Received: 17 January 2024 | Revised: 25 February 2024 | Accepted: 22 March 2024 | Published online: 27 March 2024

Green and Low-Carbon Economy
2025, Vol. 00(00) 1–14
DOI: 10.47852/bonviewGLCE42022491
BON VIEW PUBLISHING

RESEARCH ARTICLE

How Does the New-Type Urbanization Policy Affect Urban Low-Carbon Development?

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Abstract: The profound transformations brought about by the rapid advancement of urbanization have had a significant impact on low-carbon cities. In this study, we utilize the "New-type Urbanization Policy" (NTUP) as a quasi-natural experiment to examine the influence of NTUP on carbon emissions using panel data from 285 cities spanning 2008–2019 and implementing the difference-in-differences methodology (DID). Our findings indicate that NTUP effectively reduces carbon emissions and enhances emission efficiency, with consistent results even after conducting rigorous tests and addressing endogeneity concerns. Furthermore, our analysis reveals that resource-based cities, eastern cities and small- and medium-sized cities benefit more from NTUP in terms of reducing carbon emissions and improving efficiency. The mediating effect demonstrates that NTUP's impact on carbon emissions primarily operates through three mechanisms: promoting industrial structure upgrading, reducing energy use and promoting green technology innovation. This research provides critical empirical evidence for policymakers seeking to achieve carbon peak and neutrality goals through targeted urbanization initiatives.

Keywords: new-type urbanization, carbon emissions, mediating effect, heterogeneity, DID

1. Introduction

According to the IPCC's Sixth Assessment Report, carbon emissions (CE) are identified as the primary cause of global warming, with irreversible consequences. Urgent action is imperative for mitigating and adapting to climate change. In China, urban areas account for 75% of total carbon emissions due to intensive energy consumption. Urbanization has emerged as a significant factor influencing carbon emissions [1]. The Chinese government places great emphasis on sustainable urban development amidst rapid urbanization and population growth, which have led to increased energy utilization and the proliferation of high-carbon emission industries [2]. To achieve the "dual carbon goal" while managing the rise in CE resulting from rapid urban development, it is crucial for China to promote coordinated low-carbon development through new-type urbanization construction. This approach will play a pivotal role in China's low-carbon transformation efforts and contribute towards reducing global carbon emissions.

To tackle the challenges brought by rapid urbanization and prioritize people's well-being in city development, a new approach to urbanization was introduced in 2012. This innovative form of urbanization has been recognized as a driving force for China's future economic growth and an essential tool for expanding domestic demand. In 2014, the national government issued the National New-type Urbanization Plan (NTUP) which outlines its developmental trajectory, primary objectives, and strategic tasks at a national institutional level. As a result, it has sparked enthusiasm across the country towards implementing this new type of urbanization.

To implement the national strategy, a collaborative effort was made in 2014 by multiple national departments, resulting in the release of a list comprising the initial group of cities participating in the pilot program for new-type urbanization. These cities (towns) were required to achieve phased results by 2017, generating replicable and scalable experiences. Subsequently, additional cities (towns) were approved as part of the batches of NTUP during 2015 and 2016. As a result, all three groups have now entered into the construction phase of this pilot initiative. The primary distinction between NTUP and conventional urbanization lies in its emphasis on people-centric, concentrated, environmentally friendly, and sustainable urban development instead of solely pursuing economic growth and expanding city boundaries without considering these factors. The pilot cities have actively promoted local energy conservation measures through comprehensive utilization of legal frameworks, economic incentives, and administrative oversight at various stages – from pre-control to ongoing supervision to post-treatment – leading to significant progress in controlling energy-intensive projects' construction activities while enhancing resource efficiency utilization levels along with ecological quality improvements that contribute significantly towards reducing carbon emissions. Consequently, this policy serves as an ideal quasi-experiment for our study.

Using panel data for 285 cities between 2008 and 2019, this study investigates the influence of NTUP on CE through the application of the difference-in-differences (DID). The primary

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objectives are as follows: (1) To assess whether NTUP contributes to a reduction in CE and enhances emission efficiency; (2) to examine if the impact of NTUP varies across different urban areas; (3) to explore how NTUP affects carbon emissions by identifying underlying mechanisms. This paper offers several potential advancements compared to previous research: (1) It innovatively analyzes the effects of NTUP on carbon emissions using quasi-natural experiments, enabling an evaluation of policy effectiveness. Moreover, it addresses estimation bias resulting from measurement deviations associated with new-type urbanization. (2) By employing DID methodology and instrumental variable techniques, this study improves estimation accuracy by addressing endogeneity concerns related to internal variables. (3) In terms of research content, this study expands upon previous findings regarding mediating factors identified by Chen et al. [3], encompassing industrial structure, energy use, and green technology innovation. Additionally, it examines heterogeneity among cities based on resource endowment, geographical location, and population size when assessing the effects of NTUP.

The organization of this article is structured into the following: Section 2 explores the mechanism and existing literature. Section 3 presents the methodologies and data utilized. Section 4 discusses the empirical findings. Section 5 discusses the results of the study. Finally, Section 6 summarizes the conclusions drawn and highlights policy implications derived from this study.

2. Mechanism Analysis and Literature

2.1. Theoretical analysis

Market failure theory holds that government intervention can coordinate the relationship between economic macro-control and market mechanism. The NTUP mentioned in this paper is an urban planning policy led by Chinese government departments to solve the problem of urban unsustainability and correct environmental externalities through policy tools or market mechanisms. The guidance and incentive of NTUP play a driving role in alleviating the contradiction between people and land and improving the sustainable development ability of cities, and its guiding and incentive role is manifested in two aspects: "energy saving and emission reduction" and "ecological compensation."

In terms of energy saving and emission reduction, NTUP emphasizes the shift of population from dispersion to aggregation. Compared with the loose spatial layout in rural areas, high-density urban space helps to improve the utilization efficiency of public infrastructure, including shortening commuting distance and reducing the traffic demand of private cars, so as to ensure the centralized and efficient use of energy and reduce the carbon emission of urban transportation. As Glaeser and Kahn [4] have pointed out, cities with a high degree of agglomeration are more energy-efficient and environmentally friendly than rural areas with low economic density. Xiao et al. [5] also believe that agglomeration has a "domestic market effect" under certain conditions, which can alleviate the "pollution refuge" effect. In terms of ecological compensation, NTUP can optimize urban spatial layout, improve the efficiency of land resource allocation, avoid the loss of ecological spatial carbon absorption caused by excessive development of construction land, form an urban spatial structure conducive to the green development of industry and the increase of ecological carbon sink, alleviate the urban heat island effect through greening transformation [6], and thus improve the carbon absorption capacity of urban ecological space. On the whole, based on the market failure theory, the implementation of NTUP contributes to the reduction of urban carbon emissions.

