

real-world issue for China's economy as it transitions from rapid growth to high-quality development. In recent years, to expedite the transformation of energy utilization and vigorously enhance EUE, China has reduced energy consumption per unit of GDP by a cumulative total of 26.4 percent, which is equivalent to a reduction in energy consumption of approximately 1.4 billion metric tons of coal. The Chinese government's work report for 2023 made it abundantly evident that we should push for further energy reform, encourage the efficient, clean, and low-carbon use of energy, and expedite the design and development of a new kind of energy system in order to support low-carbon and green development. It is evident that achieving sustainable economic development greatly depends on strengthening China's EUE.

Cities are the main consumers of energy, and they are also the focus of frequent energy and environmental problems [8, 9]. Therefore, improving EUE should start with the cities, and perfecting the development of urbanization is the key breakthrough to solving China's energy efficiency problems. China's initial urbanization is massive, but energy efficiency is generally low due to an overly rapid and crude urbanization development approach [10]. In the beginning phase of urbanization in China, large amounts of resources are invested in infrastructure and building construction, but consideration of EUE is often neglected [11]. With an increased awareness of sustainable development, China is gradually introducing a series of policies and standards to improve the crude growth of urbanization. In 2014, the Chinese government issued the National New Urbanization Plan and began implementing the new type of urbanization comprehensive pilot policy (NTU policy). A second and third batch of pilot districts under NTU policies were launched in 2015 and 2016, respectively, after this. One of the main goals of the NTU policy is to promote the efficient use of clean energy, significantly increase the EUE, and enhance the sustainability of the city. So, with the deepening of new urbanization, can the NTU policy increase the EUE? If so, through what mechanism does the policy effect of the NTU policy work? Analyzing the above questions not only provides a useful introduction to China's new urbanization reform, but also gives empirical evidence for other countries' sustainable urbanization paths.

The main contributions of this paper are in three main directions. First, the literature currently in publication disputes whether urbanization benefits or hurts EUE. This study treats the NTU policy as a quasi-natural experiment to explore the influence of urbanization on EUE in depth from a policy perspective. Second, previous research has examined the impact of the NTU policy on urbanization development, the urban-rural income gap, and carbon emissions. However, research on the effects of the NTU policy on EUE is lacking. This study extends the relevant research on NTU policy. Third, this study also explores

the influence mechanism of the NTU policy from the perspective of green technical innovation and industrial structure upgrading, which provides a reference for deepening the reform of the NTU policy. Meanwhile, this study also investigates the heterogeneous impact of the NTU policy on EUE, which provides some reference value for the government to create a diversified low-energy urbanization development.

Literature Review

Existing studies have done a lot of related work on the influencing factors of EUE. Hu et al. (2019) [12] investigated the correlation between economic growth and EUE by using Chinese provincial data. The findings of this study suggest that economic growth significantly enhances EUE from both short and long-term perspectives. Yao et al. (2021) [13] found that financial development plays a crucial role in promoting economic growth and impacting the environment, and that financial development can improve EUE. Zafar et al. (2021) [14] identified that technological innovations can contribute to the achievement of energy efficiency goals and emphasized the need for energy efficiency innovations. Meanwhile, Wurlod and Noailly (2018) [15] investigated whether green innovations can improve EUE. Wu et al. (2021) [16] investigated that Internet development can enhance not only local EUE but also the EUE of neighboring areas. In terms of overall urban development, Li et al. (2018) [17] utilized data from Chinese provinces to examine the relationship between urbanization and EUE. The final findings suggest that the overall influence of urbanization on EUE is negative in China. Lv et al. (2020) [18] also explore the influence of urbanization on EUE in China from both short- and long-term perspectives. The results show that urbanization is beneficial to EUE in the long run. Yu and Luo (2022) [19] classify urbanization as demographic urbanization, spatial urbanization, and economical urbanization, all of which benefit EUE.

