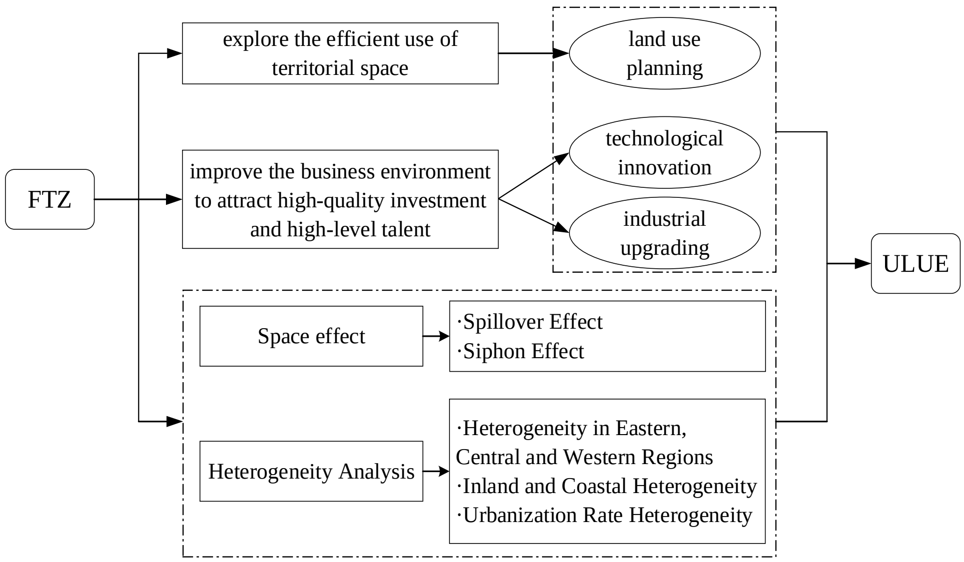

Figure 1. The theoretical hypotheses.

3. Policy Background and Research Design

3.1. Policy Background

Since the official launch of the China (Shanghai) Pilot Free Trade Zone in September 2013, by the first half of 2024, China has essentially established a new pattern of regional opening up. This pattern is comprehensive and high-level, coordinated across eastern, central, and western regions, and integrates both land and maritime strategies, with 22 Free Trade Zones forming the main framework. Specifically, in April 2015, three Chinese provinces—Guangdong, Tianjin, and Fujian—were approved as pilot free trade zones. In March 2017, seven provinces—Liaoning, Zhejiang, Henan, Hubei, Chongqing, Sichuan, and Shaanxi—were officially established as the second batch of pilot free trade zones, marking a deeper expansion of FTZs from coastal areas to inland regions. In October 2018, the China (Hainan) Pilot Free Trade Zone was established, designating the entire island of Hainan as a pilot zone. Subsequently, in August 2019, six provinces—Shandong, Jiangsu, Guangxi, Hebei, Yunnan, and Heilongjiang—were approved as pilot free trade zones. In September 2020, Beijing, Hunan, and Anhui were newly established as pilot free trade zones.

Finally, in October 2023, the first pilot free trade zone in China's northwest border region, the Xinjiang Pilot Free Trade Zone, was established. At this juncture, the network of pilot free trade zones covering coastal, border, and inland areas was formally established, becoming an essential platform for the development of China's open economy and global free trade.

The geographical distribution of China's Free Trade Zones and their founding years is shown in Figure 2.

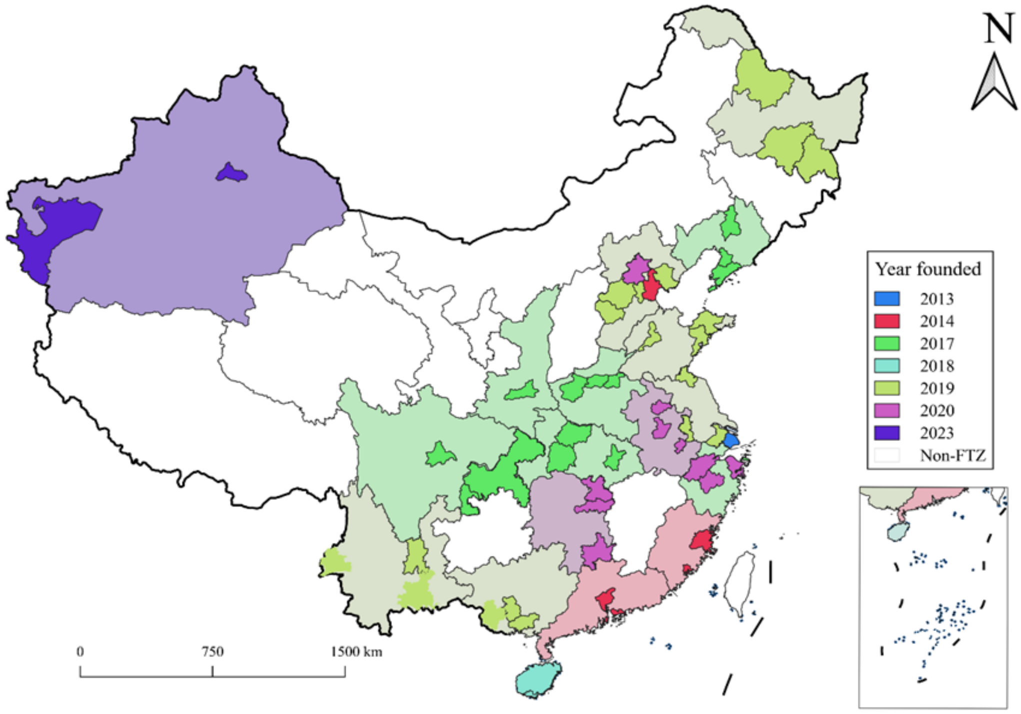

Figure 2. The Map of the Geographical Distribution of China's Free Trade Zones from 2013 to 2023. (Source: Plotted by authors based on official authoritative documents).

3.2. Model Setting

After the official establishment of the Shanghai Free Trade Zone in 2013, China established a total of 22 free trade zones in batches in 2015, 2017, 2018, 2019, 2020, and 2023, providing a favorable "quasi-natural experiment" scenario for this study. Due to data availability issues, the Xinjiang Free Trade Zone, officially inaugurated in November 2023, is not included in the analysis. Therefore, drawing from existing literature, this paper constructs a multi-period difference-in-differences model based on the implementation timing of the six batches of pilot free trade zone policies in 2013, 2015, 2017, 2018, 2019, and 2020. It establishes virtual variables for pilot free trade zone policies and analyzes their impact on urban land use efficiency. Given that urban land use efficiency in different regions is influenced by factors such as economic development level and industrial structure, and to address the problem of endogeneity arising from missing variables, we construct the following bidirectional fixed multi-period Difference-in-Differences (DID) model:

$$ULUE_{it} = \alpha + \beta \cdot DID_{it} + \sum_{j}^{n} \left(\gamma_j \cdot Control_{jt} \right) + \mu_i + \lambda_t + \eta_{pt} + \varepsilon_{it} \quad (1)$$

where $ULUE_{it}$ represents the urban land use efficiency of the city i in year t, and α is the constant term; DID_{it} is the policy dummy variable. $Control_{it}$ represents a series of control variables that may affect urban land use efficiency independently of FTZ policy, all of which are control variables of baseline regression. μ_i is the individual (city) fixed effect, indicating the characteristics of the city level that do not change with time, such as the city's terrain, climate, and other natural conditions. λ_t is the time fixed effect. In addition, after considering that the influence of province characteristics on land use efficiency has time-varying characteristics, the interactive fixed effect of province and year is added to the equation, i.e., η_{pt}. ε_{it} is the classic random error term. This paper is mainly concerned with the coefficient β in the equation, which is the impact of the implementation of the FTZ policy on urban land use efficiency. The following analysis defaults to clustering standard errors at the city level.