2.2. The direct effects of NTUP on CE

Research on the influence of urbanization on CE has attracted considerable attention from scholars, but there is still ongoing debate regarding the findings. Some scholars argue that urbanization can have either a positive or negative impact on CE. In their study, Yao et al. [7] discovered that urbanization promotes energy efficiency gains, technological innovation, industrial agglomeration, and the adoption of energy-efficient equipment – all contributing to a decrease in CE. Zhang and Xu [8] found that urbanization can modify CE by encouraging changes in urban form and promoting intensive land use for sustainable development. However, Wang et al. [9] contend that as urbanization expands the size of the urban population and increases daily energy consumption among residents, it consequently leads to higher levels of CE. Additionally, urbanization also stimulates industrial production, services, and transportation activities – further exacerbating CE [10]. Thus, Adams et al. [11] suggest that both benefits and drawbacks need to be taken into account in order to determine how exactly urbanization affects CE.

In summary, the existing studies have promoted the cognition of the relationship between urbanization and low-carbon development and provided important references for the realization of urban low-carbon development. However, researches related to new-type urbanization development mainly stay at the national, provincial, and other macro-levels, and there are few relevant researches based on the city level, and the causal inference method is rarely used, which makes the estimation results open to discussion and ignores the possible interference of endogenous problems on the results. In view of the above problems, this study will further improve the analysis framework of the influence of urbanization on CE.

2.3. The indirect effects of NTUP on CE

From the perspective of NTUP policy design, new-type urbanization guides rational industrial agglomeration through market competition mechanism, adjusts and optimizes energy use, induces green technology innovation, and finally produces economies of scale effect to reduce CE and improve emission efficiency. The corresponding impact mechanism is shown in Figure 1.

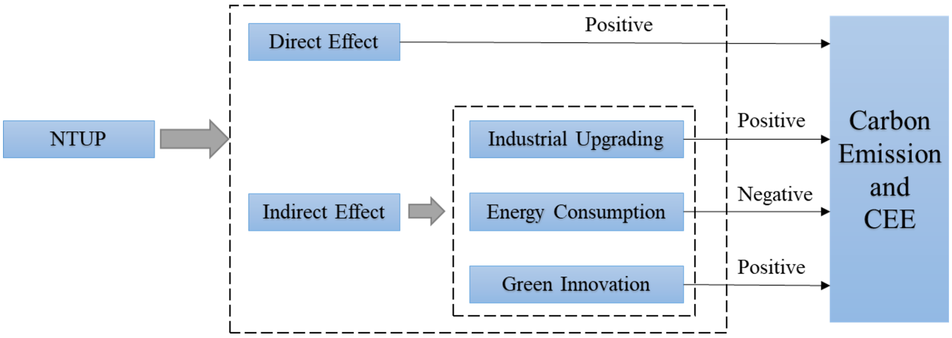
2.3.1. Industrial structure effect

By guiding pilot cities in developing clean industries, NTUP facilitates the transition to low-consumption and low-pollution sectors, promoting the growth of clean industries [12]. Simultaneously, it strictly regulates high-consumption and polluting units through an environmental assessment system. It also encourages highly polluting enterprises to shift towards cleaner practices or exit the market altogether. The implementation of industrial planning alongside an ecological environment assessment system has played a crucial role in promoting urban low-carbon and sustainable development [13]. Consequently, optimizing industrial structure may positively influence the impact of NTUP on CE.

2.3.2. Energy use effect

In the development of NTUP, emphasizing energy conservation and efficiency is crucial in various aspects such as ecological

Figure 1
The influence mechanism framework



planning, urban construction, and promoting environmental protection concepts. By embracing clean energy sources and fostering innovation in this field, we can enhance the overall energy structure while simultaneously reducing carbon emissions [14]. Extensive research indicates a strong correlation between the energy structure, CE, and productivity levels [15]. A transition towards cleaner energy sources will effectively mitigate CE and boost economic output by generating green benefits [16]. NTUP actively encourages enterprises to pioneer clean energy technologies through widespread implementation of infrastructure for conserving energy and reducing emissions. Additionally, it guides residents to embrace clean energy solutions on a large scale. Consequently, reducing wasteful energy use can play a positive role in minimizing NTUP's impact on CE.

2.3.3. Green innovation effect

NTUP plays a crucial role in fostering the advancement of eco-friendly technologies by providing economic and policy assistance, incentivizing positive outcomes, and implementing strategies for urban planning. This accelerates progress in green technology [17], leading to a decrease in harmful emissions, including CE [18]. The efficiency of reducing CE is directly influenced by technological advancements when measured using the TFP framework [19]. Moreover, NTUP attracts valuable resources like talent and innovative ideas by establishing sustainable infrastructure and creating a more livable environment. These efforts act as catalysts for driving forward green innovation. Consequently, it can be inferred that the positive impact of green technology innovation on how NTUP affects CE is significant.

3. Methods and Data

3.1. Model selection

3.1.1. Difference-in-differences (DID)

The DID has been widely employed to quantitatively evaluate the effectiveness of public policies. By constructing counterfactuals for treatment groups, it helps address potential endogeneity issues and enhances confidence in the estimated outcomes [20]. To explore the potential impact of new-type urbanization construction and urban CE, this study adopts the NTUP policy as a quasi-natural experiment and applies progressive DID analysis to assess its influence on CE. The sample consists of 285 cities in China from 2008 to 2019. Finally, we establish the following model:

$$CE_{it} = \alpha + \beta NTUP_{it} + \gamma X_{it} + \varphi_i + \delta_t + \varepsilon_{it} \tag{1}$$

where CE_{it} represents carbon emissions in city i during year t. $NTUP_{it}$ is a treatment indicator, equaling 1 if city i implements the policy in year t (and subsequent years), and 0 otherwise. X_{it} includes control variables. φ_i captures unobservable heterogeneity among cities. δ_t incorporates year-fixed effects. The error term is ε_{it}. Our main focus is on the core coefficient β, which measures the influence of the NTUP on CE.

3.1.2. Mediating effect model

What this means is to use the mediating effect model for analysis. The specific meanings of X, Y and M involved in the model are core independent variable, dependent variable and mediating variable. The steps are as follows: Step 1: Equation (2) assesses the impact of X on Y. If coefficient a is statistically significant, proceed with further testing; otherwise, terminate the analysis. Step 2: Equation (3) examines the influence of X on M, while Equation (4) investigates how both X and M affect Y. If coefficients b and d are both statistically significant, it suggests a presence of mediating effect. In case at least one of them is not statistically significant, bootstrap analysis needs to be conducted for further verification. Step 3: If coefficient c lacks statistical significance, it indicates a fully mediating effect; if it is statistically significant though, it implies a partially mediating effect.

$$Y = aX + e_1 \tag{2}$$

$$M = bX + e_2 \tag{3}$$

$$Y = cX + dM + e_3 \tag{4}$$

3.2. Variables and data

3.2.1. Explained variables

To describe the various dimensions of carbon emissions as comprehensively as possible, this paper adopts three indicators for measurement. (1) Per capita CO_2 emissions (*PCE*), expressed by dividing the total urban CE by the registered population, (2) CO_2 emission intensity (*CEI*), expressed by the total urban CE divided by GDP, (3) CO_2 emission efficiency (*CEE*), the relevant evaluation index system refers to the work by Cui and Cao [17], which uses energy, labor, and capital as input factors, takes GDP as expected output, and CO_2 emissions as non-expected output. The explanation of relevant evaluation indicators is shown in Table 1. Based on the capital in 2008, the fixed asset investment of the base year is divided by 10% according to Young [21] to calculate the fixed capital stock of the base year, and the depreciation rate is 6%. Finally, we use the Super-SBM model to calculate the *CEE*.