Furthermore, scholars have investigated the impact of key policies on EUE. Geller et al. (2006) [20] summarized the experiences of energy efficiency policies adopted in Japan, the United States, and Western Europe and showed that the relevant policies can provide substantial energy savings. Song and Han (2022) [21] demonstrated that the implementation of appropriate environmental regulatory policies promotes EUE. Tan et al. (2022) [22] showed that China's carbon trading policies are conducive to the enhancement of EUE. Wang et al. (2023) [23] found that the low-carbon pilot city policy greatly improves EUE.

Since the NTU policy has been implemented, related scholars have conducted in-depth studies on this policy. Wang et al. (2015) [24] returned to the growth process of China's urbanization and discussed the overall objectives of the NTU policy. According to Peng et al. (2021) [25], the NTU policy greatly encourages urbanization

in the Yangtze River Economic Belt's cities; however, the central pilot region does not see a major increase in urbanization as a result of the policy's implementation. Liu et al., (2022) [26] found that the NTU policy reduces the urban-rural income gap in either the short or long run. Yu (2021) [27] discovered that the NTU policy effectively reduces urban pollution emissions, and this policy effect is realized through government environmental constraints and the active introduction of foreign investment. Meanwhile, according to Cui and Cao (2023) [28], the NTU policy also helps to lower overall carbon emissions and increase carbon emissions' efficiency.

Existing literature has examined EUE and the NTU policy, which provides an important reference and support for this study. First, the findings of the existing literature are widely divergent, with some studies arguing that China's urbanization is not beneficial to EUE [17]. According to several studies, China's urbanization is beneficial to EUE [18]. Second, there is a dearth of directly relevant studies on the NTU policy. Only some studies are limited to discussing the influence of the NTU policy on urbanization development, the urban-rural income gap, and carbon emissions [26-28]. Research on the impact of the NTU policy on EUE is lacking. Therefore, to compensate for the inadequacies of previous studies, this paper examines the effects and influence mechanisms of the NTU policy on the impact of EUE using data from 276 Chinese cities.

Theoretical Analyses

Among the principle targets of the NTU policy is to enhance the sustainable development capacity of cities and promote the decarbonization of production and life [29]. First, the policy promotes the clean, low-carbon, safe, and efficient use of energy, guides the consumption of non-fossil energy in an orderly manner, replaces coal with electricity and gas, and develops distributed energy sources such as rooftop photovoltaics [30, 31]. At the same time, the policy promotes a variety of clean heating methods according to local conditions and promotes energy-saving management modes such as contractual energy management. Second, this policy stimulates the development of ultra-low-energy and nearly zero-energy buildings and pushes for the transformation of industry, construction, and transportation into green, low-carbon sectors [32]. Third, the pilot areas carry out actions to create a green life, advocate green travel and the construction of green families and communities, promote energy-saving products, and establish an incentive mechanism for residents to consume green products. Therefore, we formulate hypothesis 1.

Hypothesis 1: NTU policy significantly improves EUE.

Green technology research, development, and application can be aided by the NTU policy. First, the NTU policy provides financial support for businesses

in order to carry out research and development on energy conservation, clean energy, and renewable energy. Second, the NTU policy is conducive to attracting high-quality talents. This policy establishes a reasonable talent introduction policy, attracts high-quality talents to the pilot region for employment and entrepreneurship, and focuses on cultivating skilled talents to meet the needs of industrial upgrading. Finally, this policy has the potential to enhance technological exchanges and resource sharing while fostering the integration of industry, universities, and research. In addition to facilitating the adoption and real-world implementation of green technology, this collaboration can foster innovation and knowledge sharing.

Renewable energy sources are developed and used more often thanks to green technologies [33]. These technologies not only reduce dependence on traditional energy sources, but also have a high energy conversion efficiency, which improves the overall EUE [34, 35]. As a result, we develop hypothesis 2.

Hypothesis 2: NTU policy can significantly improve EUE by promoting green technology innovation.

The NTU policy uses a number of initiatives to support the modernization of the industrial structure. First, this policy encourages external investors to move into the pilot areas, bringing in advanced technology, management experience, and capital inflows to promote the modernization of the industrial structure [36]. Second, it simplifies administrative approval procedures and provides workers and enterprises with convenient services such as policy consultation, job placement, and labor guidance. At the same time, the pilot areas build low-cost, all-factor, facilitated, open growth open space, and space to support the development of micro, small, and medium-sized enterprises.