3.3. Variable Selection

3.3.1. Explained Variables

Urban land use efficiency (*ULUE*): Based on the literature review of urban land use efficiency measurements previously discussed, and considering the impacts of urban land use on the economy, society, and the environment—especially the high environmental costs incurred—this paper posits that urban land use efficiency should not only consider the inputs and expected outputs from production and living activities on the land but also the unintended outputs resulting from these activities. Therefore, this paper, referencing Tone (2001) [78], employs the Super-SBM model that accounts for undesirable outputs to measure urban land use efficiency. The advantage of this model lies in its ability to address the oversight of relaxation variables in the efficiency evaluation process within the radial model.

Let us consider a set of cities (n = 1, 2, …, N), where each city serves as a production decision-making unit (DMU). Each DMU comprises an input, expected output, and unexpected output, denoted as *m*, *l*, and *h*, respectively. The calculation formula is as follows:

$$min\theta^* = \frac{1 + \frac{1}{m}\sum_{m=1}^{M}\left(s_m^x / s_{jm}^t\right)}{1 - \frac{1}{l+h}\left[\sum_{l=1}^{L}\left(s_l^y / s_{jl}^t\right) + \sum_{h=1}^{H}\left(s_h^b / b_{jh}^t\right)\right]} \tag{2}$$

$$s.t.\begin{cases} x_{jm}^t \geq \sum\limits_{j=1,\, j\neq 0}^{n} \lambda_j^t x_{jm}^t + s_m^x \\ y_{jl}^t \geq \sum\limits_{j=1,\, j\neq k}^{n} \lambda_j^t y_{jl}^t - s_l^y \\ b_{jh}^t \geq \sum\limits_{j=1,\, j\neq k}^{n} \lambda_j^t b_{jh}^t + s_h^b \\ \lambda_j^t \geq 0,\ s_m^x \geq 0,\ s_l^y \geq 0,\ j = 1,2,\ \ldots,\ n \end{cases} \tag{3}$$

where θ^* represents the urban land use efficiency value; x_j^t, y_j^t and b_j^t respectively denote the input, expected output, and non-expected output values of the DMU_j at time t; s_m^x, s_l^y, and s_h^b represent the relaxation vectors for input, expected output, and non-expected output; and λ is the weight vector.

Following classical economic thought, this paper selects the most fundamental production inputs—land, capital, and labor—as factors influencing land use efficiency. The corresponding indicators are represented respectively by the built-up area, fixed capital stock, and the number of employed individuals in the secondary and tertiary industries of each city. The fixed capital stock is calculated using the perpetual inventory method, with a depreciation rate of 9.6% based on the year 2000, as per the practices of scholars such as Hall and Jones (1999) [79] and Young (2003) [80].

Economic benefit output is measured by the added value of the secondary and tertiary industries, while the general public budget revenue of local governments represents the social benefit output. The ecological environment benefit output is indicated by the green coverage rate of built-up areas. To comprehensively assess the non-expected output outputs stemming from various types of urban land use, three commonly used indicators—industrial sulfur dioxide emissions, industrial wastewater emissions, and industrial smoke and dust emissions—are selected. Additionally, carbon dioxide emissions, introduced by

Glaeser and Kahn (2008) [81], are used to characterize environmental pollution arising from commercial service land and residential land.

The evaluation indicators for *ULUE* are presented in Table 1.

Table 1. *ULUE* Evaluation Indicators.

Input and Output	Index	Variables	Unit
Inputs	Land	Built-up area	km^2
	Capital	Stock of fixed capital	Ten thousand yuan
	Labor force	Population employed in secondary and tertiary industries	Ten thousand people
Expected output	Economic benefits	Added value of secondary and tertiary industries	One hundred million yuan
	Social benefits	Local general public budget revenue	Ten thousand yuan
	Ecological and environmental benefits	Green coverage rate of built-up area	%
Non-expected output Inputs	Negative environmental benefits	Industrial wastewater	Ten thousand tons
		Industrial smoke dust	Tons
		Industrial sulfur dioxide	Tons
		CO_2 emissions	One million tons

3.3.2. Core Explanatory Variables

The dummy variable (*DID*) for the Free Trade Zone policy equals the interaction term between the treatment group dummy variable (*FTZ*) and the post-period dummy variable (*Post*).

$$DID_{it} = FTZ_i \times Post_{it} \tag{4}$$

where *FTZ* represents whether a city i is designated as a free trade zone, with a value of 1 if the city is approved as a free trade zone and 0 otherwise. *Post* represents the dummy variable for the policy implementation period, with a value of 1 for the year t when the free trade zone in city i is approved and subsequent years, and 0 otherwise. Since the establishment of the Shanghai FTZ in 2013, China has established 22 provincial FTZs in seven batches, covering four municipalities directly under the central government (Shanghai, Tianjin, Chongqing, and Beijing) and eighteen provinces.

Due to data availability constraints, we will exclude discussion on the Xinjiang FTZ, which was officially inaugurated on 1 November 2023, and focus solely on the policy effects of the first six batches of FTZs. Furthermore, it is important to note that FTZs in the four municipalities directly under the Central Government (Beijing, Shanghai, Tianjin, Chongqing) actually consist of multiple sub-zones. For ease of analysis, the baseline model assumes the existence of only one free trade zone per municipality. Hainan Province, on the other hand, is designated as a free trade port for the entire province. Given administrative consistency, the study focuses only on three prefecture-level cities in Hainan Province: Haikou, Sanya, and Danzhou. Additionally, due to data limitations and statistical considerations at the county level, if the free trade pilot area is a district or county unit, the corresponding city is taken as the study sample. Please refer to Table A1 in Appendix A for details on the establishment of the respective pilot trade zones.