Table 1
Evaluation system of the *CEE*

Category	Variables	Measurement	Units
Input	*EC*	Electricity consumption of residents	10000 kw·h
	Labor	Employees at year-end	10000 Person
	Capital	Real estate investment	100 million
Expected output	*GDP*	Gross regional domestic product	100 million
Non-expected output	*TCE*	Total urban CO_2 emissions	10000 ton

3.2.2. Core independent variable

The primary independent variable is *NTUP*. A regional dummy variable interacts with a time dummy variable to indicate whether each city belongs to the pilot program. Cities designated as NTUP cities in year *t* are assigned a value of 1; otherwise, they are assigned 0. It should be noted that NTUP cities are divided into three batches for piloting purposes. In this paper, if an entire city is considered as part of the pilot area, it receives a value of 1; whereas if only its inner district or county within the region is listed as part of the pilot area, it receives 0. Failing to distinguish between these categories may result in an overestimation of the policy's impact [22].

3.2.3. Mediating variables

Based on the earlier mentioned mechanism analysis, this study selects three mediating variables: (1) Industrial structure upgrading (*IS*), measured by the ratio of tertiary industry to secondary industry, (2) energy use (*EU*), quantified by LPG consumption per 10,000 individuals, (3) green technology innovation (*GTI*), assessed based on the number of green patents granted per 10,000 individuals [23].

3.2.4. Control variables

In addition to the existing literature, this study incorporates the following control variables [24, 25]: (1) Economic development level (*PGDP*): indicated by GDP per capita; (2) degree of openness (*OP*): represented by the ratio of FDI to GDP; (3) financialization level (*FL*): measured by the ratio of financial institutions' outstanding loans to GDP; (4) government intervention (*GI*): reflected by the ratio of government expenditure to GDP; (5) traffic level (*TL*): assessed based on the number of buses per 10,000 individuals; (6) medical level (*ML*): evaluated through medical technology practitioners; (7) talent aggregation (*TA*): determined by the proportion of employees engaged in scientific research, technical services, geological exploration, information transmission, computer services, and software development among total employees; (8) green coverage (*GC*): quantified using the green coverage rate within built-up areas.

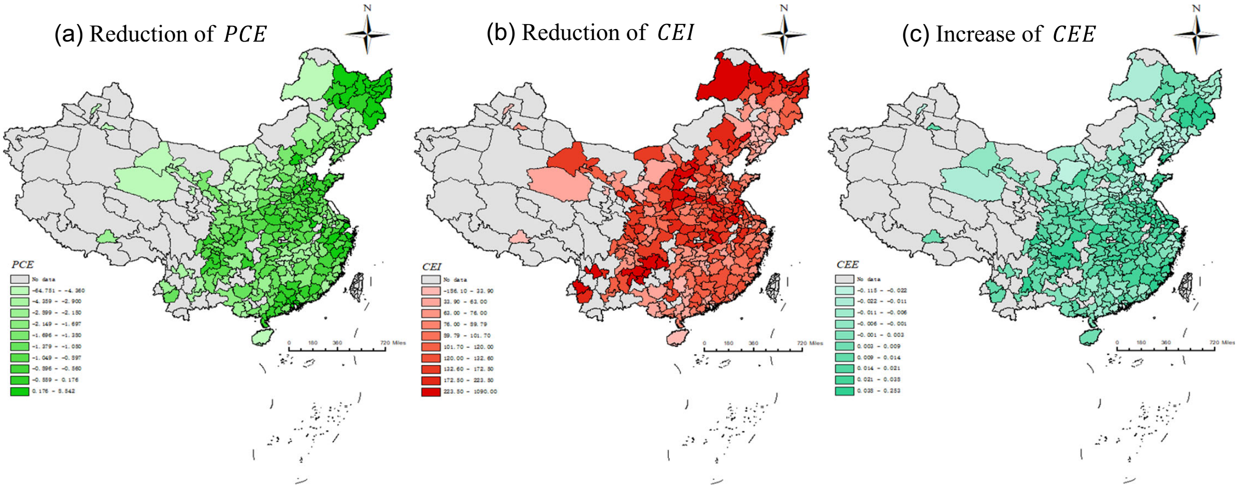
The main data sources for this study are the China City Statistical Yearbook, China Research Data Service Platform, CnOpenData, and EPS database. To address variable dimension variations, a logarithmic transformation is used to reduce heteroscedasticity. Linear interpolation filled in any missing data points. A total of 285 cities from 2008 to 2019 are selected for analysis by matching variables across databases. Descriptive statistical analysis results are presented in Table 2.

In addition, to more intuitively reflect the level of CE for each city during the sample period, Figure 2 shows the change in CE for each city in 2019 compared to 2008. It can be preliminarily found that most cities in the treatment group showed more reduction of *PCE* and *CEI* and more increase of *CEE*.

Table 2
Descriptive statistics of variables

Variables	Observations	Mean	S. D.	Min	Max
Ln (*PCE*)	3420	1.808	0.677	−0.467	4.533
Ln (*CEI*)	3420	5.098	0.591	2.465	7.415
CEE	3420	0.097	0.124	0.009	1.088
NTUP	3420	0.118	0.322	0	1
IS	3420	0.934	0.515	0.094	5.168
Ln (*EU*)	3420	3.195	1.498	−1.951	8.026
GTI	3420	0.647	1.494	0.002	24.411
Ln (*PGDP*)	3420	10.537	0.643	8.388	12.456
OP	3420	0.018	0.018	0.001	0.199
FL	3420	0.927	0.587	0.075	7.450
GI	3420	0.191	0.101	0.044	1.027
TL	3420	3.439	6.360	0.079	110.519
Ln (*ML*)	3420	8.861	0.757	6.426	11.659
TA	3420	0.029	0.019	0.006	0.196
GC	3420	0.391	0.072	0.010	0.953

Figure 2
The distribution of carbon emission change



4. Empirical Analysis

4.1. Baseline regression results

The regression outcomes of the benchmark equation are presented in Table 3, where (1) – (3) represent fixed time and city effects, while (4)–(6) include additional control variables. The findings indicate that all estimated coefficients of *NTUP* are statistically significant, suggesting that implementing NTUP policy not only reduces *PCE* and *CEI* but also enhances *CEE*. Compared to non-pilot cities, *PCE* and *CEI* decreased by 6.4% and 7.4%, respectively, while *CEE* increased by 1.2%. This conclusion aligns with scholars' perspective on how urbanization facilitates carbon emission reduction. Recognizing the challenges associated with achieving high-quality development, local governments have implemented comprehensive measures to support cities in attaining low-carbon, green, and sustainable growth during urbanization dynamics.