Industrial structure upgrading includes a shift from traditional industries to service, technology-intensive, and innovation-driven industries [37]. This shift can lead to a transformation of the economy from industries with high resource and energy dependence to knowledge-intensive and high-value-added industries, which can increase the EUE [38, 39]. Therefore, we formulate Hypothesis 3.

Hypothesis 3: The NTU policy can significantly improve EUE through industrial structure upgrading.

Fig. 1 displays the research hypothesis framework for this research project.

Research Methods and Data

Research Methods

Baseline Model

The difference-in-differences model (DID model) is utilized to evaluate the NTU policy's effect on EUE through a quasi-natural experiment. The treatment group

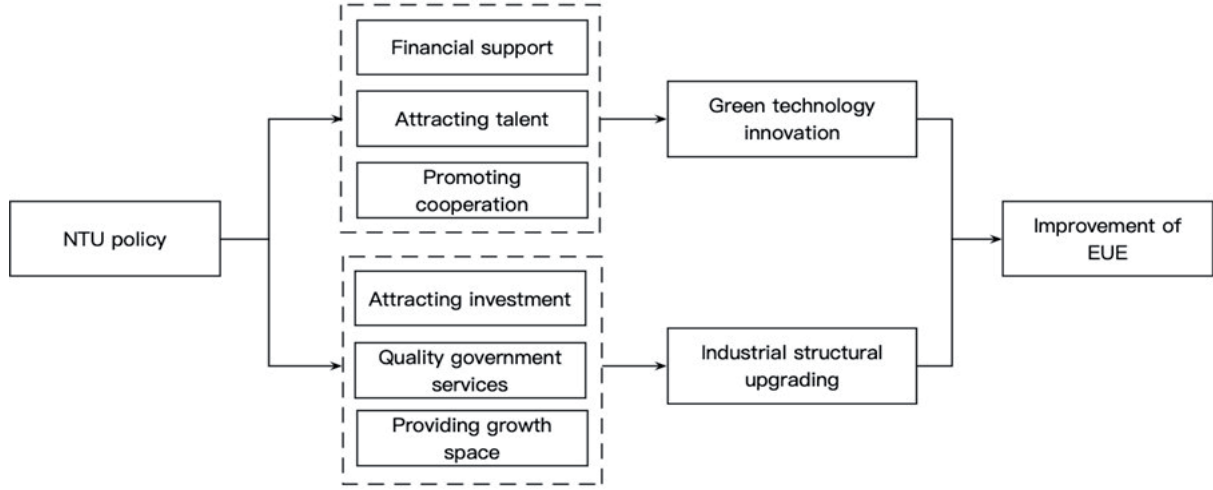


Fig. 1. Research hypothesis framework.

is the pilot area, while the control group is the non-pilot region. With reference to corresponding research [40, 41], the DID model can be put down as follows:

$$EUE_{it} = \alpha_0 + \alpha_1 NTU_{it} + \gamma Z_{it} + \lambda_t + \mu_i + \varepsilon_{it} \quad (1)$$

Where EUE_{it} is the EUE of each city, in which the subscript t represents the year and i stands for the city. NTU_{it} is the policy dummy variable. Z_{it} is the control variable ensemble. λ_t is the year fixed effect. μ_i is the city fixed effect. ε_{it} is the residual term.

Mechanism Effects Model

Combined with the research hypotheses, the mechanism effect of NTU policy is further explored. Referring to related research [42], the mechanism effect model is constructed as follows:

$$EUE_{it} = \beta_0 + \beta_1 M_{it} * NTU_{it} + \beta_2 NTU_{it} + \beta_3 M_{it} + \gamma Z_{it} + \lambda_t + \mu_i + \varepsilon_{it} \quad (2)$$

Where M_{it} is the mechanism variable, and the choices for the remaining variables follow those in Equation (1). Equation (2) focuses on the coefficient of $M_{it} * NTU_{it}$. If β_1 is remarkable, it indicates that M_{it} is the influence mechanism of NTU policy's effect on EUE.