3.3.3. Control Variables

In addition to being influenced by policies of the pilot free trade zone, urban land use efficiency in the FTZ is also closely associated with factors such as the level of social and economic development, regional industrial structure, population size, and local financial support. To minimize estimation bias resulting from missing variables, this paper incorporates a set of city-level control variables into the empirical model, drawing from existing literature on urban land use efficiency and pilot free trade zone policies. Specifically: (1) Level of economic development ($lnAGDP_{pc}$): The natural logarithm of per capita GDP is used to represent the level of economic development. Generally, cities with stronger economic strength tend to have higher scientific and technological investment, greater human resource capacity to utilize resources, and, thus, higher urban land use efficiency. (2) Level of industrial structure (*ind*): The level of industrial structure is measured by the ratio of the added value of the tertiary industry to the added value of the secondary industry. Changes in industrial structure directly or indirectly affect land use structure and patterns, thereby influencing land use efficiency. (3) Population size ($lnPop$): Population size is represented by the logarithm of the total population of the city. Generally, the crowding effect resulting from population agglomeration reduces the land's carrying capacity, leading to a decline in urban land use efficiency. (4) Government intervention (gov): The degree of government intervention is reflected through the proportion of fiscal expenditure to GDP. Generally, government intervention, to a certain extent, improves urban land use efficiency because the government considers both efficiency and equity to ensure the region's sustainable development. (5) Level of human capital (hum): The level of urban human capital is represented by the number of college students per capita. Human capital is also a crucial factor influencing land use efficiency. (6) Level of openness to the outside world ($open$): The proportion of foreign direct investment in GDP is used to reflect the city's level of openness to the outside world. Generally, a higher level of openness allows the region to understand and adopt foreign advanced experience and technology earlier, resulting in relatively higher initial urban land use efficiency.

Table 2 presents the definitions of all variables.

Table 2. Definition and description of variables.

Type	Symbol	Definition
Explained variable	*ULUE*	Urban land-use efficiency measured using the Super-SBM model considering undesired outputs
Explanatory variable	*DID*	Interaction term for area and time of implementation of free trade pilot zones
Control variable	$lnAGDP_{pc}$	Logarithmic value of GDP per capita
	ind	Ratio of value added of tertiary sector to value added of secondary sector
	lnpop	Logarithmic value of total urban population
	gov	Ratio of fiscal expenditure to GDP
	human	Value of university students per capita in cities
	open	Ratio of foreign direct investment to GDP

3.4. Sample and Data Description

This paper selects data from prefecture-level cities spanning from 2005 to 2021 as samples to investigate the impact of pilot free trade zone policies on urban land use efficiency. The relevant data primarily originate from the "China City Statistical Yearbook", "China Urban Construction Statistical Yearbook", statistical yearbooks and bulletins of individual cities, "China Statistical Yearbook on Environment", and the China Carbon Emission Accounts and Datasets (CEADs). To ensure the accuracy of the research conclusions, interpolation methods were utilized to address missing data, and samples with significant missing data were excluded during the study period. The descriptive statistics of the main variables are presented in Table 3.

Table 3. Descriptive statistics.

Variables	Observed Quantity	Mean Value	Standard Deviation	Min	Max
ULUE	4932	0.40	0.25	0.000	1.000
DID	4932	0.039	0.194	0.000	1.000
$\ln AGDP_{pc}$	4932	10.43	0.76	4.595	13.056
ind	4932	0.98	0.56	0.094	5.929
ln*pop*	4932	5.83	0.79	−1.609	8.141
gov	4932	0.19	0.14	0.043	2.349
hum	4932	4.69	1.01	0.000	7.165
open	4932	0.14	0.93	0.000	57.694

4. Result Analysis and Robustness Test

4.1. Baseline Regression Results

To test Hypothesis 1, regression was performed on Model (1), and the results are shown in Table 4. Without including control variables, column (1) shows that the regression coefficient for the construction of Free Trade Pilot Zones on urban land use efficiency is 0.1735, significant at the 1% level as positive, suggesting that the establishment of Free Trade Pilot Zones improves urban land use efficiency, preliminarily validating Hypothesis 1. After adding control variables and fixing individual effects (City FE) and time effects (Year FE), the coefficient of the core explanatory variable in column (2) is 0.0375, significant at the 5% level as positive. This implies that, with all other conditions being constant, cities with Free Trade Pilot Zones have increased their land use efficiency by 0.0375 compared to cities without such zones, which is equivalent to 9.375% of the average land use efficiency among the sample cities, with both statistical and economic significance. Furthermore, to control for the annual changes in the impact of the Free Trade Pilot Zone policy on ULUE, column (3) further controls for province-year interaction fixed effects (Province*Year FE), and column (4) performs a province-clustered analysis based on column (3), finding that the coefficient of the core explanatory variable is significantly positive at the 1% level. These results indicate that the Free Trade Pilot Zone policy significantly enhances urban land use efficiency, thus validating Hypothesis 1.

Table 4. Baseline result.

	(1)	(2)	(3)	(4)
	ULUE	*ULUE*	*ULUE*	*ULUE*
DID	0.1735 *** (9.4665)	0.0375 ** (2.5073)	0.0592 *** (4.0201)	0.0592 ** (2.4514)
$\ln AGDP_{pc}$		0.1759 *** (5.8811)	0.1726 *** (3.4519)	0.1726 *** (3.2838)
ind		−0.0637 *** (−4.5244)	−0.0124 (−0.8299)	−0.0124 (−0.5840)
ln*pop*		0.1422 *** (4.6358)	0.1579 *** (4.2481)	0.1579 *** (4.2787)
gov		−0.0779 ** (−2.0508)	−0.0709 (−1.0789)	−0.0709 (−0.7052)
hum		−0.0127 ** (−2.2572)	−0.0027 (−0.4286)	−0.0027 (−0.4975)
open		−0.0025 (−0.8424)	−0.0015 (−0.4982)	−0.0015 * (−2.0551)
City FE	/	√	√	√
Year FE	/	√	√	√
Province*Year FE	/	/	√	√
Constant	0.3947 *** (111.7285)	−2.1265 *** (-5.3851)	−2.2817 *** (-3.3854)	−2.2817 *** (−4.5713)
N	4932	4932	4845	4845
R^2	0.0188	0.7089	0.7581	0.7581

Note: Robust standard errors in parentheses. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

4.2. Robustness Test

4.2.1. Parallel Trend Test

The prerequisite for using the difference-in-differences model is that the treatment group and the control group should adhere to the parallel trend assumption before the policy shock. That is, before the implementation of the free trade zone policy, the urban land use efficiency of the treatment group and the control group should ideally exhibit similar trends. Only under these circumstances can the policy effect coefficient more accurately reflect the impact of the policy.

This study employs an event analysis approach, where the year a city is established as a free trade zone is assigned a value of 0. The year following establishment (Year 1 or Year 2) is assigned a value of +1 (+2), while the year preceding establishment (Year −1 or Year −2) is assigned a value of −1 (−2), and so forth. The sample range in this study is [–15, 8]. Following the approach of Fajgelbaum et al. (2020) [82] and considering the scarcity of observations on both sides, this study sets relative years that are less than or equal to −8 uniformly to −8 and relative years that are greater than or equal to 6 all to 6. Additionally, the year preceding the city's designation as a free trade zone (−1 period) is considered the base period, from which corresponding regression coefficients are obtained.