4.2. Robustness tests

4.2.1. Parallel trend

The DID method must satisfy the parallel trend hypothesis, meaning that the change trends of pilot cities and non-pilot cities should be consistent before implementing the NTUP. This study adopts Beck et al.'s [26] event analysis method, which includes a cross-product term with dummy variables for each year and experimental group. The base period refers to the year prior to policy implementation, excluding its corresponding product term in model (5). Here is the formulation of the model:

$$CE_{it} = \alpha + \sum\nolimits_{t=2008}^{2019} \theta_t NTUP_{it} + \gamma X_{it} + \varphi_i + \delta_t + \varepsilon_{it} \qquad (5)$$

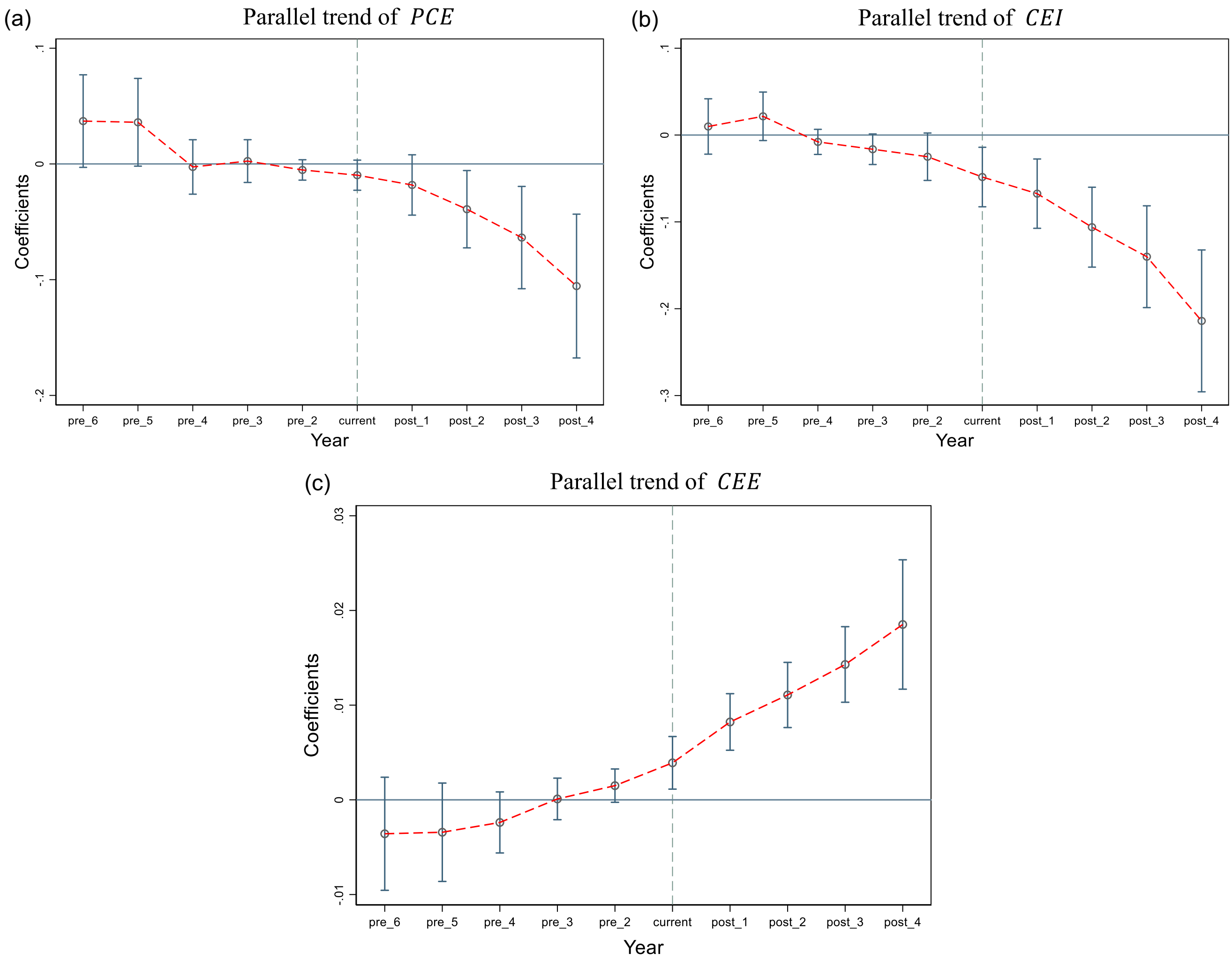
The results of the parallel trend analysis conducted on CE are shown in Figure 3. Prior to NTUP implementation, the estimated coefficients for pre-policy years are not statistically significant at the 95% confidence level, indicating similar trends in CE between pilot and non-pilot cities. However, the coefficients for each year after implementation are largely significant at the 95% level and show a decrease or increase in trend. These findings suggest that compared to non-pilot cities, the implementation of NTUP in pilot cities leads to a reduction in *PCE* and *CEI* while increasing *CEE*. Furthermore, the results of the event analysis also show that with the increase of the implementation time of NTUP, the policy effect presents a continuous and significant state, and the gap between the reduction of *PCE* and *CEI* and the improvement of *CEE* gradually increases between the pilot and non-pilot cities.

Table 3
Estimates of the NTUP on carbon emissions

Variables	*PCE* (1)	*CEI* (2)	*CEE* (3)	*PCE* (4)	*CEI* (5)	*CEE* (6)
NTUP	−0.066***	−0.123***	0.016***	−0.064***	−0.074***	0.012***
	(0.021)	(0.023)	(0.003)	(0.018)	(0.018)	(0.002)
Control variables (CV)	×	×	×	√	√	√
City fixed effect (CFE)	√	√	√	√	√	√
Year-fixed effect (YFE)	√	√	√	√	√	√
Obs.	3420	3420	3420	3420	3420	3420
R^2	0.479	0.745	0.197	0.538	0.863	0.403

Notes: (1) Robust standard errors clustered at the city level are reported in parentheses; (2) ***p < 0.01, **p < 0.05 and *p < 0.1. (The same below)

Figure 3
Parallel trend test of CE



4.2.2. Self-selected problem alleviation

Most studies of policy effect evaluation have the self-selected problem; that is, the experimental and control group are not randomly selected. In this study, the choice of pilot cities of the NTUP may also be affected by a variety of factors. In order to alleviate the self-selection problem, this study adopts two methods: (1) Referring to the method of Edmonds et al. [27], the product term of the benchmark variable and the time trend is further added into model (1) as the control variable, including whether the city is "two control areas," provincial capital and the north as the proxy variable. (2) PSM-DID method is used for testing [28], in which one-to-one matching and radius matching are used, and the selected covariables were consistent with the control variables.