Variables

Explanatory Variable

The explanatory variable is energy utilization efficiency (EUE). The Stochastic Block Model (SBM) is used in this study to measure the EUE. Higher values of EUE indicate a higher level of energy utilization in the region. Pollutant emissions are the undesirable output variable, GDP is the desired output, and labor, capital, and energy are the desired inputs for the EUE indicator.

The precise indicators utilized to calculate EUE are displayed in Table 1.

Fig. 2 shows the year-to-year development of EUE in the pilot and non-pilot regions of the NTU policy. The pilot areas continuously have a greater EUE than the non-pilot areas, as seen in Fig. 2. This could mean that when choosing pilot zones for NTU policy, the government favors areas with a particular degree of foundation. After the adoption of the EUE policy, the trend of EUE growth was significantly stronger in the pilot regions. This phenomenon provides early evidence of the effectiveness of the NTU policy in improving EUE.

Core Explanatory Variable

A dummy representing the NTU policy serves as the core explanatory variable. In the event that a city is accepted as a test site for the NTU policy in a given year, the value of the city in that year and the years that follow is 1, while the value of the city in years prior is 0. All the years for non-pilot cities are set to 0. In addition, since the beginning of the NTU policy, the three batches of pilot regions all took place at the end of the years 2014, 2015, and 2016, respectively. The start years of policy implementation for the three pilot regions have not contained the majority of the current year's months. Setting the start of NTU policy implementation at the original time may influence the accurate assessment of the policy's effect. Therefore, this study resets the start time of implementation in the three pilot regions to 2015, 2016, and 2017 in the actual construction of the core explanatory variable.

Mechanism Variables

The mechanism variables adopt green technology innovation and industrial structure upgrading.

The number of green patents awarded per capita, which is determined by dividing the total number

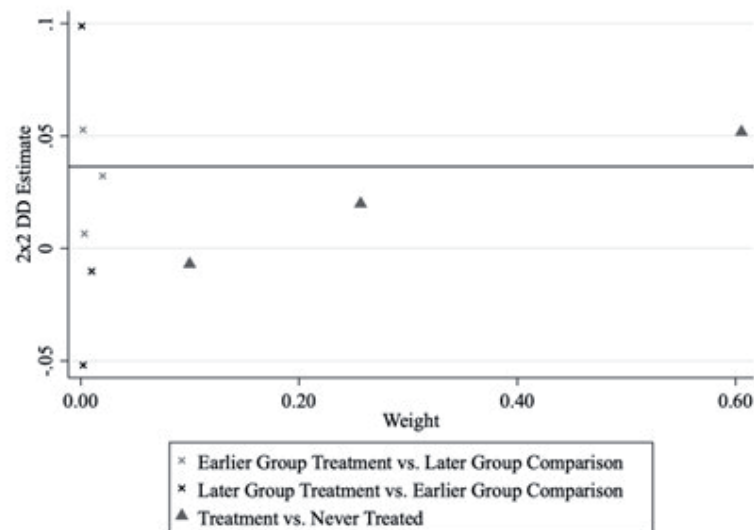


Fig. 5. Bacon decomposition test.

Bacon Decomposition Test

The DID model in this study is a staggered DID model. However, a staggered DID model may lead to estimation bias in the results [47]. To test for the presence of estimation bias, this paper implements the Bacon decomposition on the benchmark regression results. Fig. 5 presents a scatter plot of the weight distribution of the Bacon decomposition results. The decomposition results show that most of the estimates are from the completion of the comparison between the treatment and control groups. This result indicates that the benchmark regression results are stable.

Propensity Score Matching (PSM)-DID Test

When selecting pilot regions for the NTU policy, the government takes into account the population

size, economic development, and other elements of each region and prefers to implement the policy in regions that already have a certain foundation. This kind of sample selection may have bias, which leads to biased regression results. Therefore, the effect of the NTU policy on EUE is re-estimated using the PMS-DID model. Matching is done using nearest neighbor matching, kernel matching, and radius matching. The computed coefficients are all statistically positive, as shown in Table 4, which validates the conclusion that NTU policy can significantly improve EUE.