As illustrated in Figure 3, prior to the implementation of the pilot free trade zone policy, the regression coefficients of both the treatment and control groups were not significant and fluctuated around 0. This suggests that there was no significant difference between the regression coefficients of the two groups before the policy implementation, thus satisfying the parallel trend hypothesis. Furthermore, examining the dynamic effect after the implementation of the pilot free trade zone policy, in the first year after policy implementation, the estimated coefficient $\hat{\beta}$ may not be significant due to lag effects, while in the second year after policy implementation, $\hat{\beta}$ is positive and significant. But in the third year, it becomes insignificant suddenly, which may be affected by the unexpected epidemic outbreak. Subsequently, the coefficient $\hat{\beta}$ is gradually and significantly positive, showing an upward trend, indicating that the pilot free trade zone policy can improve urban land use efficiency, consistent with the baseline regression results.

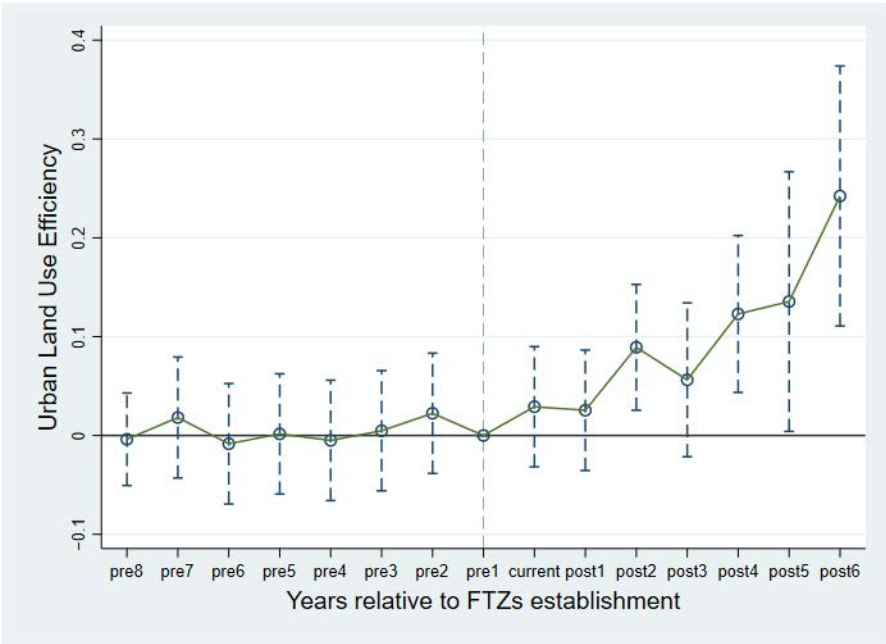

Figure 3. Results of Parallel Trend Test.

4.2.2. Placebo Test

The baseline regression results confirm that FTZ policy can improve urban land use efficiency. However, this result may be influenced by other random factors, and the regression results above could be biased due to other confounding policies or unobserved factors. Therefore, a random policy treatment group was obtained by randomly sampling samples and randomly generating the policy implementation year. Meanwhile, interaction terms of pseudo-virtual policies were generated for placebo tests. In order to enhance the effectiveness of the placebo test, this paper randomly selected 1000 samples and conducted 1000 regression iterations according to model (1). Figure 4 illustrates the coefficient kernel density obtained from regression and the corresponding *p*-value distribution. The centers of distribution of the coefficients from the random sampling test are all near zero, significantly different from the estimated coefficient of the baseline regression (dashed line value = 0.0592). Most of the *p*-values are greater than 0.1, indicating that the coefficients are not statistically significant, at least at the 10% level. This suggests that the baseline regression results are robust and less affected by other policies or unobservable factors.

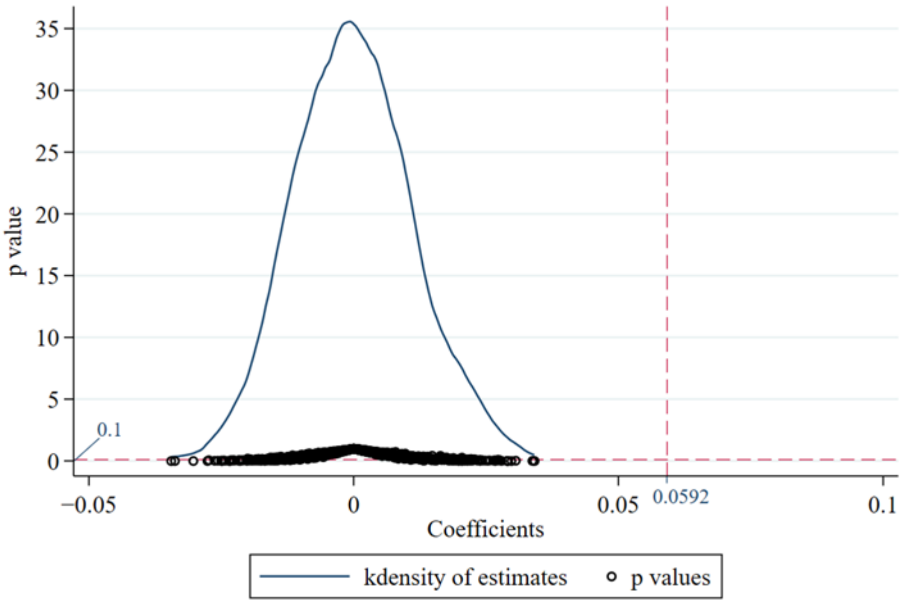

Figure 4. Results of the Placebo Test.

4.2.3. PSM-DID

Since cities with FTZs may have different initial conditions compared to those without, there could be endogeneity issues. Additionally, cities establishing FTZs may exhibit better economic development levels, industrial structures, and policy environments, leading to a potential "self-selection effect". Consequently, direct regression on all samples of cities with and without FTZs may introduce "sample selection bias", resulting in biased research conclusions. To address this potential "self-selection effect", Propensity Score Matching with Difference-in-Differences (PSM-DID) was employed to identify comparable control group cities for those with FTZs. Subsequently, matched samples were utilized for regression analysis.

In this paper, the core explanatory variable (DID) is treated as the treatment variable, while six control variables in the baseline regression are selected as first-order covariates. Additionally, 17 interaction terms, such as gov#gov, pop#ind, and ind#ind, are chosen as second-order covariates. The logit model is employed, and the default kernel function and bandwidth are utilized for kernel matching. The matching results are presented in Table 5. The average treatment effect on the treated (ATT) is calculated as 0.028447, with an absolute T-value of 3.29. This T-value exceeds the absolute value of 2.56 at the 5% significance level, indicating that the average treatment effect is statistically significant at the 1% level. Therefore, the treatment variable significantly impacts the outcome variable.

Table 5. Average Treatment Effect.