Table 4 reports the results after alleviation of the self-selection problem. Figure 4 shows that the regional differences between the pilot and non-pilot cities after matching are significantly reduced, indicating that the PSM results are reliable. As a whole, whether the benchmark factors are further added or the PSM-DID test, the results show that coefficients are highly significant, indicating that after considering the inherent regional differences, the estimation result of the baseline regression is still robust; that is, new-type urbanization can significantly reduce per capita CE and emission intensity and improve emission efficiency.

4.2.3. Concurrent events

Due to the intensive implementation of a number of environmental protection policies in China during the sample period, a concern is that the baseline regression results may be influenced by other policies and thus fail to clearly reflect the effects of NTUP. Thus, this study focuses on three events: the low-carbon city policy, smart city policy, and carbon emission trading policy [29], and adds them to model (1) for regression analysis again. Table 5 shows the results. It can be seen that the coefficients of *NTUP* are still significant, indicating that the results of baseline regression are robust.

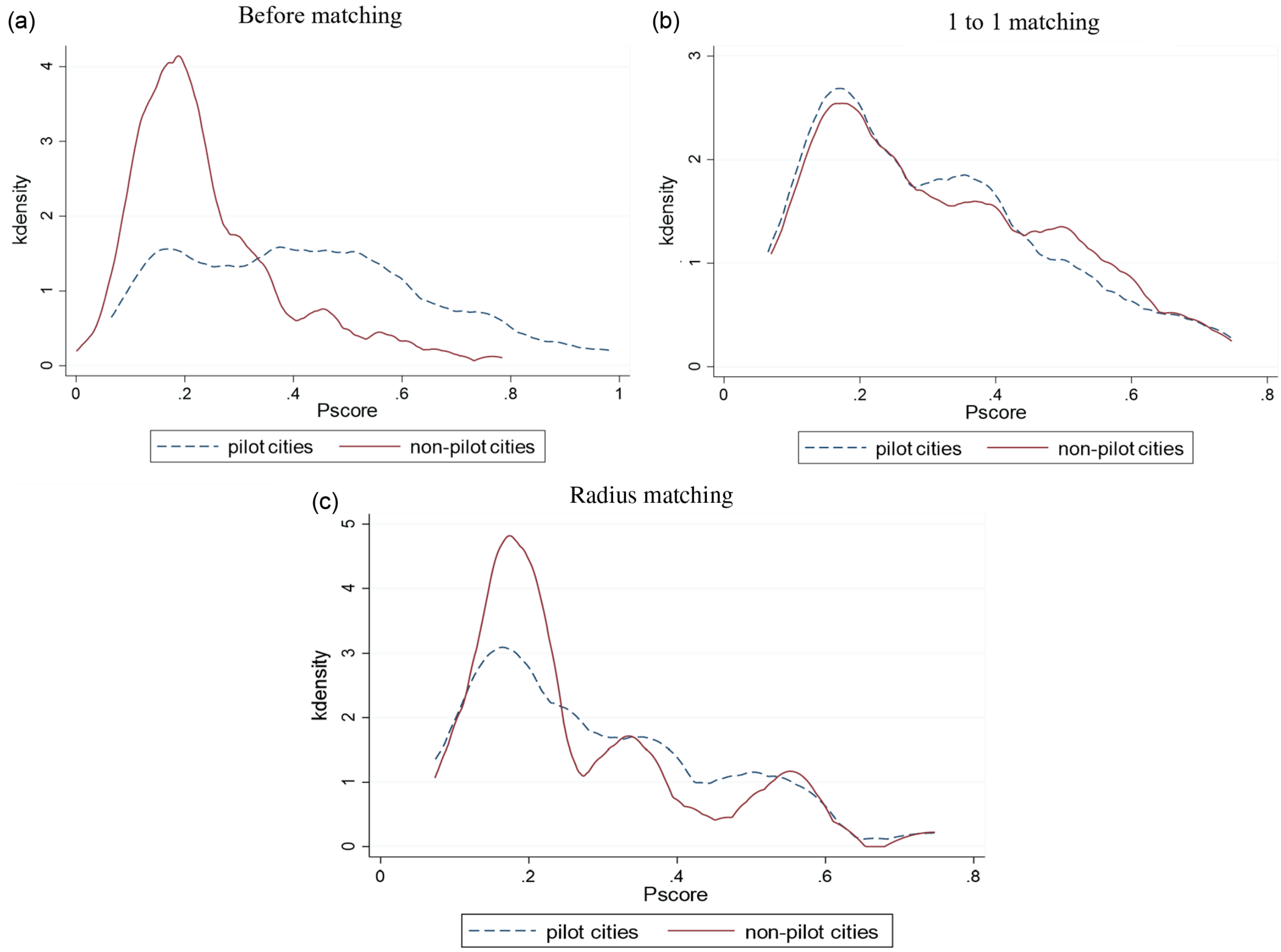
4.2.4. Placebo test

Another concern regarding the DID method is the potential impact of unobservable changes in city characteristics over time on our estimates. To address this, we adopt a similar approach as

Table 4
Tests for self-selected problem

	Method 1			Method 2–1 to 1			Method 2-radius (0.001)		
Variables	*PCE* (1)	*CEI* (2)	*CEE* (3)	*PCE* (4)	*CEI* (5)	*CEE* (6)	*PCE* (7)	*CEI* (8)	*CEE* (9)
NTUP	−0.061***	−0.068***	0.011***	−0.039***	−0.049***	0.007***	−0.056***	−0.062**	0.007***
	(0.019)	(0.018)	(0.002)	(0.012)	(0.012)	(0.003)	(0.013)	(0.029)	(0.002)
Benchmark variables	√	√	√	×	×	×	×	×	×
CV	√	√	√	√	√	√	√	√	√
CFE	√	√	√	√	√	√	√	√	√
YFE	√	√	√	√	√	√	√	√	√
Obs.	3420	3420	3420	1200	1200	1200	1020	1020	1020
R^2	0.551	0.867	0.466	0.515	0.862	0.468	0.545	0.887	0.472