Removing Interference from Other Policies

Related environmental policies can also improve EUE, such as the carbon trading policy and the low carbon pilot policy. This study adds dummy variables that interfere with policies, including *CTP* and *LCP*,

Table 4. PSM-DID test.

Variables	(1)	(2)	(3)
	Neighbor matching	Kernel matching	Radius matching
	<i>EUE</i>	<i>EUE</i>	<i>EUE</i>
<i>NTU</i>	0.024***	0.024***	0.023***
	(4.127)	(4.127)	(4.096)
City-fixed effect	Y	Y	Y
Year-fixed effect	Y	Y	Y
Control variables	Y	Y	Y
Cons	0.067*	0.222***	0.173***
	(1.710)	(4.501)	(3.957)
Obs	3000	2976	2952
R ²	0.722	0.720	0.718

Table 7. Geographic heterogeneity results.

Variables	(1)	(2)	(3)
	Eastern	Central	Western
	<i>EUE</i>	<i>EUE</i>	<i>EUE</i>
<i>NTU</i>	0.036***	0.025	0.005
	(3.492)	(1.235)	(0.654)
City-fixed effect	Y	Y	Y
Year-fixed effect	Y	Y	Y
Control variables	Y	Y	Y
Cons	-0.066	0.149**	0.227***
	(-1.351)	(2.535)	(7.325)
Obs	1100	1078	858
R ²	0.693	0.683	0.787

which hinders the advancement of energy use efficiency. Furthermore, there is less opportunity for increasing energy consumption efficiency in the central and western areas due to their lower levels of economic development, smaller cities and densities, and comparatively fewer employment possibilities and economic activity. Thus, in order to increase energy use efficiency, special emphasis must be given to infrastructure development, economic development, strengthening energy management, and technical innovation when executing the NTU strategy in the central and western areas.

Administrative Level Heterogeneity

China divides its cities into administrative classes such as directly governed cities, provincial capitals, planned cities, and prefectural cities according to their political status. In China, cities with higher administrative registrations not only have larger economies, but also benefit from a range of policies or resources [50]. Therefore, when implementing the same policies, there are significant differences in policy implementation among cities with different administrative levels. The total sample is divided into high administrative level regions, and low administrative level regions. Directly administered cities, provincial capitals, and planned cities are examples of high administrative level areas; other cities are considered low administrative level regions.

Column (1) of Table 8 indicates that the coefficient of *NTUC* is apparently positive, and column (2) indicates that the coefficient of *NTUC* is not significant. This indicates that NTU policy can only improve EUE when implemented in high administrative level regions and NTU policy cannot improve EUE when implemented in low administrative level regions. The following are some potential explanations for this heterogeneity: regions with a high administrative level have high-quality

resources and are more likely to receive favorable government policies. These areas may greatly increase EUE by fostering the growth of the energy sector since they have greater financial and human resources available to them.

In contrast, the reason that the implementation of NTU policy in areas with low administrative levels in China cannot effectively improve EUE is mainly due to the relatively weak infrastructure and resource conditions. These areas lack appropriate financial and technical assistance, have a comparatively antiquated industrial structure, and have low levels of economic development. Furthermore, individuals in low-income areas might not be as conscious of the need to save energy and protect the environment or be as eager to do so due to their restricted budget. In order to gradually improve EUE, it is therefore required to provide

Table 8. Administrative level heterogeneity results.