Variables	Samples	Treatment Group	Control Group	Differences	Residuals	T-Value
ULUE	Unmatched	0.568218452	0.394671119	0.173547334	0.017876457	9.71
	ATT	0.56962411	0.663307424	−0.093683314	0.028447391	−3.29
	ATU	0.541227468	0.439847344	−0.101380124		
	ATE			−0.100082037		

Before sample matching, the *p*-values of control variables in both the treatment group and the control group were significant at the 1% level, indicating a significant difference between the two groups. After propensity score matching, the absolute values of standard deviations of each covariate were all less than 20%, and the *p*-values after matching were all greater than 1%, indicating no significant difference between the treatment group and the control group post-matching. Propensity score matching effectively corrects the distribution bias of propensity score values, rendering the matched data in this paper valid and credible. The balance test of propensity score matching is presented in Table A2 in Appendix A.

In order to clearly explain the impact of establishing the pilot free trade zone on urban land use efficiency, this paper employs data after kernel matching for regression analysis to underscore the robustness of the regression results. As depicted in Table 6, in the presence of city fixed effects (City FE), time fixed effects (Year FE), and province-year fixed effects (Province*Year FE), columns (1) and (2) show the regression results without and with control variables, respectively, where the estimated coefficients of the core explanatory variables are significant at the 5% and 10% levels, respectively. Columns (3) and (4) show the regression results without and with control variables, respectively, under further province-clustered analysis, where the estimated coefficients of the core explanatory variables are 0.0687 and 0.0520 and are significant at the 5% and 10% levels, respectively.

Table 6. PSM-DID Estimation.

	(1)	**(2)**	**(3)**	**(4)**
	ULUE	***ULUE***	***ULUE***	***ULUE***
DID	0.0687 **	0.0520 *	0.0687 **	0.0520 *
	(2.2282)	(1.7916)	(2.3960)	(1.7597)
Constant	0.5344 ***	−0.7317	0.5344 ***	−0.7317
	(79.7026)	(−0.6451)	(107.8556)	(−0.5687)
Controls	/	√	/	√
City FE	√	√	√	√
Year FE	√	√	√	√
Province*Year FE	√	√	√	√
N	949	949	949	949
R^2	0.8432	0.8466	0.8432	0.8466

Note: Robust standard errors in parentheses. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Observing the regression results post data matching, it becomes evident that the coefficient of the pilot free trade zone variable is significantly positive, signifying a notable positive impact of establishing the pilot free trade zone on urban land use efficiency. The significance of each variable remains largely consistent before and after matching, in comparison with the baseline regression results, thereby further affirming the robustness and reliability of the baseline regression model.

4.2.4. Entropy Balance

Compared to PSM matching, entropy balance matching can further ensure a multidimensional balance of covariates between the treatment group and the control group. This involves narrowing the sample moment difference of covariates between the two groups, thereby minimizing the influence of selection bias without losing samples. In this paper, six control variables from the baseline regression were selected as covariates. Entropy balance matching was applied, and the method of moment balance was adopted to align the distribution of first-order, second-order, and third-order moments of covariates between the control group and the treatment group, achieving inter-group equilibrium.

As depicted in Tables 7 and 8, the mean, variance, and kurtosis of the six covariates in both the treatment and control groups are nearly identical. Subsequently, regression analysis was conducted on the samples following entropy balance matching. The outcomes are illustrated in Table 9. Controlling for city fixed effects (City FE), time fixed effects (Year FE), and province-year fixed effects (Province*Year FE), columns (1) and (2) respectively show the regression results without and with control variables, where the estimated coefficients of the core explanatory variables are 0.1012 and 0.0946, both significant at the 1% level. Columns (3) and (4) involve further province-clustered analysis, displaying the regression results without and with control variables, where the estimated coefficients of the core explanatory variables are 0.1012 and 0.0946, respectively, with corresponding standard errors of 2.9898 and 3.2605, both significant at the 1% level. Overall, the estimated coefficients of the core explanatory variables after entropy balancing are consistently significant at the 1% level and positive, confirming the reliability of the baseline regression results.

Table 7. Characteristics of Covariates of Treatment Group and Control Group Before Entropy Matching.

	Treatment			Control		
	Mean	**Variance**	**Skewness**	**Mean**	**Variance**	**Skewness**
$\ln AGDP_{pc}$	11.4	0.1905	−0.4032	10.39	0.5532	−0.3684
ind	1.798	0.9312	2.047	0.9492	0.2627	2.474
ln*pop*	6.295	0.6997	−0.6473	5.814	0.6196	−2.242
gov	0.1723	0.003718	1.548	0.1909	0.02048	5.695
hum	5.78	0.635	−0.4511	4.641	0.9813	−0.01645
open	0.2062	0.03595	1.033	0.1367	0.8894	52.43

Table 8. Characteristics of Covariables in the Treatment Group and Control Group after Entropy Matching.

	Treat			Control		
	Mean	**Variance**	**Skewness**	**Mean**	**Variance**	**Skewness**
$\ln AGDP_{pc}$	11.4	0.1905	−0.4032	11.4	0.1905	−0.4031
ind	1.798	0.9312	2.047	1.797	0.9311	2.047
ln*POP*	6.295	0.6997	−0.6473	6.295	0.6997	−0.6473
gov	0.1723	0.003718	1.548	0.1723	0.003718	1.548
hum	5.78	0.635	−0.4511	5.78	0.635	−0.4512
open	0.2062	0.03595	1.033	0.2063	0.03597	1.034

Table 9. Entropy-balancing Estimation.

	(1)	**(2)**	**(3)**	**(4)**
	ULUE	***ULUE***	***ULUE***	***ULUE***
DID	0.1012 *** (3.6955)	0.0946 *** (3.3388)	0.1012 *** (2.9898)	0.0946 *** (3.2605)
Constant	0.5364 *** (36.3990)	−0.1496 (−0.1383)	0.5364 *** (30.3554)	−0.1496 (−0.0970)
Controls	/	√	/	√
City FE	√	√	√	√
Year FE	√	√	√	√
Province*Year FE	√	√	√	√
N	4841	4841	4841	4841
R^2	0.9197	0.9220	0.9197	0.9220

Note: Robust standard errors in parentheses. *** $p < 0.01$.

4.2.5. Expected Effect Test

The premise of considering the policy shock of joining the pilot free trade zone as a quasi-natural experiment is that this policy shock exists in randomness. Drawing from Lu and Yu's method [83], this paper tests the expected effect of the policy shock from the pilot free trade zone. By adding dummy variables for the pre-implementation period of the pilot cities (represented respectively as one year before, two years before, and three years before) and their interactions with "treatment" in the baseline regression model, we examine whether cities approved as pilot zones have already formed adjustment expectations in the one, two, or three years prior to the policy shock. If the coefficients of these interaction terms are significantly non-zero, it indicates that cities approved as pilot zones had anticipatory effects on the policy before the implementation of the pilot free trade zone. In this case, the outcome variables of the treatment and control groups in the difference-in-differences (DID) estimation in this paper are not comparable before the policy shock of the pilot free trade zone, resulting in bias in the estimation results of DID.

The test results, as shown in Table 10, indicate that the estimated coefficients for the three interaction terms are 0.0000, 0.0371, and 0.0116, none of which passed the significance test. After including the aforementioned interaction terms in the regression, the estimated coefficients of the core explanatory variables are significantly positive and not much different from the baseline regression result of 0.1735. This indicates that cities approved as FTZs did not anticipate adjustments before the impact of FTZ policies, suggesting a strong policy externality. Therefore, the DID estimation results described above are deemed more credible.