Figure 4
Probability density function



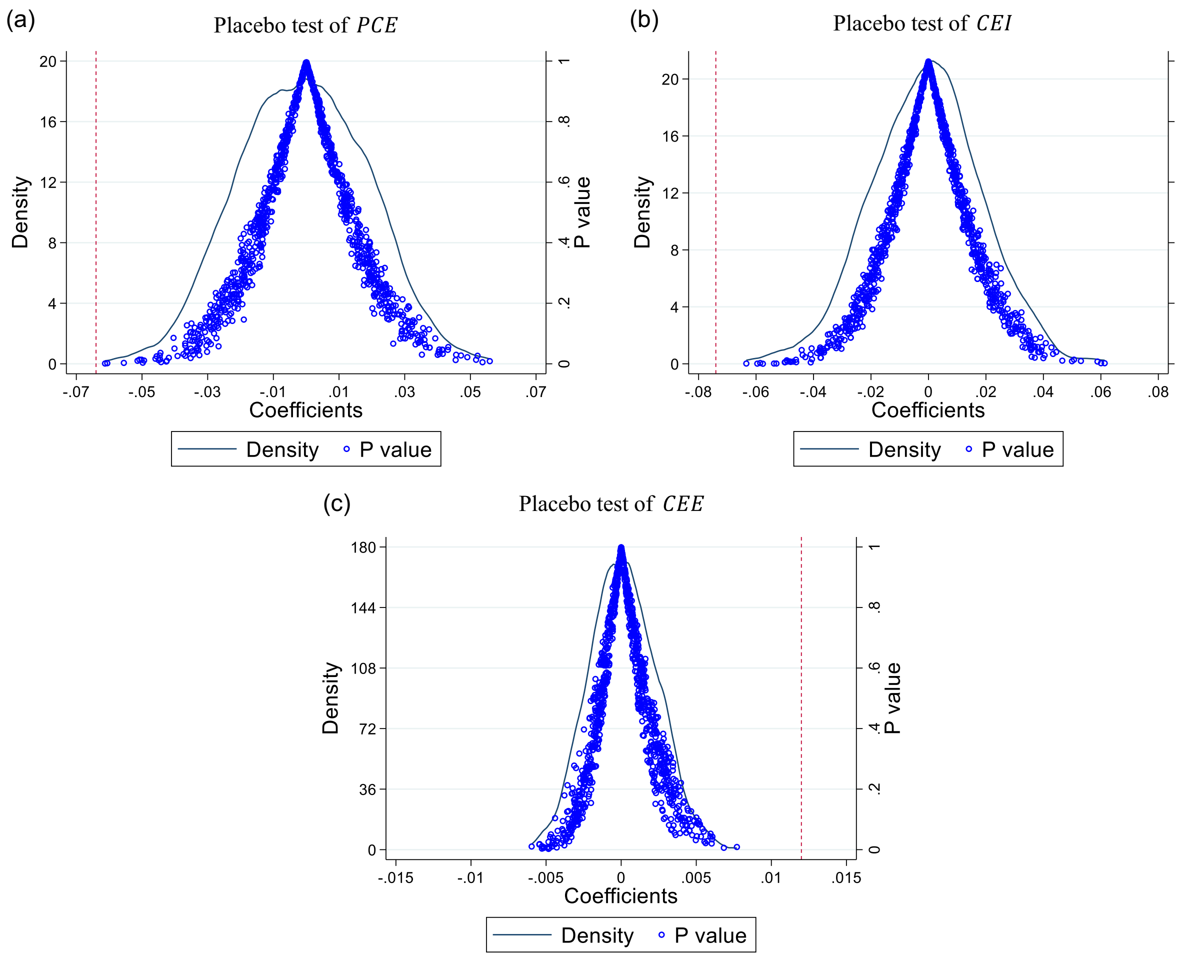
Notes: The hollow circle is the estimated θ for each period. The range of vertical lines across the circle is a confidence interval above and below 95% of the estimated coefficient.

Chetty et al. [30] by randomly selecting pilot cities to create pseudo-treatment and control groups. This allows us to conduct placebo tests where NTUP is randomly assigned to cities, ensuring the validity of our baseline results. We perform 1000 placebo tests and obtain 1000 coefficients for $NTUP^{false}$ and then test whether their mean equals zero. Figure 5 displays the distributions of these coefficients, which all center around zero. In contrast, the policy effect from our baseline regression (−0.064, −0.074, 0.012) stands out as a clear outliers in the placebo test. These findings provide further confidence in the robustness of our baseline results.

Table 5
Tests for concurrent events

Variables	*PCE* (1)	*CEI* (2)	*CEE* (3)
NTUP	−0.063*** (0.018)	−0.071*** (0.017)	0.011*** (0.002)
Other policies	√	√	√
CV	√	√	√
CFE	√	√	√
YFE	√	√	√
Obs.	3420	3420	3420
R^2	0.560	0.870	0.425

Figure 5
Placebo test of CE



Notes: The solid curve represents the distribution of coefficients, the blue hollow circle represents the P-value, and the red vertical dash line corresponds to the true estimated coefficients in columns (4)–(6) of Table 3.

4.2.5. Counterfactual test

In order to further verify that the reduction of CE and improvement of efficiency are caused by the implementation of NTUP, this study uses the method of Cheng et al. [31] and artificially advances the implementation time of the NTUP by 2 and 3 years. If the estimated coefficients are not significant, indicating that NTUP reduces CE and improves efficiency. Otherwise, indicating that other factors besides NTUP affect carbon emissions. The counterfactual test results in Table 6 show that the estimated coefficients of *NTUP* are no longer significant after the policy implementation time point is advanced, indicating that the reduction of CE and improvement of efficiency are indeed brought about by the implementation of NTUP.

4.2.6. Endogeneity treatment

In addition, cities in China with higher carbon emissions have greater population concentration and a relatively higher level of urbanization, giving them a “first-mover advantage” in the development of new-type urbanization. This leads to endogenous

Table 6
Tests for changing implementation time

	2 years in advance			3 years in advance		
Variables	*PCE* (1)	*CEI* (2)	*CEE* (3)	*PCE* (4)	*CEI* (5)	*CEE* (6)
NTUP	−0.009 (0.015)	−0.015 (0.015)	−0.005 (0.004)	−0.004 (0.013)	−0.009 (0.013)	0.001 (0.003)
CV	√	√	√	√	√	√
CFE	√	√	√	√	√	√
YFE	√	√	√	√	√	√
Obs.	3420	3420	3420	3420	3420	3420
R^2	0.538	0.863	0.403	0.538	0.863	0.402

issues in the empirical causal relationship. Therefore, we use the topographic slope data of each city as an instrumental variable for NTUP. On one hand, topographic slope is directly related to urban construction costs and resource distribution, which significantly impact the level of urban development and whether a city is included in the NTUP pilot area, thus meeting correlation requirements. On the other hand, topographic slope is a naturally occurring geographic variable that satisfies exclusivity conditions. However, since the original selected data are in cross-sectional form, it cannot be directly used for quantitative analysis of panel data. This paper adopts Nunn and Qian [32] method by introducing a time-varying variable to construct panel data. Specifically, we take the cross-product term of mean economic growth over the next two years and topographic slope for each city as an instrumental variable for current NTUP.

Based on the findings in Table 7, both the RKLM and RKF tests indicate no weak instrumental variable issue. Moreover, the coefficients of *NTUP* significantly pass the 1% significance test, suggesting that new-type urbanization initiatives contribute positively to reducing carbon emissions and enhancing efficiency.