Variables	(1)	(2)
	High administrative level	Low administrative level
	<i>EUE</i>	<i>EUE</i>
<i>NTU</i>	0.056***	0.001
	(5.315)	(0.101)
City-fixed effect	Y	Y
Year-fixed effect	Y	Y
Control variables	Y	Y
Cons	0.051	0.381***
	(1.026)	(8.995)
Obs	385	2651
R ²	0.879	0.701

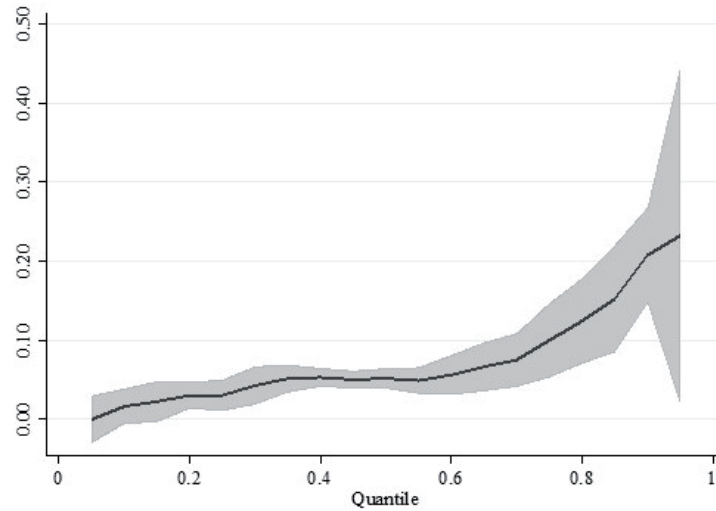


Fig. 6. Quantile regression results.

areas may pay less attention to energy issues and lack sufficient motivation and willingness to promote the improvement of EUE. Therefore, when implementing the NTU policy in non-old industrial areas, differentiated policies and actions must be developed in accordance with local circumstances and traits, and local energy usage efficiency awareness and standards must be raised.

Heterogeneity of Different Levels of EUE

Differences in EUE levels may lead to heterogeneity in NTU policy implementation. Therefore, this paper uses quantile regression modeling to investigate the marginal impact of the NTU policy on EUE.

Fig. 6 demonstrates that the magnitude of the regression coefficients gradually increases as the quartiles gradually increase, which suggests an incremental trend in the promotion of the NTU policy on EUE. In short, for regions with low EUE, the NTU policy has a relatively small effect on EUE improvement. For areas with high EUE, the NTU policy has a relatively large effect on EUE. Possible reasons for this heterogeneity are as follows: Areas with higher EUE usually have advanced energy supply systems, quality infrastructure, and a high level of technical support. This provides a favorable environment for the NTU policy to increase EUE.

Conclusions and Policy Comments

Reducing carbon emissions and resource consumption through increased energy efficiency has become crucial in light of the growing worldwide concern about climate change and environmental protection. Cities, as the main carriers of energy consumption, face continuously increasing energy demand in the rapid urbanization process. The NTU

policy is a key policy in China's new urbanization process. An in-depth understanding of the NTU policy's impact on EUE can help formulate effective energy planning and promote sustainable urban development. Taking 276 cities in China as the research sample, this study examines the influence of the NTU policy on EUE in a comprehensive and detailed manner using the DID model. The following are the research's principal conclusions: (1) The NTU policy can apparently improve EUE. This finding still holds after a series of robustness tests, such as the parallel trend test, placebo test, bacon decomposition test, PSM-DID test, and removing other policy interference. (2) The mechanism analysis findings show that the NTU policy improves the EUE, mainly relying on the promotion of green technology innovation and industrial structure upgrading. (3) The heterogeneity analysis findings show that different regions exhibit differentiated effects in the implementation of the NTU policy. This is mainly reflected in the fact that the NTU policy has a more obvious effect on the enhancement of EUE in eastern regions, high administrative level regions, high population density regions, old industrial regions, and high EUE lever regions.

In order to further enhance the EUE, this study suggests the following policy suggestions for the NTU policy, based on the previously mentioned findings:

(1) The pilot areas of the NTU policy need to be further expanded. First, it is commented that the NTU policy should further expand the scope of the pilot areas to further enhance the EUE. Second, in order to assure the efficient application of the policy, the government can strengthen the monitoring and evaluation mechanism, establish a scientific indicator system, and track and evaluate the progress of the pilot work in a timely manner. Finally, the government should strengthen cooperation with all parties, including enterprises, research institutions, and social organizations, to jointly promote the NTU policy and achieve new results.