Table 10. Expected Effect Test.

	(1)	(2)	(3)
	ULUE	***ULUE***	***ULUE***
DID	0.0573 ***	0.0604 ***	0.0582 ***
	(3.7987)	(3.9821)	(3.8403)
treat × one year before	0.0000		
	(0.0018)		
treat × two year before		0.0371	
		(1.5576)	
treat × three year before			0.0116
			(0.4786)
_cons	0.3964 ***	0.3959 ***	0.3962 ***
	(202.3755)	(201.8074)	(201.7808)
N	4845	4845	4845
R^2	0.7490	0.7491	0.7490

Note: Robust standard errors in parentheses. *** $p < 0.01$.

4.2.6. Excluding Interference from Other Relevant Policies

As national or regional central cities, the cities approved as pilot free trade zones are often affected by various location-oriented policies at the national level. In order to exclude the influence of other location-oriented policies, this paper focuses on the following two types of major location-oriented policies at the national level: ① The Industrial Structure Transformation (Pilot) Zone (ISTZ). The main goal of the ISTZ is to accelerate the transformation and upgrading of old industrial cities and resource-based cities by promoting urban renewal and industrial structure adjustment, which undoubtedly affects the ULUE of relevant cities. China has supported the construction of two batches of the ISTZ in 2017 and 2019, which intersected with the FTZ policy. In view of the above reasons, it is necessary to exclude the policy interference of the ISTZ. As shown in column (1) of Table 11, after controlling for the ISTZ policy, the estimated coefficient of the core explanatory variable, DID, is 0.0597, significant at the 5% level. ② The Ecological Conservation (Pilot) Zone (ECZ). According to a document released by the Ministry of Ecology and Environment of the People's Republic of China, a total of seven ECZ zones were established between 2017 and 2023 at a rate of one batch per year. The ECZ encompasses administrative units at various levels, including provinces, cities, districts, and counties. However, this paper focuses on the ecological civilization demonstration zones at the prefecture-level city level. It is important to note that due to the intersecting nature of the list of ecological civilization demonstration zones, districts or counties within the same city are considered as research samples if they are designated as demonstration zones. In cases where different districts and counties within the same city are designated as demonstration zones at different times, they are categorized into batches based on their implementation dates. In addition, this paper's study period spans from 2005 to 2021. Given that the fifth batch of the ECZ was established in October 2021, its policy effects are challenging to investigate within this timeframe. Consequently, this paper only considers the policy effects of the first four batches of the ECZ. The results are presented in column (2) of Table 11. In column (2), the estimated coefficient for the ECZ is 0.0346, and the estimated coefficient for the core explanatory variable DID is 0.0715, significant at the 5% level. Column (3) of Table 11 shows the regression results when controlling for both the ISTZ and ECZ policies, where the estimated coefficient for the core explanatory variable DID is 0.0720, also significant at the 5% level. These results indicate that whether controlling separately or jointly for the ISTZ and ECZ, the estimated coefficients of the core explanatory variable are significantly positive at the 5% level. This demonstrates that, even after excluding interference from related policies, the positive impact of the Free Trade Zone policy on ULUE remains evident.

Table 11. Excluding the Interference of Other Relevant Policies.

	(1)	(2)	(3)
	ULUE	*ULUE*	*ULUE*
DID	0.0597 **	0.0715 **	0.0720 **
	(2.4579)	(2.4881)	(2.5151)
ISTZ	−0.0224		0.0345 **
	(−0.9962)		(2.7893)
ECZ		0.0346 **	−0.0176
		(2.7872)	(−0.4269)
_cons	−2.2543 ***	−3.0777 ***	−3.0469 ***
	(−4.4662)	(−3.6379)	(−3.5924)
Controls	√	√	√
City FE	√	√	√
Year FE	√	√	√
Province*Year FE	√	√	√
N	4846	2156	2156
R^2	0.7582	0.8198	0.8198

Note: Robust standard errors in parentheses. ** $p < 0.05$, *** $p < 0.01$.

5. Further Analysis

5.1. Spillover Effect or Siphon Effect

Based on Model (1) discussed earlier, it has been found that the establishment of Free Trade Pilot Zones can significantly enhance urban land use efficiency. Since the Free Trade Zones carry the significant mission of exploring new paths and accumulating new experiences for comprehensively deepening reforms and expanding openness, this paper intends to explore, based on the fundamental conclusions, whether the Free Trade Pilot Zones have produced spatial effects on neighboring cities. If so, the question remains whether these are spillover effects or siphon effects. Based on this, and referring to Model (1), the following model is constructed:

$$ULUE_{it} = \alpha + \beta_1 \cdot FTZ_{it} + \sum_{j}^{n} (\gamma_j \cdot Control_{jt}) + \mu_i + \lambda_t + \eta_{pt} + \varepsilon_{it} \quad (5)$$

In Equation (5), FTZ_{it} represents whether city i has a neighboring city with a pilot free trade zone in year t; if it does, it is assigned a value of 1; otherwise, 0. Take Xiamen, Fujian Province, as an example. Xiamen is adjacent to Quanzhou and Zhangzhou, and Xiamen was approved as an FTZ in 2015. Therefore, before 2015, there were no neighboring cities with FTZs for Xiamen, so the value was 0; from 2015 onwards, the value is assigned as 1. If a city is adjacent to multiple pilot free trade zone cities, it is considered to be adjacent to the city that established the FTZ earlier. If a city's neighboring cities have never established an FTZ during the sample period, the value of FTZ_{it} is consistently assigned as 0. Other variables and parameters in the model are the same as in Model (1), with β_1 serving as the test basis for the spillover effect of FTZs. If β_1 is significantly positive, it indicates that the establishment of FTZs can drive the improvement of urban land use efficiency in surrounding neighboring cities, indicating a radiation effect. If β_1 is significantly negative, it indicates that the establishment of FTZs will reduce the urban land use efficiency of surrounding neighboring cities, indicating a siphoning effect. It should be noted that this model primarily examines the impact of pilot free trade zones on surrounding cities, so the model estimation does not include samples from the cities within the pilot free trade zone itself. Table 12 presents the estimation results of Model (5). Specifically, column (1) controls for city fixed effects (City FE), time fixed effects (Year FE), and province-year fixed effects (Province*Year FE) but does not include control variables. The estimated coefficient of the core explanatory variable is 0.0351, which is significant at the 1% level. Column (2) builds on column (1) by introducing control variables, with the estimated coefficient of the core explanatory variable being 0.0365, which is also significant at the 1% level. The regression results indicate that the establishment of pilot free trade zones has a positive and significant effect on the urban land use efficiency of surrounding neighboring cities. This suggests a clear radiating effect of pilot free trade zone construction on surrounding cities. Hypothesis 2 is supported.

Table 12. Analysis of Spatial Effects of Free Trade Pilot Zones.