4.3. Heterogeneity analysis

Due to the influence of urban resource endowment, geographical location, and population size, the regional distribution of urbanization construction level and carbon emissions has obvious heterogeneity. So, we conduct heterogeneity analysis according to different types of cities. The estimated results are shown in Tables 8, 9, and 10.

The results show that NTUP has a more significant impact on CE in RB cities. As resource endowment plays an important role in regulating the relationship between urbanization development and CE, RB cities are more dependent on related energy sources than non-RB cities, resulting in more serious environmental pollution. Therefore, the government pays more attention to the

Table 7
Tests for endogeneity

Variables	*PCE* (1)	*CEI* (2)	*CEE* (3)
NTUP	−0.299*** (0.083)	−0.906*** (0.124)	0.081*** (0.012)
First-stage results	0.314*** (0.043)	0.314*** (0.043)	0.314*** (0.043)
CV	√	√	√
CFE	√	√	√
YFE	√	√	√
Kleibergen-Paap rk LM	49.758	49.758	49.758
Kleibergen-Paap rk Wald F	52.537	52.537	52.537
Obs.	3420	3420	3420
R^2	0.404	0.372	0.320

Table 8
Analysis of resource heterogeneity

	RB			Non-RB		
Variables	*PCE* (1)	*CEI* (2)	*CEE* (3)	*PCE* (4)	*CEI* (5)	*CEE* (6)
NTUP	−0.079** (0.032)	−0.079** (0.034)	0.013*** (0.002)	−0.040* (0.021)	−0.049** (0.019)	0.006*** (0.001)
CV	√	√	√	√	√	√
CFE	√	√	√	√	√	√
YFE	√	√	√	√	√	√
Obs.	1380	1380	1380	2040	2040	2040
R^2	0.544	0.869	0.536	0.620	0.890	0.354

Table 9
Analysis of geographical heterogeneity

	Eastern			Central and Western		
Variables	*PCE* (1)	*CEI* (2)	*CEE* (3)	*PCE* (4)	*CEI* (5)	*CEE* (6)
NTUP	−0.110*** (0.011)	−0.111*** (0.011)	0.015*** (0.004)	−0.046* (0.025)	−0.066** (0.025)	0.007*** (0.002)
CV	√	√	√	√	√	√
CFE	√	√	√	√	√	√
YFE	√	√	√	√	√	√
Obs.	1200	1200	1200	2220	2220	2220
R^2	0.329	0.891	0.427	0.615	0.856	0.560

Table 10
Analysis of population heterogeneity

	Small- and medium-sized			Medium- and large-sized		
Variables	*PCE* (1)	*CEI* (2)	*CEE* (3)	*PCE* (4)	*CEI* (5)	*CEE* (6)
NTUP	−0.103*** (0.038)	−0.092*** (0.034)	0.012*** (0.004)	−0.016 (0.015)	−0.039** (0.017)	0.006** (0.002)
CV	√	√	√	√	√	√
CFE	√	√	√	√	√	√
YFE	√	√	√	√	√	√
Obs.	1716	1716	1716	1704	1704	1704
R^2	0.509	0.814	0.407	0.632	0.917	0.431

transformation development of RB cities through diversified means to help cities achieve sustainable development by reducing CE and improving efficiency.

Furthermore, the results in Table 9 show that when evaluating the influence of NTUP on CE in different geographical locations, urbanization development in eastern cities has a more obvious effect on the improvement of CE reduction and efficiency. At the same time, in the cities located in the central and western, the coefficients are also significant, but the influence is weak. It is worth noting that the urbanization development level of the eastern region itself is relatively high, and it has perfect infrastructure and strong policy support. In contrast, the level of urbanization in the central and western regions has yet to be improved, which explains why there is still a lot of room for improvement in carbon emission impact in these regions.

As urban population size is one of the important factors affecting carbon emissions, this study divides the sample into small- and medium-sized scale and medium- and large-sized scale based on the average population of each city during the sample period, so as to test whether there is heterogeneity in the implementation effect of NTUP among cities of different sizes. The regression results in Table 10 show that, compared with medium- and large-sized cities, the implementation effect of NTUP in small- and medium-sized cities is better, as shown by reducing more *PCE* and *CEI* and increasing more *CEE*. This result is consistent with existing research, because the population concentration in large cities will increase pollution emissions, which greatly reduces the emission reduction effect of relevant policies [22].

4.4. Mediating effect analysis

Table 3 confirms the initial stage of testing the mediating effect, which demonstrates that NTUP significantly influences carbon emissions. This study further investigates the mediating effects of industrial structure (*IS*), energy use (*EU*), and green technology innovation (*GTI*). The corresponding findings can be observed in Tables 11, 12, and 13.

The data in column (1) of Table 11 clearly show that *NTUP* has a significant positive impact on *IS*, indicating the successful improvement of industrial structure through new-type urbanization. The

Table 11
The mechanism test of *IS*

Variables	*IS* (1)	*PCE* (2)	*CEI* (3)	*CEE* (4)
NTUP	0.126*** (0.024)	−0.058*** (0.008)	−0.067*** (0.018)	0.011*** (0.002)
IS		−0.057*** (0.010)	−0.081*** (0.027)	0.006*** (0.002)
CV	√	√	√	√
CFE	√	√	√	√
YFE	√	√	√	√
Obs.	3420	3420	3420	3420
R^2	0.405	0.542	0.869	0.411

Table 12
The mechanism test of *EU*

Variables	*EU* (1)	*PCE* (2)	*CEI* (3)	*CEE* (4)
NTUP	−0.086** (0.039)	−0.062*** (0.008)	−0.066*** (0.018)	0.012*** (0.002)
EU		0.008** (0.004)	0.019** (0.007)	−0.002*** (0.001)
CV	√	√	√	√
CFE	√	√	√	√
YFE	√	√	√	√
Obs.	3420	3420	3420	3420
R^2	0.061	0.551	0.871	0.410

Table 13
The mechanism test of *GTI*

Variables	*GTI* (1)	*PCE* (2)	*CEI* (3)	*CEE* (4)
NTUP	0.610*** (0.176)	−0.039** (0.018)	−0.049*** (0.017)	0.009*** (0.002)
GTI		−0.041*** (0.006)	−0.041*** (0.006)	0.004** (0.002)
CV	√	√	√	√
CFE	√	√	√	√
YFE	√	√	√	√
Obs.	3420	3420	3420	3420
R^2	0.379	0.574	0.874	0.442

results in columns (2)–(4) reveal significant coefficients for both *NTUP* and *IS*, suggesting that NTUP not only directly reduces CE and enhances efficiency but also further plays a role by promoting the upgrading of industrial structure.

The data in column (1) of Table 12 clearly show that the introduction of *NTUP* has a significant negative impact on *EU*, indicating that energy use decreases with urban development. The subsequent columns (2)–(4) reveal significant coefficients for *NTUP* and *EU*, suggesting that NTUP not only directly reduces CE and enhances efficiency but also plays a role by reducing energy use.