	(1)	**(2)**
	ULUE	***ULUE***
Space Effect	0.0351 ***	0.0365 ***
	(3.9439)	(3.5396)
_cons	0.3826 ***	−1.9652 ***
	(160.5378)	(−6.3669)
Controls	/	√
City FE	√	√
Year FE	√	√
Province*Year FE	/	√
N	4144	4115
R^2	0.6915	0.7669

Note: Robust standard errors in parentheses. *** $p < 0.01$.

5.2. Heterogeneity Analysis

5.2.1. Heterogeneity in Eastern, Central, and Western Regions

As mentioned earlier, pilot free trade zones are dispersed across various regions of China, each with significant differences in development level, stage of development, and resource endowment. Therefore, it is necessary to assess the heterogeneity of pilot free trade zone policies on urban land use efficiency using traditional methods for Eastern, Central, and Western China. Utilizing data from the National Bureau of Statistics of China and standard classification criteria, this study categorizes sample cities into eastern, central, and western regions and conducts empirical regression analysis. Each control variable is included, and the regression results, including fixed effects and province cluster analysis, are presented in Table 13.

Table 13. Heterogeneity in Eastern, Central, and Western China.

	(1)	**(2)**	**(3)**
	East	**Central**	**West**
DID	0.0385	0.0326	0.1732 *
	(0.8212)	(1.3883)	(1.8310)
Constant	−2.0308 *	−3.3349 ***	−1.7914 ***
	(−2.3877)	(−8.5998)	(−4.8042)
Controls	√	√	√
City FE	√	√	√
Year FE	√	√	√
Province*Year FE	√	√	√
N	1394	1512	1481
R^2	0.7779	0.6986	0.6981

Note: Robust standard errors in parentheses. * $p < 0.1$, *** $p < 0.01$.

In the eastern and central regions, the estimated coefficients for the core explanatory variables are 0.0385 and 0.0326, but they are not significant, indicating that the pilot free trade zone policy has no significant impact on the land use efficiency of cities in these regions. This may be attributed to the fact that the eastern and central regions already possess a solid development foundation and well-established development plans, resulting in a limited spatial effect of the policy and making it challenging to demonstrate its true impact. In the western region, the estimated coefficient for the core explanatory variable is 0.1732, which is significant at the 10% level. A possible explanation is that the economic resources and development systems in the western region are relatively weak. The implementation of the Free Trade Pilot Zone policy in the western region can initially release greater innovation and opening benefits, fully leveraging its "latecomer advantage" to enhance urban land use efficiency. Thus, the pilot free trade zone policy not only contributes to China's sustained economic growth but also facilitates the balanced development of China's eastern, central, and western regions.

5.2.2. Inland and Coastal Heterogeneity

Considering the differences in the functional orientation of each Free Trade Zone and the resource endowments of their respective regions, this paper categorizes the sample cities into coastal and inland cities and investigates their respective differences in urban land use efficiency, as presented in Table 14. The impact coefficient of the Free Trade Zone policy on the land use efficiency of coastal cities is 0.0354, but it is not significant; the impact coefficient of the Free Trade Zone policy on the land use efficiency of inland cities is 0.0854, which is significant at the 10% level, indicating that, compared to coastal cities, inland cities lack advantages in economic and trade development and factor flow. Consequently, pilot free trade zone policies are likely to have a more significant impact on improving land use efficiency in inland cities.

Table 14. Coastal and Inland Heterogeneity.

	(1)	(2)
	Coastal	**Inland**
DID	0.0354 (0.9902)	0.0854 * (2.0103)
Constant	−2.2535 ** (−3.3513)	−2.1847 *** (−3.0703)
Controls	√	√
City FE	√	√
Year FE	√	√
Province*Year FE	√	√
N	1903	2942
R^2	0.7967	0.6967

Note: Robust standard errors in parentheses. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

5.2.3. Urbanization Rate Heterogeneity

Under the context of China vigorously coordinating the advancement of new urbanization, the urbanization rate has a direct or indirect impact on urban land use efficiency. To investigate this, the study divides the sample into two categories—high urbanization rate and low urbanization rate—using the median urbanization rate of the overall sample. Population regression analysis is then conducted according to Equation (1). The regression results are presented in Table 15. The estimated coefficient of the Free Trade Pilot Zone policy on the land use efficiency of cities with high urbanization rates is 0.0564, which is significant at the 5% level. For cities with low urbanization rates, the estimated coefficient of the core explanatory variable is 0.0037, which is not significant. This indicates that the Free Trade Pilot Zone policy has a more significant impact on the land use efficiency of cities with high urbanization rates. This discrepancy may be attributed to the fact that, compared to areas with low urbanization rates characterized by extensive land use, regions with higher urbanization rates have more optimized urban spatial layouts and intensive land use. As a result, the free trade zone policy has a more substantial impact on urban land use efficiency in these areas.

Table 15. Heterogeneity of Urbanization Rate.

	(1)	(2)
	High Urbanization Rate	**Low Urbanization Rate**
DID	0.0564 ** (2.1871)	0.0037 (0.1017)
Constant	−3.1166 *** (−5.1512)	−1.0748 * (−1.7768)
Controls	√	√
City FE	√	√
Year FE	√	√
Province*Year FE	√	√
N	2390	2344
R^2	0.8224	0.7161

Note: Robust standard errors in parentheses. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

6. Conclusions and Policy Implications

Pilot Free Trade Zones (FTZs) represent special economic zones established independently by China. With institutional innovation as their core principle and replicability as a fundamental requirement, FTZs conduct pilot trials to accelerate the transformation of government functions, explore institutional and mechanism innovations, and facilitate investment and trade, thereby paving the way for comprehensive reform and expanded opening up. Given that land serves as a crucial asset for the establishment and development of FTZs, it is imperative to examine the relationship between FTZ construction and urban land use efficiency. However, as mentioned in the literature review section, existing studies have paid little attention to the impact of Free Trade Pilot Zones on urban land use efficiency. In addressing this, the present paper treats the FTZ policy as a quasi-natural experiment. Leveraging panel data from 297 cities in China spanning from 2005 to 2021, we employ a multi-period differential method to empirically investigate the relationship between FTZ construction and urban land use efficiency. The research findings are as follows: Firstly, pilot free trade zone policies can significantly enhance urban land use efficiency, offering practical insights and a solid foundation for both established and prospective pilot free trade zones. The expansion of pilot free trade zones should be further encouraged to fully leverage and amplify the positive impact of this policy. Secondly, this study conducted parallel trend tests and placebo tests, employing methods such as PSM-DID, entropy balance, and control for other relevant policies of the same period. The results consistently support the beneficial effect of FTZs on urban land use efficiency. Thirdly, the impact of FTZ policies on urban land use efficiency varies across regions. Through heterogeneity analysis, we found that compared to central and eastern cities, as well as coastal cities and those with a high urbanization rate, the effect of this policy is more pronounced in western regions, inland cities, and cities with lower urbanization rates. It is noteworthy that pilot free trade zones also exhibit spatial spillover effects on the land use efficiency of neighboring cities.

Based on the aforementioned research findings, this paper proposes the following policy implications: Firstly, it is crucial to further promote the establishment of pilot free trade zones. The fundamental conclusion that pilot free trade zone policies can significantly enhance urban land use efficiency provides a solid rationale for advancing the implementation of such policies and refining urban land planning strategies. Secondly, in the endeavor to promote pilot free trade zones, due consideration should be given to the heterogeneity of cities in terms of their geographical location and urbanization rate. Tailored policy combinations should be devised for pilot free trade zones situated in eastern and central regions, as well as in inland and less urbanized areas, to maximize the effectiveness of policy implementation. Thirdly, there is a need to bolster inter-regional cooperation and development efforts, fostering synergies between local and neighboring regions and fully harnessing the positive spatial spillover effects of pilot free trade zone policies.

During the implementation of the free trade zone policy, government departments should also be aware of the potential negative impacts associated with free trade zones. For instance, in countries or regions with relatively insufficient technological advantages, more liberalized trade may reduce economic welfare, gradually exacerbating regional development disparities [84]. In industries with more severe pollution, stricter environmental regulations could reduce the likelihood and volume of exports [85]. Furthermore, heightened levels of trade liberalization might increase pollution [86], intensifying the globalization of pollution [87]. In response, regions should develop preemptive strategies to maximize the effectiveness of policy implementation.

However, this paper still has several shortcomings including the following: First, due to the lack of relevant data, the time span of the study sample covers 2005–2021, which makes the empirical part of this paper relatively weak. Second, since Free Trade Pilot Zones are actually divided into districts, this paper uses prefecture-level city data for analysis, which may bias the empirical results. Further research on this aspect requires additional verification and discussion in the future.

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Appendix A

Table A1. The Establishment of China's Pilot Free Trade Zones.

Year	Province/Municipality	Prefecture-Level Cities
2013	Shanghai	
2015	Canton	Guangzhou, Shenzhen, Zhuhai
	Tianjin	
	Fujian	Fuzhou, Xiamen
2017	Liaoning	Yingkou, Shenyang, Dalian
	Zhejiang	Zhoushan (In 2020, Hangzhou, Ningbo, and Jinhua were added.)
	Henan	Luoyang, Kaifeng, Zhengzhou
	Hubei	Yichang, Xiangyang, Wuhan
	Chongqing	
	Sichuan	Chengdu
	Shaanxi	Xi'an
2018	Hainan	Sanya, Haikou, Danzhou
2019	Shandong	Jinan, Qingdao, Yantai
	Jiangsu	Nanjing, Suzhou, Lianyungang
	Guangxi	Chongzuo, Qinzhou, Nanning
	Hebei	Baoding, Shijiazhuang, Langfang, Tangshan
	Yunnan	Kunming
	Heilongjiang	Harbin, Heihe, Mudan River
2020	Beijing	
	Hunan	Yueyang, Chenzhou, Changsha
	Anhui	Bengbu, Wuhu, Hefei
2023	Xinjiang	Khorgos, Kashgar, Urumqi

Source: Ministry of Commerce, People's Republic of China.

Table A2. Propensity Score Matching Balance Test.

Variables	Samples	Mean		Deviation %	Deviation Reduction Rate %	T-Value	P > |t|
		Treatment Group	Control Group				
$\ln AGDP_{pc}$	Before matching	11.404	10.387	166.8	98.7	18.87	0
	After matching	11.398	11.385	2.1		0.28	0.779
ind	Before matching	1.7975	0.94918	109.8	90.1	21.5	0
	After matching	1.7502	1.8342	−10.9		−0.86	0.393
$\ln pop$	Before matching	6.2954	5.8139	59.3	90.2	8.31	0
	After matching	6.3164	6.3636	−5.8		−0.58	0.563
gov	Before matching	0.17226	0.19094	−17	88.9	−1.81	0.071
	After matching	0.16923	0.1713	−1.9		−0.32	0.746
open	Before matching	0.20623	0.13668	10.2	75.4	1.02	0.306
	After matching	0.20608	0.18899	2.5		0.87	0.383
hum	Before matching	5.7799	4.6409	126.7	92.2	15.77	0
	After matching	5.7751	5.6859	9.9		1.08	0.282
gov#gov	Before matching	0.03337	0.05693	−16.5	96	−1.63	0.103
	After matching	0.03226	0.0332	−0.7		−0.32	0.748
$\ln pop\#ind$	Before matching	11.13	5.5208	128.5	87.2	24.48	0
	After matching	10.966	11.684	−16.4		−1.15	0.252
ind#ind	Before matching	4.1574	1.1635	72.9	83.4	20.1	0
	After matching	3.847	4.3453	−12.1		−0.98	0.33
$\ln AGDP_{pc}\#\ln AGDP_{pc}$	Before matching	130.24	108.44	169.5	98.7	19.66	0
	After matching	130.11	129.82	2.3		0.29	0.775
hum#ind	Before matching	10.51	4.4516	129.8	94.6	27.41	0
	After matching	10.24	10.565	−7		−0.54	0.592
gov#ind	Before matching	0.33229	0.20707	44.4	76.8	6.05	0
	After matching	0.31503	0.34409	−10.3		−1.01	0.315
hum#gov	Before matching	0.98036	0.85595	23.5	97.1	2.52	0.012
	After matching	0.96076	0.9571	0.7		0.11	0.91
$hum\#\ln AGDP_{pc}$	Before matching	66.106	48.517	153.9	93.8	19.72	0
	After matching	66.025	64.942	9.5		0.98	0.326
hum#hum	Before matching	34.039	22.519	126.2	90.8	16.89	0
	After matching	34.001	32.936	11.7		1.16	0.247
$ind\#\ln AGDP_{pc}$	Before matching	20.423	9.866	124.1	91.1	25.08	0
	After matching	19.892	20.829	−11		−0.85	0.395
$open\#\ln pop$	Before matching	1.3335	0.74707	25.5	82.3	2.71	0.007
	After matching	1.3297	1.226	4.5		0.83	0.41
open#open	Before matching	0.07829	0.90788	−2.4	98.9	−0.23	0.815
	After matching	0.07873	0.06941	0		0.64	0.521
$hum\#\ln pop$	Before matching	36.481	27.019	131.1	97.5	18.19	0
	After matching	36.576	36.337	3.3		0.32	0.753
hum#open	Before matching	1.2371	0.69449	15.7	77.1	1.58	0.114
	After matching	1.2366	1.1124	3.6		1.06	0.289
$\ln pop\#\ln pop$	Before matching	40.328	34.421	64.5	91.4	9.84	0
	After matching	40.549	41.057	−5.5		−0.51	0.609
$\ln pop\#\ln AGDP_{pc}$	Before matching	71.844	60.328	119.2	95.9	17.26	0
	After matching	72.042	72.514	−4.9		−0.47	0.639
$gov\#\ln pop$	Before matching	1.0657	1.0833	−3.2	−40.9	−0.35	0.724
	After matching	1.0519	1.0767	−4.6		−0.68	0.497

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