The data in column (1) of Table 13 clearly show that *NTUP* has a significant positive influence on *GTI*, indicating that the advancement of *NTUP* contributes to promoting *GTI*. The coefficients estimated in columns (2)–(4) demonstrate strong associations between *NTUP* and *GTI*, suggesting that NTUP not only directly reduces CE and enhances efficiency but also plays a further role through green innovation effect.

5. Discussion

This study finds that the implementation of NTUP significantly reduces *PCE* and *CEI* and improves *CEE* and plays a role by promoting industrial upgrading, reducing energy consumption, and promoting green technology innovation. NTUP is an important measure proposed by the Chinese government to promote sustainable urban development, and promoting energy saving and emission reduction is one of its goals. This study confirms the "emission reduction" effect of NTUP. For example, Li et al. [33] concluded that NTUP contributes to the reduction of carbon emission intensity, and its impact has a spatial spillover effect on neighboring areas. In addition, the implementation of NTUP can improve resource utilization in pilot cities by influencing industrial structure, energy use, and green technology innovation and ultimately achieve emission reduction targets. This conclusion is consistent with the research result of Qiu et al. [34]. It can be said that the implementation of NTUP promotes the continuous adjustment of industry and energy consumption and makes continuous efforts in the aspects of "energy saving and emission reduction" and "ecological compensation," thus helping cities achieve green and low-carbon development [35].

In order to start a dialogue with different studies, this paper further discusses the impact of traditional urbanization on CE, so as to find the implementation effect of NTUP in comparison. Some studies confirm that urbanization improves CE and that there is spatial heterogeneity across different regions [36]. In contrast, other studies have shown that traditional urbanization has failed to promote improvements in CE due to industrial structure, energy intensity, and other factors [37]. In addition, other studies reveal the nonlinear relationship between urbanization and CE and find that there is an inverted U-shaped relationship between the two. In the early stage, CE will be improved with the advancement of urbanization, but once the urbanization level exceeds the critical point, the impact of urbanization on CE will be negative [38]. To sum up, in the initial stage of the implementation of NTUP, due to the disadvantages of traditional urbanization and extensive development model blindly pursuing quantity and scale, spatial layout is unreasonable, ecological environment degradation, and other problems, to a certain extent, the improvement of CE will be weakened. With the increase of policy implementation time and the gradual maturity of relevant institutional mechanisms, NTUP takes health, green economy, and efficiency as its core goals and has made significant contributions to the improvement of CE.

The results of heterogeneity in the effects of NTUP on CE show that: First, at the resource level, RB cities that rely on the development of the secondary industry gradually overcome the single problem of industrial structure and develop into clean, efficient, and diversified industries, attracting a large number of talents, capital, and innovative resources, thus maximizing the emission reduction effect of NTUP. Secondly, at the regional level, the eastern region gathers a large amount of capital, talent, and technology, and has more advantages in urban construction and social production than the central and western regions, thus releasing the role of NTUP in emission reduction and efficiency enhancement [39]. In addition, in terms of population size, although the talent concentration and scientific and technological level of large cities are relatively high, the excessive population leads to urban congestion and heat island effect, and the agglomeration of enterprises also increases pollution emission. Under the comprehensive effect of various factors, the implementation effect of NTUP is difficult to be reflected in large cities, but it promotes the low-carbon development of small- and medium-sized cities.

6. Conclusion and Policy Implications

To address the current economic crisis and achieve carbon peak and neutrality, it is crucial to pursue high-quality urbanization while simultaneously reducing carbon emissions. This study uses NTUP as a quasi-natural experiment to assess its impact on CE using panel data. The key findings are as follows: (1) NTUP effectively reduces CE and enhances efficiency, even after accounting for potential endogeneity issues through various tests. (2) The effectiveness of NTUP in reducing carbon emissions varies, particularly benefiting resource-based cities, eastern cities, and small- and medium-sized cities. (3) By promoting industrial upgrade, curbing energy use, and fostering green technology innovation, NTUP can effectively reduce CE while improving efficiency.

Based on the above conclusions, this paper puts forward some policy implications.

1) Studies show that the implementation of NTUP reduces carbon emissions and improves emission efficiency. To further consolidate the effect of NTUP, the following approaches can be adopted. First, strengthen the top-level design of new-type urbanization, clearly incorporate energy conservation goals into the official performance assessment system, and enhance the scientific and systematic assessment. Meanwhile, we should fully respect the decisive role of the market in resource allocation, stimulate the autonomy and vitality of market players, provide a good business environment and innovation conditions for the society, guide, and promote *GTI* of enterprises according to the situation, and thus reduce CE.
2) The research finds that the biased pilot policy tilted to the central and western regions did not play the expected effect, the root cause of which is the violation of the market law. It is suggested to formulate differentiated policies according to local conditions, clarify the huge differences in resource endowment and economic foundation of various regions, and combine the comparative advantages of the region to plan and develop appropriate industries, so as to achieve low-carbon development. Second, we should insist on the decisive role of the market in resource allocation, promote the cross-regional allocation of resources, alleviate the mismatch of land, population, and economic development, and then help the underdeveloped areas accelerate development.
3) Studies suggest that upgrading industrial structure, reducing energy use, and innovating green technologies are key methods for reducing carbon emissions in new-type urbanization. These approaches can be further enhanced at both macro and micro levels. First, it is crucial for the government to actively encourage incentives and subsidies for green innovation while emphasizing differentiation among subjects involved in technological advancements. Additionally, governments should proactively establish energy and industrial plans and leverage environmental regulatory systems to promote the adoption of clean energy sources and facilitate sustainable transformation and upgrade of industries. Second, governmental guidance should aim to foster a continuous improvement mindset within enterprises by providing internal targets, implementing effective management mechanisms, and establishing operational systems. This will stimulate independent innovation among businesses while facilitating their transition towards cleaner development practices.

This article has some limitations. Based on the existing research results and data availability, this paper constructs the evaluation index system of *CEE*. However, the expression of emission efficiency is not uniform, and the evaluation system needs to be improved. Second, we have chosen three key mediating mechanisms – industrial structure, energy use, and green technology innovation – to investigate the impact of NTUP on CE. It should be noted that due to data constraints, there may exist numerous other potential mechanisms not included in this study, making their individual verification challenging. This aspect will be a focal point for future research endeavors and requires further exploration.

Ethical Statement

This study does not contain any studies with human or animal subjects performed by the author.

Conflicts of Interest

The author declares that he has no conflicts of interest to this work.

Data Availability Statement

Data are available from the corresponding author upon reasonable request.

Author Contribution Statement

Huijie Xu: Conceptualization, Methodology, Software, Validation, Formal analysis, Investigation, Resources, Data curation, Writing – original draft, Writing – review & editing, Visualization, Supervision, Project administration.

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How to Cite: Xu, H. (2025). How Does the New-Type Urbanization Policy Affect Urban Low-Carbon Development? *Green and Low-Carbon Economy*. https://doi.org/10.47852/bonviewGLCE42022491